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TECHNICAL PROGRESS REPORT

FOR

THE MAGNETOHYDRODYNAMICS

COAL-FIRED FLOW FACILITY

For The Period
January 1, 1990 - March 31, 1990

November 1990

Work Performed Under Contract No. DE-AC02-79ET10815

Prepared for:
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Prepared by:
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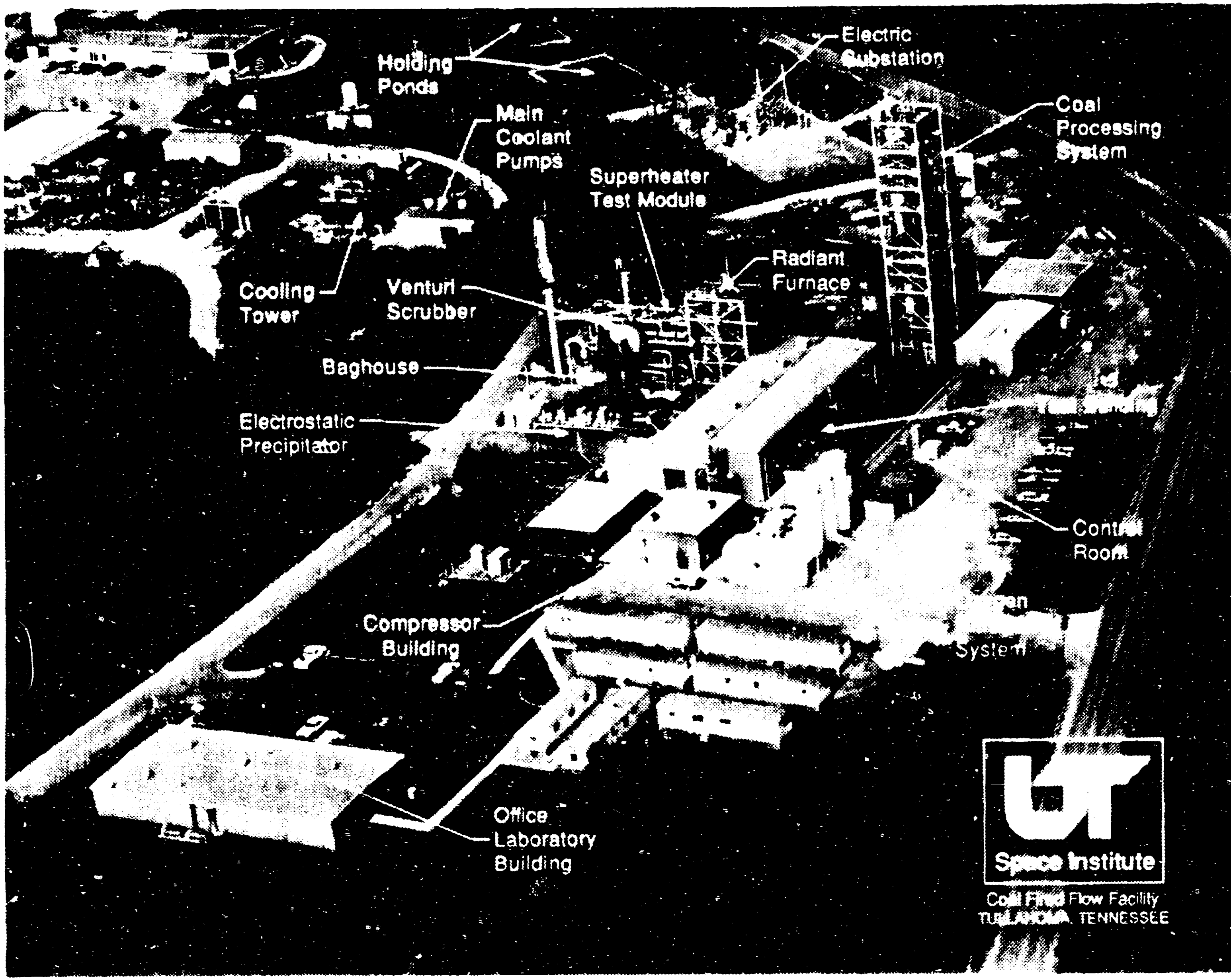
Energy Conversion Research and Development Programs



COAL-FIRED FLOW FACILITY

PREFACE

The purpose of this report is to provide the status of a multi-task research and development program in coal fired MHD/steam combined cycle power production (more detailed information on specific topics is presented in topical reports). Current emphasis is on developing technology for the Steam Bottoming Cycle Program. The approach being taken is to design test components that simulate the most important process variables, such as gas temperature, chemical composition, tube metal temperature, particulate loading, etc., to gain test data needed for scale-up to larger size components.

Previous reports have provided comprehensive data on NO_x and SO_x control, radiant heat transfer, particulate control (baghouse and electrostatic precipitator), the environmental baseline, and analyses of test data on the convective heat transfer components (superheater and air heater). For this quarter, additional data on these subjects and analysis of tube corrosion data are reported. Detailed data analyses will be contained in test reports, topical reports or technical papers.

By the use of these quarterly technical progress reports, MHD program participants and others interested in the technology will be able to gain the knowledge necessary for the confident design of a scaled-up steam bottoming plant.

ABSTRACT

In this Quarterly Technical Progress Report, UTSI reports on progress in developing the technology for the steam bottoming portion of the MHD Steam Combined Cycle Power Plant.

No Proof-of-Concept (POC) testing was conducted during the quarter but data analyses are reported from the test conducted during the prior quarter. Major results include corrosion data from the first 500 hours of testing on candidate tube materials in the superheater test module (SHTM). Solids mass balance data, electrostatic precipitator (ESP) and baghouse (BH) performance data, diagnostic systems and environmental data results from previous POC tests are included.

The major activities this quarter were in facility modifications required to complete the scheduled POC test program. Activities reported include the installation of an automatic ash/seed removal system on the SHTM, the BH, and the ESP hoppers. Also, a higher pressure compressor (350 psi) is being installed to provide additional blowing pressure to remove solids deposits on the convective heat transfer tubes in the high temperature zone where the deposits are molten. These activities are scheduled to be completed and ready for the next test, which is scheduled for late May 1990.

Also, experiments on drying western coal are reported. The recommended system for modifying the CFFF coal system to permit processing of western coal is described.

Finally, a new effort to test portions of the TRW combustor during tests in the CFFF is described.

The status of system analyses being conducted under subcontract by the Westinghouse Electric Corporation is also described.

Significant findings and conclusions are highlighted by bold type in Section II of this report.

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SECTION I

OBJECTIVE AND SCOPE OF WORK

Under Contract No. DE-AC02-79ET10815, the overall objective is to advance the technology of direct coal fired MHD components and systems required for MHD power generation operating under conditions simulating those of central power stations.

The specific objectives of the DOE Coal Fired Flow Facility (CFFF) are to resolve experimentally and analytically the key technical areas of concern which have been identified or which may be found to occur in direct coal fired MHD systems with moderate to high ash carryover. The key areas involve (l) combustor performance, (2) ash/seed particle collection efficiency from the exhaust gas stream, (3) effects of plugging, fouling and corrosion during normal operation, (4) performance of candidate materials in a direct coal fired MHD environment and (5) the operation, conditions, procedures and equipment needed to meet pollution control requirements.

The overall scope of work is summarized under each of the following TASK headings.

TASK 1 - CONSTRUCTION OF THE CFFF

This task was completed under a prior contract.

TASK 2 - DESIGN AND FABRICATION OF THE 8 LB/SEC TOTAL GAS FLOW, HIGH SLAG THROUGHPUT TEST EQUIPMENT

Provides for specification, design, fabrication and installation of the air heater, superheater, baghouse filter, and electrostatic precipitator. All of these components are installed and have been functionally tested.

TASK 3 - BASE OPERATIONS FOR THE CFFF

Provides for the operation of the CFFF and supporting laboratories and services which, in addition to management of the facility organization, include: a) Graphics Support Services, b) Engineering Services, c) Test Control and Support, Data Processing and Documentation, d) Analytical and Chemistry Laboratory Services, e) Environmental Monitoring, f) CFFF Mechanical Maintenance Operations, g) Instrumentation and Control, h) Quality Assurance, i) CFFF Preventive Maintenance and j) Safety.

TASK 4 - OPERATION AT 8 LB/SEC TOTAL GAS FLOW HIGH SLAG THROUGHPUT TEST

Encompasses the testing of the CFFF equipment and designed components, test data collection, analyses and reporting. Testing will focus on proof-of-concept tests to accumulate (during the current contract period of May 1, 1989 - July 31, 1990) 900 hours at MHD conditions to evaluate heat recovery-seed recovery (HRSR) equipment on eastern coal. In addition, a cost performance model for the MHD/Steam Power Plant to evaluate the technical and economic significance of testing data obtained from current MHD experience will be maintained and improved as the need arises.

TASK 5 - TESTING OF DOE SUPPLIED COMPONENTS

Provides for the testing of DOE supplied components. Efforts were initiated to integrate a TRW supplied combustor spool piece into the LMF test train to evaluate the material under CFFF testing conditions scheduled for May 1990. The integrating hardware has been designed and is being fabricated.

TASK 6 - MODIFICATIONS TO THE CFFF

Provides for major facility modifications which include conversion to a western coal processing system, and an auto seed/ash handling system for the superheater test module, air heater, electrostatic precipitator, and baghouse.

The Babcock & Wilcox Company (B&W) and UTSI are designing and specifying the necessary equipment/hardware that will allow the CFFF to process western coals. This sub-bituminous coal has a much higher moisture content than eastern coals and requires modified handling and processing techniques. UTSI has coordinated with B&W in the planning and preparation of this modification and in design reviews. UTSI will complete the final design, procure and install/integrate this equipment into the CFFF.

B&W and UTSI are also designing an automated seed/ash handling system during FY89-90 as part of the Integrated MHD Bottoming Cycle program. UTSI will procure, install and make all necessary facility modifications required to integrate the new equipment with existing hardware. This includes providing proper interfaces for all utilities (fuel oil, electrical, instrument air, cooling water, etc.) as well as any piping and structural modifications required.

The high temperature air heater (HTAH) program has been redirected toward determining the feasibility of recuperative air heater concepts rather than regenerative approaches. New ceramic materials available in the market place have made the former technology more viable. Currently, candidate materials are installed in the primary and secondary furnace of the CFFF to study their ability to endure the MHD flue gas corrosion, erosion and temperature conditions.

TASK 7 - MHD TECHNOLOGY DEVELOPMENT PROGRAM

Provides for additional technology development services on a task order basis as approved by DOE. Systems engineering studies related to key technology issues involved in the MHD Integrated Bottoming Cycle Program and the evaluation of other technological and economic issues bearing on MHD commercialization will be conducted under this task.

TASK 8 - TEST INTEGRATION AND INTERFACE

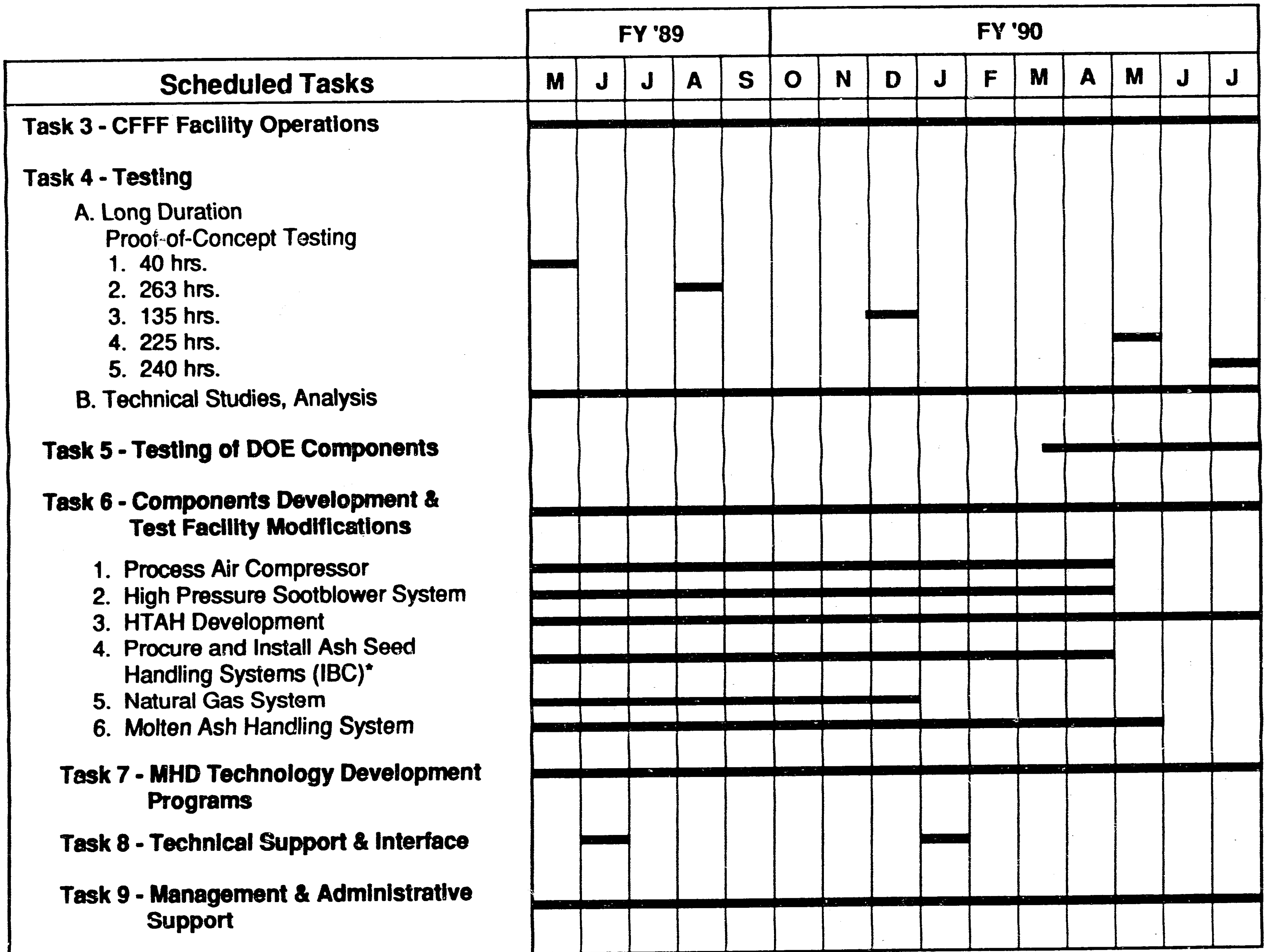
Provides for technical expertise and support to DOE in the form of meetings, conferences, and review panels relating to MHD systems. UTSI's involvement in the annual MHD contractors' program reviews and in the MHD Technology Transfer Integration Review Committee sessions are examples.

TASK 9 - PROGRAM MANAGEMENT

Provides for the overall management of the program which entails the planning, organizing, scheduling, directing, coordinating and controlling of resources required in the performance of the contract. Specific support staff functions include project control, reporting, accounting and financial affairs, government property administration, and contract administration.

CFFF PROGRAM GOALS AND SCHEDULE

The following chart shows the major program tasks and scheduled activities for completion during the current contract period May 1, 1989 - July 31, 1990.



*(IBC) - Integrated Bottoming Cycle

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SECTION II

SUMMARY OF TECHNICAL PROGRESS

This section addresses the technical progress of work conducted during the period January 1 - March 31, 1990 according to the objectives and scope of work tasks outlined in Section I. Tasks 1 and 2 are completed and no further effort is being expended in these areas.

TASK 3 - BASE OPERATIONS FOR THE CFFF

FACILITIES OPERATION, MAINTENANCE, AND REPAIR

The December 89 (LMF4-S) test was terminated due to the rupture of a cooling tube in the superheater. The water leaking into the superheater caused extensive damage to the refractory and insulating board. Repairs to the refractory and insulating board were completed during this quarter.

During LMF4-S, problems in maintaining negative furnace pressure were encountered. These appeared to have been caused by a buildup of material in the ducting between the baghouse (BH)/electrostatic precipitator (ESP) outlet and the induced draft (ID) fan. The ducts were cleaned.

The coal tower remote actuated valves 3A, 4A, and 4B were rebuilt. The remaining remote actuated valves are being reworked and will be completed prior to the next test.

All sootblowers were removed for maintenance and modifications. Welding and fabrication was started on the high pressure sootblower system. The support stand and high pressure sootblower receiver tank were installed in the pit area (see Figure 1).

The spent seed tank modifications, started in the last quarter, were completed. A new tank top was fabricated and installed. A new baghouse adapter and a new baghouse shaker section were installed.

Other repair, maintenance, and installation tasks performed during this quarter include:

- Completed annual maintenance requirements on the induced draft (ID) fan and motor, forced draft (FD) fan, superheater cooling pump, bridge crane, and the rotary valves and exhaust blower on the Carl Mayer heater;

- Replaced the self cleaning cooling water strainer in the test building;

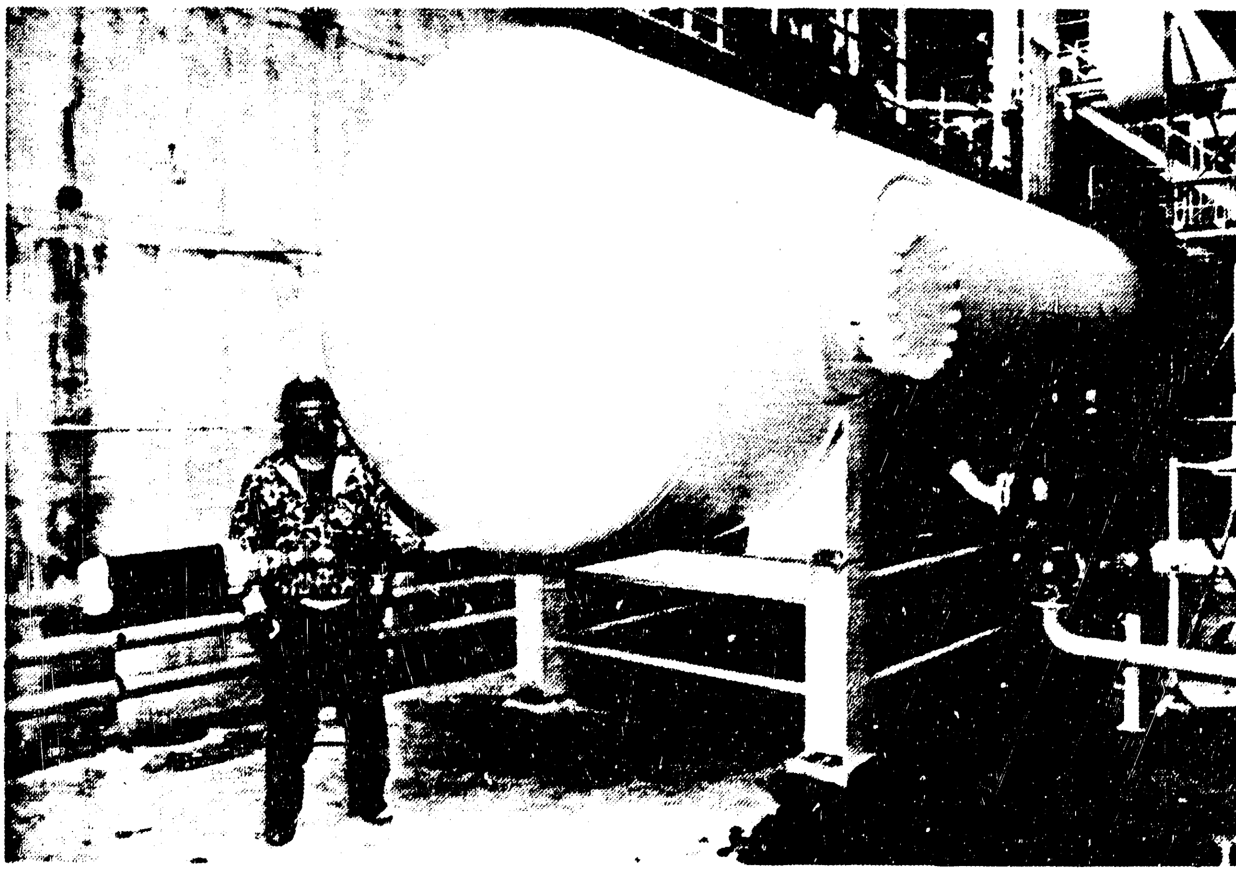

FIGURE 1. Sootblower Receiver Tank in Test Building Pit

- Replaced the kickplates on the superheater catwalk;
- Repaired cryogenic tanks and installed new steam control valves.
- Installed a natural gas line to the test buidling and to the 600 hp boiler.
- Installation of the high (350 psi) pressure sootblowing compressor to be used for sootblowing on the upstream leg of the SHTM.

TEST CONTROL AND SUPPORT

Major activities this quarter were devoted to preparation for the May 90 (LMF4-T) test, conducting western coal flow studies, evaluation of replacement coal flow meter candidate devices, and coordinating the development and installation of operational procedures for the ash removal system.

The search for a reliable and accurate replacement for the existing coal meter continues. The single flow path MicroMotion C model coriolis based flow meter, that was very successfully used to measure coal flow during past tests, is no longer in production. A previously tested Neptune coriolis meter and an Endress Hauser coriolis meter, evaluated this quarter, were found to be unsuitable for measuring coal flow. The meters did not produce any usable output measurements during coal flow tests, although the results were very good with water flow tests. Smith Meter Inc. has offered the trial of a used meter, at no cost, so that the suitability of their meter to measure coal flow can be evaluated. This evaluation will be completed during the next quarter.

A maintenance scheduling and tracking computer program (MP2) was received. Implementation to effectively utilize the system is expected to be completed during the next quarter. When activated, the program will allow accurate tracking of preventative maintenance costs and provide complete equipment maintenance histories.

DATA ACQUISITION SYSTEMS

A major renovation of the gas sampling instrumentation system was completed. The instrumentation was removed from the existing cabinets in the gas sampling building and reinstalled in alternate cabinets with new wiring and tubing. The renovation permitted both wiring and tubing simplification which will simplify and improve the overall system operation and reliability.

Progress toward conversion of the Data Acquisition database to Structured Query Language software on the MV 15000 computer continued. The Data Acquisition System database, or setup file, contains all of the information pertinent to each measurement on the MHD test train. The Structured Query Language software will replace the present in-house developed software. It will allow easier access to Data Acquisition System information and will allow more efficient maintenance of the database.

Disk drive backups on the Data Acquisition Computers were installed. Modifications and maintenance of the setup file required to support new test requirements and hardware configuration changes were performed. Revision and upgrade of the Data Acquisition System software programs to take advantage of MV15000 computer system capabilities and software was continued.

Instrumentation calibration was accomplished this quarter. Periodic calibration of the Data Acquisition system is performed to insure that the system is reading correct volts from measurement sensors and transmitters. The sensors are also calibrated against a National Institute of Standards and Technology traceable source and the resulting data is entered into the Data Acquisition System database to convert volts to engineering units.

New electrical systems and the numerous electrical system changes dictated by test requirement changes are being documented. This consists of updating drawings, cable lists, and measurement tag numbers on a computer aided drafting (CAD) system.

ANALYTICAL AND CHEMISTRY LAB SERVICES

All routine analyses on the August 89 (LMF4-R) test and the December 89 (LMF4-S) test samples submitted were completed. This includes chemical analysis of composite samples and metallurgical analysis of superheater tube deposits. Also, water samples from six CFFF sampling sites were collected each month and analyzed for routine water/wastewater parameters.

Methods have been developed to analyze coal ash and slag for major inorganic constituents using the inductively coupled plasma atomic emission spectrometer (ICP). The results from the ICP compare favorably with data from the atomic absorption spectrophotometer (AAS). In the future, the majoritity of samples will be analyzed with the ICP due to its speed and accuracy.

The study of the mechanism for MHD flyash formation using the scanning electron microscope (SEM) dot-mapping capability is still in progress. The purpose of this study is to determine whether the flyash is formed by heterogeneous or homogeneous nucleation. Multiple washings of the flyash with water show a decrease in potassium and sulfur and an increase in small (less than 1 micron) flyash particles. Attempts are still being made to obtain a cross-section view of the flyash particles. Details will be reported when the study is completed.

A paper entitled "Priority Pollutants in Combustion Products from the Department of Energy's Magnetohydrodynamics (MHD) Coal-Fired Flow Facility" has been accepted for presentation at the 1990 Symposium on Engineering Aspects of Magnetohydrodynamics (SEAM) to be held in Chicago, IL in June 1990. This paper will present new data on extraction procedure (EP) toxicity results of flyash and slag as well as future plans to collect volatile organics and metals in the MHD combustion gases using the recently acquired volatile organic sampling train (VOST).

ENVIRONMENTAL CONTROL

Efforts focused on the preparation of the 1989 CFFF Annual Site Environmental Report (SER). Chemical data from the water quality program and the trace element study have been compiled and submitted for inclusion in the SER. This year, data from the water internal quality control program will be included to show the accuracy of the lab procedures and/or personnel. The results generally show excellent agreement with theoretical values.

Water Quality

Holding pond effluent conditions were monitored throughout the quarter and **effluent conditions were maintained within permit limits.** Heavy rainfall during the quarter did not cause an elevation in pond pH as noted in late 1989. This is thought to be due to the leaching of the coal pile by precipitation which currently is at a limit equivalent to the buffering potential of the ponds themselves. **Area runoff now appears effective in buffering coal pile leaching.** Solids levels within the ponds have risen as a result of recent construction within the CFFF and subsequent erosion. **The monthly discharge monitoring report (DMR) was completed and forwarded to the State of Tennessee, Division of Water Pollution Control.**

Terrestrial Ecology

Efforts this quarter concentrated on preparing terrestrial inputs to the 1989 SER. The scope of analyses during the next quarter will be on soil chemistry and a literature review on related topics.

Ambient Air Monitoring

Emphasis within this study area has also been on the preparation of data for the 1989 SER. Data assembly and preliminary filtering for CY 89 data has been completed. Data archiving includes the original raw data as well as the DATATRIEVE files created on the VAX computer. Long term data storage is accomplished using streaming tape backup technology. The Total Suspended Particulate (TSP) sampler located on the roof of H-Wing of the main UTSI building was moved to the Impact I location north of the CFFF. The sampler will be utilized in conjunction with the fractional ambient particulate sampling effort. For this study it is planned to collect both Inhalable Particulate (IP) samples and duplicate fractional samples on alternating sixth-day sample dates. Results from the study will be used as baseline data for fractional ambient particulate inventories. Sampling during CFFF test operations will entail back-to-back 24 hour samples.

Theoretically, the overall potential impact of CFFF operations should be apparent in the amount and analysis of smaller size fraction inventories.

POLLUTION CONTROL

The report on the SO_2 results of the CFFF performance test was sent to the State of Tennessee EPA (Ref 1). The results were within the State permit and NSPS limits. The State will now review the results and supporting data to approve/verify and document the CFFF performance tests (particulate and SO_2), and issue a new operating permit. A graphical representation of the EPA Method 8 results along with results from the continuous analyzer for comparison are shown in Figure 2. (The major difference shown in test 7 is attributed to a contaminated sample.)

The performance tests for SO_2 and particulate have been accepted for presentation at the 1990 Symposium on Engineering Aspects of Magnetohydrodynamics (SEAM).

The gas sampling instruments and supporting equipment located in the Gas Sampling Shelter are being completely overhauled. The existing hardware has been in service since the early 80's. Additional new equipment has arrived including, a Beckman SO_2 (IR) analyzer and a Beckman O_2 (in situ) analyzer, and will be installed prior to the next test. The Lear-Seigler updated version of the NO/SO_2 (in situ) analyzer is also ready for installation.

A closed loop cooling water system using softened water has been designed for cooling the gas sampling probes. Much of the hardware required is presently on-hand or on order. A sketch of the system is shown in Figure 3.

A summary of the CY1989 emissions testing results were compiled for inclusion in the 1989 SER.

Based on SO_2 results, which have been variable, it is planned to recommend testing at various K_2/S ratios during future tests. The SO_2 data generally correlated with K_2/S, but the deviations are larger than expected. Data analysis methods are being evaluated that will minimize variability caused by problems when directly correlating times for SO_2 and K_2/S (coal-seed) analyses, sootblowing cycles, air infiltration, furnace draft, etc.

TASK 4 - OPERATION AT 8 LB/SEC TOTAL GAS FLOW HIGH SLAG THROUGHPUT TEST

TESTING

No MHD testing was scheduled in the CFFF for this quarter. Table 1 shows the proof-of-concept (POC) testing to date and planned through July 1990. The next long-

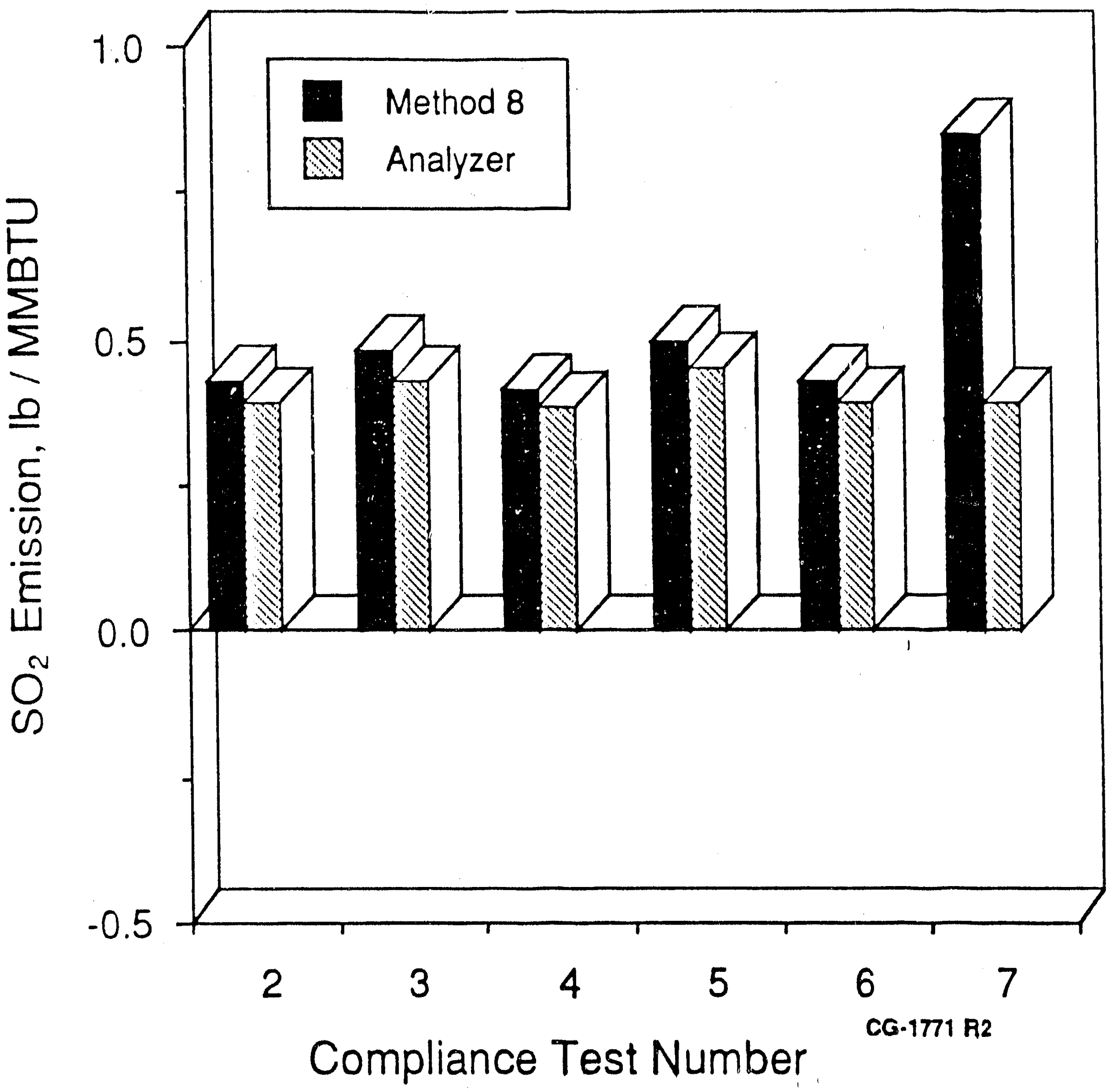

FIGURE 2. SO_2 Compliance Test Results - LMF4-S

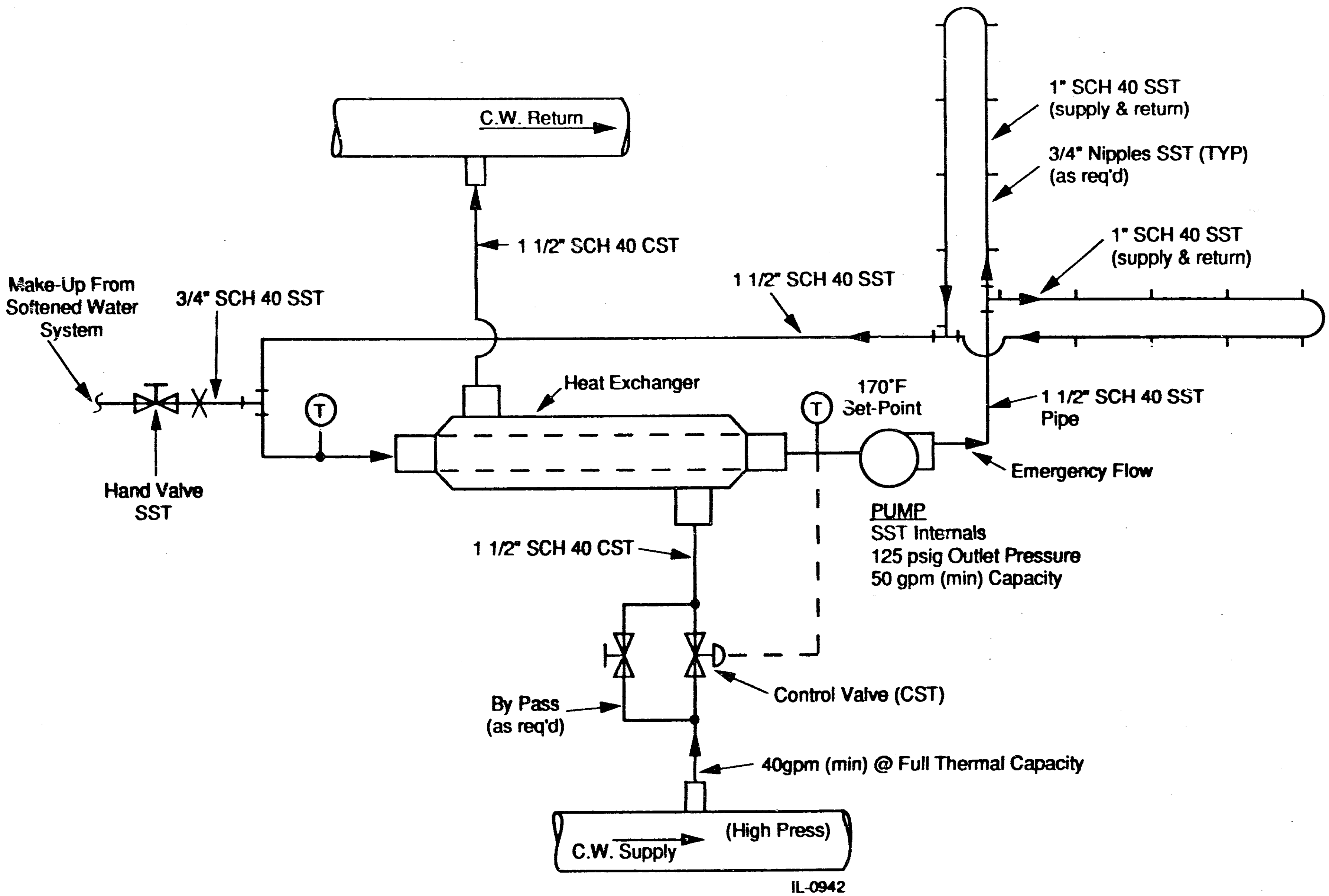

FIGURE 3. Sketch of Closed Loop Cooling Water System

duration POC test scheduled for April 1990 has been postponed until May 1990 due to late delivery of ash/seed handling system components. This system will be completed prior to the May 1990 test.

Table 1. LMF4 Proof-of-Concept Test Series

	TEST CONFIGURATION	DATE OF COMPLETION	HOURS ON COAL
COMPLETED	POC-LMF4K	09-87	198
	POC-LMF4L	12-87	63
	POC-LMF4M	02-88	57
	POC-LMF4N	05-88	185
	POC-LMF4O	09-88	252
	POC-LMF4P	11-88	101
	C/O-SHTM/AH MODS (LMF4Q)	05-89	40
	POC-LMF4R	08-89	263
	POC-LMF4S	12-89	135
			SUBTOTAL 1294
PLANNED	POC (Projected)	05-90	225
	POC (Projected)	07-90	240
			TOTAL 1759

Total test train operation time to date is 1832 hours (vitiation heater)

UPSTREAM COMPONENT SYSTEMS

During this quarter, the major work efforts on the upstream LMF flow train involved readying this portion of the flow train for the next scheduled long-duration test. **After the December 89 (LMF4-S) test, most of the upstream components (vitiation heater, coal disperser plate/combustor, supersonic nozzle, aerodynamic duct and the diffuser) were in good condition and are considered to be adequate for continued testing.**

However, repair work was required on the second section of the aerodynamic duct. Minor leaks developed in several cooling rings of this section during the LMF4-S test.

The damaged rings were replaced. A small crack through the wall of diffuser section #5 into the cooling water circuit developed during the test. The crack, found in post test inspection, was repaired.

The upstream hardware has accumulated many hours of test time, to date. Although serviceable life has been impressive, the total service life of each major component is not yet ascertained. Consequently, as a precaution, a back-up component for each major upstream component is under construction. Prior to the next test, spares will be available for the combustor, nozzle, the first two sections of the aerodynamic replacement duct and the constant area diffuser. This approach will allow for the expedient replacement of any component which may fail during upcoming long-duration tests.

DOWNSTREAM COMPONENTS SYSTEMS

Activities during this quarter centered on repair and modification of downstream equipment and analysis of data from recent prior tests. Also, preparation of a topical report on Superheater Test Module (SHTM) tube corrosion was initiated during this quarter.

Superheater Test Module (SHTM)

A rupture of one of the SHTM cooling section #1 (CS1) tubes during LMF4-S was reported in the last quarterly report. Figure 4 shows this rupture in the tube. The tube (SA178C carbon steel) is 2.5" DIA and the hole in the tube is also about 2.5" DIA. Wall thickness on the upstream face of the tube was about 1.5mm from an original wall thickness of about 4.8mm. Figures 5 shows the location of the tube in the tube bundle. An analysis of this tube indicated that the failure was due to high temperature gas-side corrosion (above 1100°F), caused by a blockage of the tube by mineral deposits. To help prevent this in future tests, the water flow direction will be reversed and thus put the coolest and greatest pressure water into the highest temperature region of the SHTM. Additional water treatment measures will also be implemented.

A draft topical report on the evaluation of SHTM Test Section tubes exposed to approximately 500 hours of coal firing is near completion. The evaluation included measurement of corrosion scale thickness and depth of sulfur penetration into the tube metal, examination and photography of corrosion scales to determine the morphology and composition, and a measurement of the near-tube deposit composition. TS1 and TS2 results were outlined in last quarter's report. TS3 tube corrosion samples were prepared and measurements made during this quarter. Corrosion rates at the hot ends of the tubes, where the temperature was near 1000°F, averaged 0.82 mm/yr for 5Cr-0.5Mo steel and 0.68 mm/yr for 2.5Cr-1Mo steel. The scales were mixtures of oxides and sulfides. Technical personnel from UTSI, ANL, and B&W will review the results of all three investigations and recommed future requirements.

FIGURE 4. Superheater Test Module Cooling Section #1 Tube Rupture During LMF4-S (Hole is approximately 2.5" Dia.) (Front View)

(SA 178C carbon steel tubing exposed to approximately 1100°F during test)

FIGURE 5. 2.5 Inch DIA Superheater Test Module Cooling Section #1 Tube Bundle After Tube Rupture (Gas flow was from right to left of photo.)

Corrosion analyses were also completed of corrosion probe ring samples which were exposed for 405 hours during the November 88, June 89 and August 89 (LMF4-P, -Q, and -R) tests, with the exception of alloy HR-160 which was exposed only for 263 hours during LMF4-R. Two probes were employed, one located downstream of the secondary combustor at a gas temperature of about 2400°F and the other in the TS1 section at a gas temperature of about 2250°F. The indicated metal temperatures on the secondary combustor (SC) probe were about 750°F at the end closest to the center of the duct (away from the wall) and about 1200°F at both the center and the end nearer the wall. The low temperature at the outer end, which was reported earlier to be the result from excessive cooling air entering the sample ring annulus at that point, may have been an erroneous measurement, as discussed below. For the TS1 probe, temperatures of the metal were 800°F at the end away from the wall, an average of 980°F at the center, and 860°F at the end nearer the wall. The TS1 probe could not reach its intended 1200°F control temperature as a result of an oversized control valve which allowed excessive air flow. This problem is being corrected for future tests. The deposits on the two probes differed as a result of the different metal and gas temperatures and environment. The deposit on the secondary combustor (SC) probe was hard and quite adherent, while that on the TS1 probe spalled-off during test shutdowns. The SC probe deposits had a greenish-yellow color while that of the TS1 probe was dark brown similar to that on the TS1 tubes.

Corrosion data for the SC and TS1 corrosion probes are given in Tables 2 and 3, respectively. Most SC probe samples had roughly an order of magnitude greater corrosion than did the corresponding TS1 probe samples. To some extent, this may be attributed to higher SC probe temperatures. The HR-160 samples on the two probes, however, had about the same indicated temperature. Therefore, the SC probe thermocouple may have been reading incorrectly throughout the exposure. HR-160, a high alloyed Nickel-base alloy with 28% Chromium, 27% Cobalt, 4% Iron and 2.75% Silicon, had the best corrosion resistance on both probes. It should be noted that the alloy 316 corrosion was less than alloy 304 and, also, that corrosion of 253MA was less than 310, despite 310 having a higher Chromuim content. The 316 material also has a higher Molybdenum content. The measured corrosion of the T-11 and SA-192 samples on the TS1 probe, as indicated by scale thickness, was much less than for the higher Chromium T5 sample, leading to speculation that scales from those samples may have spalled-off at some time during the exposure.

SC probe corrosion rates were also far greater than those of TS1 tubes, in some cases by an order of magnitude. For alloy 310, for example, the average SC probe metal recession was 2.7 mm/yr as compared to about 0.2 mm/yr of the TS1 tube at similar temperature. The TS1 corrosion probe rates, on the other hand, compare well with those of TS1 tubes. One possible cause of the high SC probe corrosion is the fact that the probe is located just down-stream of the secondary combustor where incomplete combustion is taking place resulting in lower O_2 partial pressure and relatively higher S partial pressure. If this is the case, the SC probe data may be applicable to exposure in the secondary combustor region. It does point out, however, the importance of convection tube banks in an actual MHD boiler being located sufficiently far downstream of the secondary combustor to allow complete combustion.

Table 2. *Secondary Combustor Corrosion Probe Data For 405-Hour Exposure* [1]

ALLOY	TEMP °F	CORROSION SCALE THICKNESS				INTERNAL PENETRATION DEPTH				EFFECTIVE METAL RECESSION			
		AVERAGE		MAXIMUM		AVERAGE		MAXIMUM		AVERAGE		MAXIMUM	
		µm	mm/yr	µm	mm/yr	µm	mm/yr	µm	mm/yr	µm	mm/yr	µm	mm/yr
HR-160	750	18.83	0.63	42.50	1.41	21.88	0.73	35.00	1.16	40.71	1.33	77.50	2.58
253MA	1192	38.33	0.83	100.00	2.16	49.38	1.07	50.00	1.08	87.71	1.90	150.00	3.24
310	1199	34.72	0.75	100.00	2.16	87.12	1.95	137.50	2.97	121.84	2.70	237.50	5.14
316	1197	73.89	1.60	192.50	4.16	75.30	1.62	125.00	2.70	149.19	3.23	317.50	6.87
304	1193	70.51	1.53	192.50	4.16	98.09	2.12	137.50	2.97	168.60	3.65	330.00	7.14
T5	1038	1542.25	33.35	2420.48	52.33	0.00	0.00	0.00	0.00	1542.25	33.35	2420.48	52.33
T11	1163	2607.94	56.39	4181.80	90.39	0.00	0.00	0.00	0.00	2607.94	56.39	4181.80	90.39

[1] HR-160 Exposed for 236.4 Hours

Table 3. TS1 Corrosion Probe Data For 405-Hour Exposure [1]

ALLOY	TEMP °F	CORROSION SCALE THICKNESS				INTERNAL PENETRATION DEPTH				EFFECTIVE METAL RECESSION			
		AVERAGE		MAXIMUM		AVERAGE		MAXIMUM		AVERAGE		MAXIMUM	
		µm	mm/yr	µm	mm/yr	µm	mm/yr	µm	mm/yr	µm	mm/yr	µm	mm/yr
HR-160	768	3.28	0.11	22.50	0.75	1.11	0.04	6.25	0.21	4.39	0.15	28.75	0.96
253MA	882	8.39	0.18	22.50	0.49	0.00	0.00	0.00	0.00	8.39	0.18	22.50	0.49
316	830	16.73	0.36	30.00	0.65	0.00	0.00	0.00	0.00	16.73	0.36	30.00	0.65
304	857	19.43	0.42	33.76	0.73	0.00	0.00	0.00	0.00	19.12	0.42	33.76	0.73
T5	982	111.10	2.40	63.00	3.41	0.00	0.00	0.00	0.00	111.10	2.40	63.00	3.40
T11 [2]	948	41.15	0.89	62.48	1.35	0.00	0.00	0.00	0.00	41.15	0.89	62.48	1.35
SA-192 [2]	931	51.35	1.11	75.02	1.62	0.00	0.00	0.00	0.00	51.35	1.11	75.02	1.62

[1] HR-160 Exposed for 236.4 Hours
[2] Scales May Have Spalled from These Samples During Exposure, Accounting for Less Apparent Corrosion Than T5

Electrostatic Precipitator (ESP)

Only two particulate samples were taken at the exit to the baghouse and ESP during the LMF4-S test of the previous quarter. Baghouse collection efficiencies at 5400 and 6000 cfm were both 99.7%. ESP collection efficiencies were 99.3 and 96.8% at 7500 and 6000 cfm, respectively. The explanation for the lower efficiency at lower flow rate is due to the operation during baghouse cleaning cycles. When the baghouse was taken off-line for cleaning, all flow was diverted through the ESP after which performance was degraded for at least one hour. K_2/S for the LMF4-S test was 1.0.

Several minor hardware modifications to the ESP are in progress to improve both operation and performance. Thermal insulation in the interior of the electrical insulator housings has been removed and replaced with exterior insulation, thus eliminating electrical shorting in the ESP due to detachment of the insulation from the interior walls. In addition, eliminating interior insulation will improve post test cleanout of the insulator housings. Arcing also has been observed at the location where the high voltage rod penetrates the ESP interior at the insulator housing. Sheets of 1/16 inch thick Teflon will be used to wrap the rod which should eliminate localized arcing. This material will be closely monitored as previous materials used developed pinholes, resulting in arcing. The eight steel access doors to the ESP are being modified with polycarbonate windows to allow visual inspection of the ESP during operation. This will significantly enhance troubleshooting of potential problems within the ESP.

During the prior two CFFF tests ESP performance has been erratic, possibly due to the increased number of small particles entering the device (caused by increases in total potassium input). Space charge and/or ion quench can occur with only a small increase in the number of small particles entering an otherwise efficient ESP. To more accurately investigate this phenomenon, efforts are underway to evaluate the use of continuous real-time particle sizing device capable of measuring particle size distributions as small as 0.2 micrometers. A vendor has tentatively agreed to perform a demonstration of their instrument's capabilities under actual CFFF run conditions.

ADVANCED MEASUREMENT SYSTEMS

The UTSI wide band system was used together with the stand-alone line reversal system to process the dynamic Helium bleed pressure fluctuations, luminosity fluctuations, microphone fluctuations, and coal flow dynamic data recorded during the December 89 (LMF4-S) test. Analysis of this data concentrated on evaluation of fluctuations occurring in association with the noise pulses or "rumble" associated with the low mass flow train operation. Table 4 describes the diagnostic devices employed in the study. A schematic of the CFFF flow train showing the locations of the diagnostics is given in Figure 6. The CFFF has exhibited this audible rumble during coal operation of the LMF flow train. The cause(s) of this rumble are of concern to CFFF operating personnel. The loudness and frequency of these rumbles varies and has reached sufficient intensity and repetition that test operators have temporarily shut down the flow train during long-duration testing on numerous occasions. The rumble has been noted over a period of several years but in the past no extensive study of the phenomena has been carried out, although the

TABLE 4. Diagnostics Used To Characterize Disturbance Phenomena

Device	Number	Frequency	Locations	Comments
Line Reversal	3	1 kHz Temperature Measurement	Diffuser (2) Radiant Furnace	The two diffuser systems measure the same spatial location but can be used at different wavelengths
Helium Bleed Pressure Transducers	4	25 kHz Resonant Frequency	Vitiation Heater Duct (2) Diffuser	These are dynamic transducers and communicate directly with the combustion gas
Microphone	1	20 kHz	Radiant Furnace	This device measured the audible boom
Luminosity Probes	2	5 kHz	Duct (2)	Cross correlation between probes allows measurement of disturbance velocity

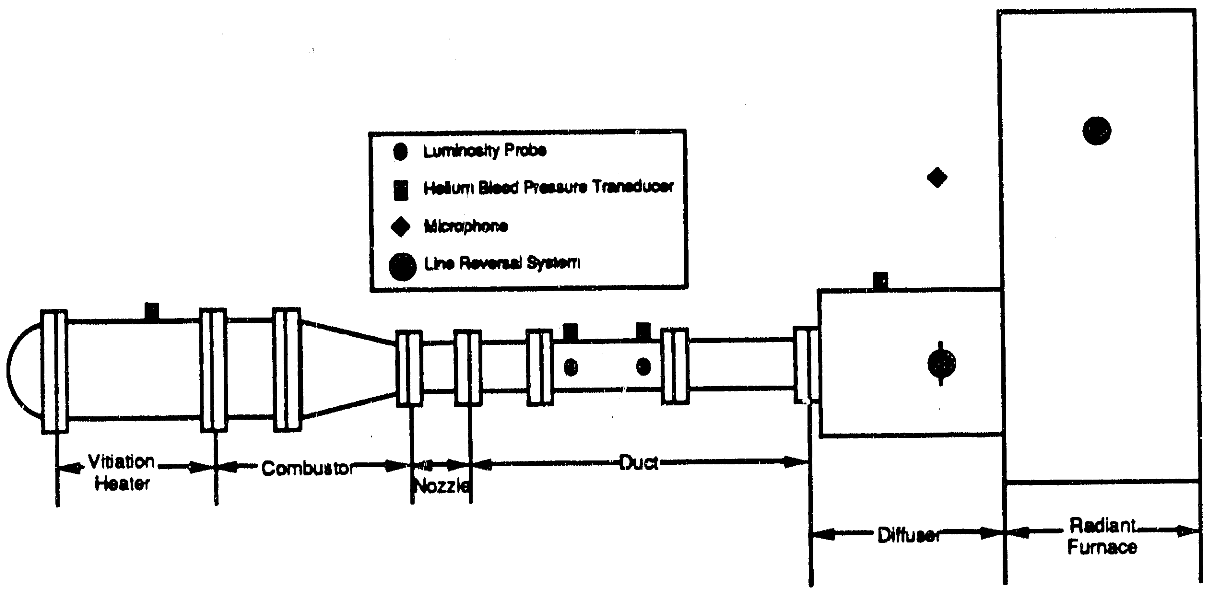

FIGURE 6. Flow Train Schematic Showing Locations of Diagnostics

disturbances were considered in relation to the uncertainty of the modified line reversal temperature measurements made by UTSI (Ref 2). Visual/aural observations showed a correlation existed between the rumbles and large drops in the intensity of visible light emanating from the diffuser optical diagnostic ports. The primary goal of the current study is to analyze quantitative measurements of parameters that would allow discovery of the underlying cause of the flow disturbances with the goal of properly considering this phenomena when scaling the MHD system.

Time traces of the helium bleed dynamic pressure measurements, luminosity measurements, line reversal measurements, and the microphone output were correlated to identify phenomena associated with the rumble. Typical time traces are shown in Figure 7, and show that the rumble occurred after the vitiation heater pressure would significantly increase. After the heater pressure started to increase, the diffuser pressure would increase, then decrease below normal level, with all pressures returning to normal as the line reversal signal levels came back up. The high frequency line reversal systems indicate the noise pulses correspond to a decrease in gas emissions near the potassium line. The furnace gas emissions drop more gradually, starting at a time about 0.4 seconds after the diffuser drop. The luminosity probes indicated a sharp drop in the potassium emissions just before the line reversal decrease, and the drop time/distance between the luminosity probes indicated the rumble propagated down the aerodynamic duct at approximately 305m/sec (1000fps). Detailed acoustic measurements at multiple locations are planned in future CFFF tests to locate the source of the rumble pulses.

Figure 8 gives time traces of both the lamp plus plasma (lamp) and plasma alone (plasma) diffuser line reversal signals during a typical rumble event. The UTSI diffuser spectrometer line reversal system has a time resolution on the order of 1msec for temperature measurements and on the order of 10μsec for optical emission measurements. Most of the drop in the lamp and plasma line reversal signals occurs over a period of less than 100msec which clearly necessitates wide band diagnostics to adequately resolve the event. The instrumentation available for this purpose consisted of three line reversal systems, four helium bleed dynamic pressure transducers, one acoustic microphone, and two luminosity probes.

During the December 89 (LMF4-S) test all instrumentation worked well with the exception of two helium bleed pressure transducers located in the duct which apparently were plugged by slag. Data was collected during 6 periods of a 135 hour test. Individual disturbance events were recorded by triggering the data acquisition system on drops in the diffuser line reversal signals. Approximately 300 events were accumulated during the six periods which covered a total time of 42 minutes. Data from one typical event is presented in this report. Future continuing analysis will examine the general character of all the events using statistical and stochastic analyses to ascertain the magnitude and temporal relationships that exists between the measured parameters.

The results presented in Figures 9 and 10 are time traces of the measured parameters during a single typical event. All of the plots have the same time scale with time zero being defined as the time the data acquisition system was triggered. Comparison of the pressure plots given in Figure 9 shows a clear temporal relationship between them. The vitiation heater pressure increases and reaches a maximum of about 2 psi slightly before time zero. Note, that since a dynamic pressure transducer is used,

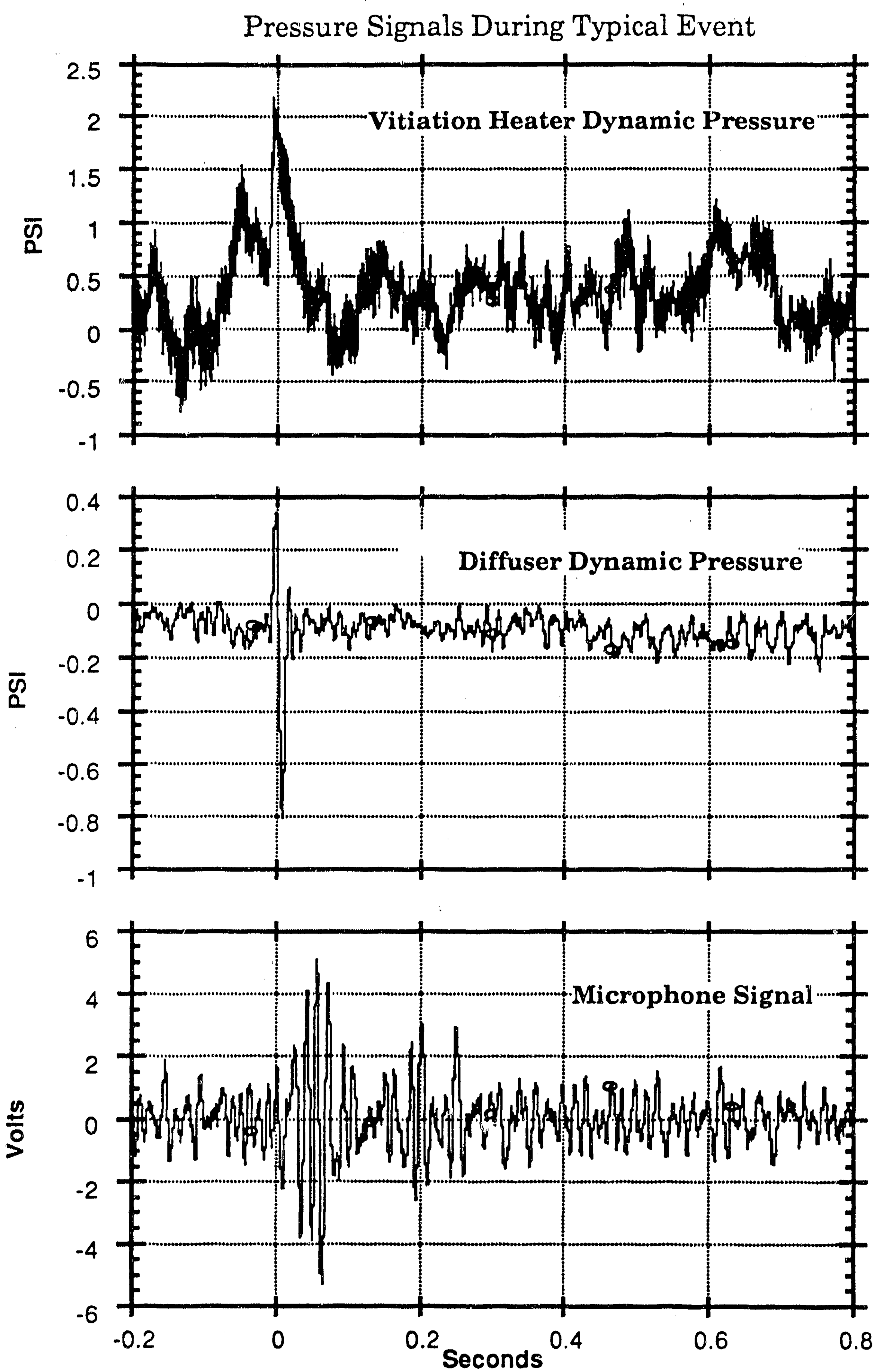

FIGURE 7. Comparison of Pressure Measurements During Typical Event

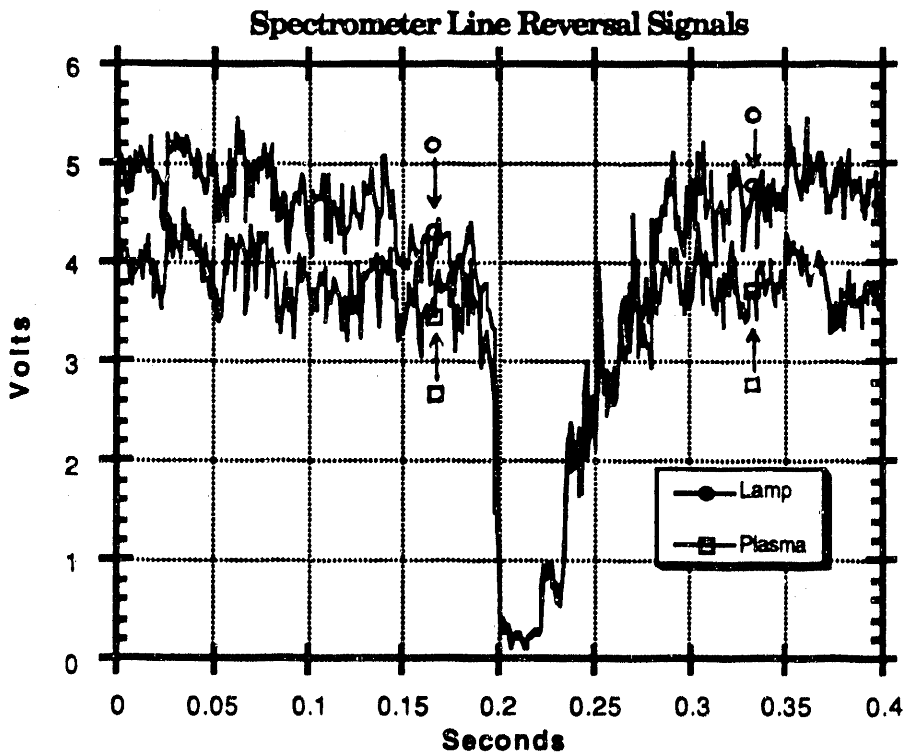

FIGURE 8. Typical Dropouts Seen in the Line Reversal Signals During a Rumble Event

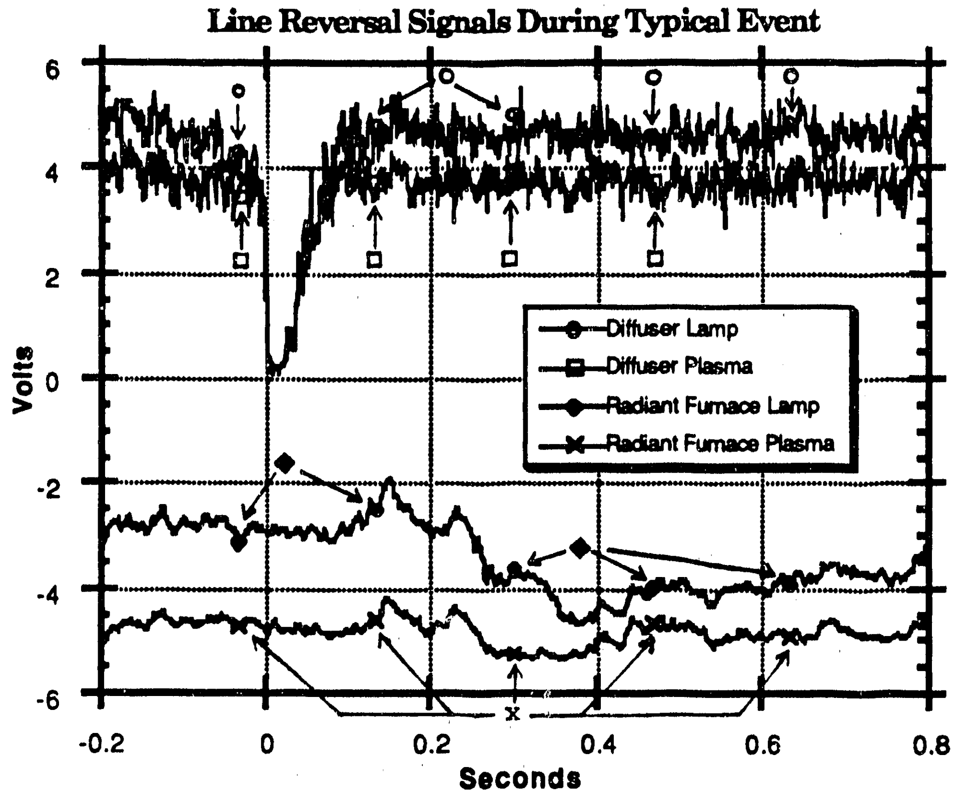

FIGURE 9. Comparison of Line Reversal Signals During Typical Event

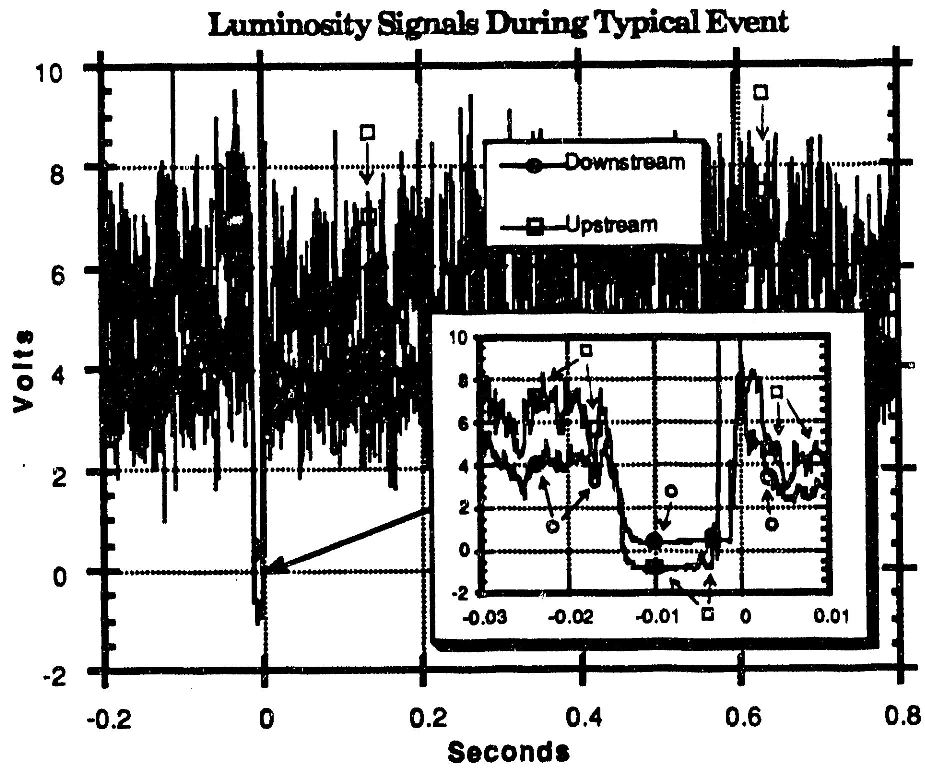

FIGURE 10. Comparison of Luminosity Signals During Typical Event

this is a pressure rise over the average level. Pressure rises up to 5 psi were measured which is about 7% of the nominal vitiation heater pressure. As seen in the trace of the diffuser dynamic pressure, there is a well defined pulse in the diffuser pressure which is much narrower and of smaller magnitude than the vitiation heater pressure pulse. The peak of the diffuser pressure pulse occurs very near time zero of the plot (thus this pulse coincides with the drops in the line reversal signals). The rumble sound generated during this event is evident in the microphone pressure trace as a burst of pulses starting just after time zero and reaching a maximum amplitude about 0.05 seconds later. From this figure, it appears that the audible rumble has a frequency of about 50Hz.

The line reversal signals for the diffuser and radiant furnace are compared in Figure 10. The transmission of the gas, which can be obtained from these signals, is given by

$$\tau = \frac{S_{lamp} - S_{plasma}}{S_{calib}}$$

where τ is the transmission, S_{lamp} is the lamp plus plasma signal, S_{plasma} is the plasma signal, and S_{calib} is the lamp signal when no plasma is present. During the event, the gas in the diffuser becomes nearly opaque at the measurement wavelength of 750nm since $S_{lamp} \cong S_{plasma}$. The temperature also decreases which is indicated by the decrease of the magnitude of both diffuser signals indicating lower gas emission. (In Figure 9 the reference level is 0.0V for the diffuser signals and -7.0V for the radiant furnace signals.) Similar behavior is seen in the radiant furnace signals though the effect reaches its maximum about 0.4sec later and is not as severe. Thus, during the event the temperature of the gas in the diffuser and the furnace drops precipitously along with a decrease in the transmission of the gas. Furthermore, the furnace measurements are effected for a much longer period than the diffuser signals. Recovery of the diffuser signals from their minimum is completed in about 0.1 second while the furnace signals are still recovering 0.5 second after their minimum.

Traces of the luminosity signals are shown in Figure 10. The event is well defined temporally in these signals and is very brief. As seen on the inset graph the entire event takes place in less than 20msec and is completed before time zero of the plot. Since the spatial separation (d) of the luminosity probes is known, a velocity (v) of the disturbance can be calculated along with a characteristic length (L) of the disturbance. If the time delay between the two signals is Δt, the velocity is simply $d/\Delta t$. The characteristic length is defined by $L = vt$ where t is the time width of the event. The data in Figure 10 gives a velocity of 300m/sec $\pm$ 100m/sec which leads to a characteristic length of the disturbance of 3.6m $\pm$ 1.2m. **The temporal ordering of the luminosity and line reversal signals clearly suggests a disturbance that originates upstream of the luminosity probes and moves downstream through the diffuser and into the radiant furnace. As the disturbance moves downstream it becomes more diffuse as is seen in the width of the event at each location. The signals from the helium bleed**

pressure transducers also support the conclusion that a disturbance is moving downstream. (The microphone signal is of no value in determining the disturbance propagation direction since it measured the acoustic noise near the duct, not the pressure in the duct.)

In addition to the data analysis effort, preparations for the upcoming test (LMF4-T) were initiated this quarter. The slag chopping optical ports, implemented successfully on an experimental basis last quarter, were modified to overcome the observed shortcomings and to increase durability. These ports will be installed early next quarter. Modifications to the diffuser microprocessor line reversal system to increase sensitivity were completed, and plans are being formulated to validate the low temperature measurement capabilities and measurement uncertainties of this system for potential use near the superheater inlet. Discussions with Mississippi State University (MSU) relating to particle and space charge diagnostics led to plans for additional instrumentation to evaluate ESP performance and how that performance might be improved for different operating conditions, as well as instrumenting to better understand performance effects of ESP rappers and other ESP cyclical events. Discussions have also been initiated with vendors for commercial particle characterization instruments to determine if a commercially available instrument might provide a significant portion of the needed ESP diagnostics. Other plans for the next test include operation of most of the CFFF advanced measurement systems and the recently utilized MSU diagnostics. These plans include continued measurements with the coherent anti-Stokes Raman spectroscopy (CARS) spatially resolved temperature measurement system, the spectroscopic water injection system, the surface emission characterization of the high temperature air heater (HTAH) test materials, and the intrusive multi-probe system, in addition to the MSU particle diagnostics. MSU is not planning to pursue emission scans for water leak detection until this diagnostic approach can be shown to have the potential for adequate water quantification to distinguish between changes in conditions and leaks. MSU will continue operating their diagnostics from both their large mobile laboratory and from the recently completed particulate sampling shelter, as appropriate. Plans are also being formulated to add several microphones and luminosity probes in the LMF flow train to aid in diagnosing the acoustic rumble phenomenon.

WASTE MANAGEMENT

CFFF Mass Balance Program

The mass balance input files for the August 89 (LMF4-R) test were completed with the receipt and addition of six superheater/air heater solids analyses. (The LMF4-R mass balance previously run was based on an assumed composition.) The balance program was then run using average raw data and gas analysis data. The December 89 (LMF4-S) test analyses were completed and a balance was run during this quarter. The data files were reorganized and put into several new subdirectories. Programs that need to access this data were then rewritten to reflect the new locations for input data. A mass balance program data input file for the LMF4-S test was also created. Average process conditions and solids loading data for the test were calculated and entered. All analyses required were entered. The EPA-17 analyses that were entered were from the previous test due to insufficient sample quantities generated during LMF4-S. The LMF4-R test superheater solids analysis was used since these solids could not be recovered following the LMF4-S test. The dew point measurement was not available during the test, and therefore a dew point was calculated. The mass balance program was then run. With the exception of sodium, the overall input and output measurements for inorganic coal ash constituents were within approximately 16%. Sodium usually showed much higher output than input, probably because of the difficulty of measuring small quantities of sodium in the presence of very large amounts of potassium. Potassium output levels were less than inputs. The major reason is believed to be the amount of potassium not recovered after tests from furnace deposits, absorbed in refractories, deposited in ducts and on tube surfaces and other locations throughout the flow train, and also because of the conditions and limits noted above. About 70% of incoming coal ash constituents were removed from the slag tap during both tests. EPA Method 5 measurements of dust loadings and flows and weights recovered from the baghouse agreed within 18% for LMF4-R, and 13% for LMF4-S. Work is continuing toward refining of the methods. The new ash removal system should help in improving balances.

During the June 89 (LMF4-Q) and August 89 (LMF4-R) tests, samples of absorbed acid gases were obtained by passing aspirated exhaust gases, collected during particulate measurements, through suitable impingers. Both sets of samples have been analyzed for chlorine/chloride anions. **The results indicate that an excess of chlorine was exiting from the particulate control devices in the gaseous phase. Additional data collection is planned in future tests to reduce the uncertainty of measurements and close the balance.**

Work is continuing on an investigation of an improved system for the data analysis of CFFF data. A number of deficiencies in the program (DATATEST) as well as desirable enhancements were identified for resolution. This program is also being used to calculate and plot new channels of data in a way that appears to offer the potential for greatly enhancing data analysis.

The major activity in the area of CFFF data reduction and analysis during the quarter involved the development of new routines to "clean-up" the raw data. The data for several process parameters has been identified in past quarterly reports as being of lower quality than desired. Data "clean-up" routines will be developed and tested as a means of addressing this issue. A computer routine was developed to calculate coal flowrate based on readings of the coal feedtank load cells. The routine identifies events (such as a filling of the feed tank) to assure that data is valid, and includes a calculational procedure to extract average feedrate from the measured weights. The routine was applied to existing raw data and adjusted until the desired results could be achieved. These results were than compared to Coriolis meter readings, and comparable outputs were obtained. Thus, it is now felt that the coal feedrate can now be obtained from two completely unrelated instruments and methods, to provide a check on the Coriolis meter and an increase in the confidence of measurement accuracy. It is planned to integrate this and other similar routines into the DATATEST data reduction program.

Work was started on developing a routine to "clean-up" the gas analysis data in similar fashion to eliminate purge cycles, calibration, and other 'non-data' points. As a first step, about six hours of raw data from a recent test was obtained and various plots were generated. The data and plots are now being examined in order to identify problems that might negatively impact the quality of the gas analysis data. This problem is of a much larger scope than the coal feedrate problem, as a large variety of individual analyzers, located throughout the flowtrain, provide partial gas analysis data.

A period of relatively steady operating conditions that occurred during the LMF4-R test was identified. Chemical analyses of slag from that period and future tests will be performed so that the work to evaluate potassium levels as a function of operating time may continue.

A new wire mesh screen will be installed in the pulverized coal transport line before the next test. This should assure more uniform distribution in the line and thus provide a more representative sample.

A truck will be sent by TRW to pick up the Tote bins filled with ash/spent seed from the last month. With TRW's consent, one of the filled Tote bins is being retained for use in commissioning the automated ash handling system. During the quarter, activities included:

- Level measurements were obtained for the Tote bins to enable TRW to determine solids settling characteristics during shipment. This information was sent to TRW.

- The identification numbers of the unfilled and the one retained Tote bin were obtained and transmitted to Mr. J. Jones, of TRW.

- Analyses of the LMF4-S baghouse and ESP composite samples for carbonate were requested in order to provide this information to Mr. E. Barrish of TRW.

Work was started on setting up a user friendly database for chemical analysis results. The current effort concentrates on setting up the "shell." Thirteen menu forms and eight help forms were created, to date, using the forms management software (FMS) system on the VAX computer. A forms library was also created and a driver program was written in Fortran. Also, investigating the possible use of the Datatrieve computer program for this application was started.

Coal sieve analyses on past data was completed. Upon completion, the data (on eastern and western coals) was transmitted to Mr. C. Thomas of PETC.

TASK 5 - TESTING OF DOE SUPPLIED COMPONENTS

TRW/UTSI COOPERATIVE TESTING

In informal discussions between TRW and UTSI, a decision was made to consider the possible use of the CFFF, on a non-interfering basis, as a test bed for TRW in their development work for hardware of the Integrated Topping Cycle (ITC). This effort was undertaken at the suggestion of PETC and was initiated through general review of the TRW ITC program plans/schedule, along with UTSI's FY1990 CFFF test schedule. The plan being considered was that of taking advantage of the FY1990 long-duration tests in the CFFF to obtain experimental information on the durability of materials, hardware and design concepts specified for the ITC. It was noted in this review that one area of cooperation appeared to be compatible between these two programs. That area was in experimental evaluation of the materials and design concept for cooling panels of the ITC slagging combustor. The test component which afforded this evaluation was the TRW 20 MW_t first stage combustor spool section. This section was installed in the AVCO Mark VI test train during the 1989 combustor tests that were conducted at that facility. It was subsequently transported back to TRW for refurbishment and no immediate use was planned.

During this quarter, engineering studies were initiated at both UTSI and TRW to determine precisely what requirements would be necessary to allow installation of the TRW 20 MW_t, first stage spool section into the CFFF LMF test train. These studies concluded that this spool section could be mated to the existing UTSI combustor with only minor system modifications. Specifically, the spool piece could be installed into the UTSI combustor as a replacement for the existing combustor cylindrical section. To accommodate the slight difference in the internal diameters of these two units, specially built adapter flanges would be required.

These studies continue with the expressed objective of installing the spool section into the LMF test train for an upcoming CFFF test. An accelerated effort on the part of TRW has been initiated to refit the 20 MW_t spool section with materials and the design for the internal cooling panels that are specified prototypical to the ITC design. UTSI has also begun an accelerated effort to design and fabricate the adapter flanges. The goal of this program is to try to incorporate the spool section into the LMF test train as early as possible, possibly for the next scheduled CFFF long-duration test (LMF4-T) in May 90.

TASK 6 - MODIFICATIONS TO THE CFFF

COMPONENT DEVELOPMENT AND TEST FACILITY MODIFICATIONS

Auto Ash/Seed Handling System

Work on the automated ash/seed handling system continued with installation of the screw conveyors under the superheater test module (SHTM) and air heater (AH), and the pneumatic system under the ESP and BH. The ESP has only one discharge point while the BH has one for each of its two compartments.

The ash removal system power installation, control interface design, and documentation effort is continuing. Cable trays and the motor control center will be installed prior to the next test.

The ash removal system transport piping from the BH and ESP to the spent seed storage tank was fabricated and welded and will be installed prior to the next test. In addition, two ash grinders, three sections of the screw conveyor, and the rotary valves for the superheater were installed. The concrete pads for the transport system were installed and the four Denseveyor Ash Vessels were assembled and put in place. The pipe supports for the transport piping were fabricated and are being installed in conjunction with piping installation.

Western Coal System

Temporary modifications to the coal system were completed for the western coal flow tests. Because of the high oxygen content of the coal, it was necessary to pulverize in an inert atmosphere. To insure an inert atmosphere, nitrogen was plumbed into the air heater that normally provides heated air to dry the coal. Thus, the coal was dried with heated nitrogen, instead of heated air. The heated nitrogen was then used as the transport medium to the coal system baghouse.

A shipment of approximately 25 tons of Montana Rosebud coal (29% moisture) was received at the CFFF for flow testing. This coal was stored in the feed tank to the pulverizer under a nitrogen blanket. Tests were conducted with and without potassium carbonate mixing. The flow of nitrogen to the pulverizer (to prevent combustion) was set at 20,000 lb/hr. The maximum primary nitrogen temperature entering the pulverizer was limited to 550°F due to temperature limitations of the E-35 mill addition to the pulverizer. The pulverizer exit temperature was maintained at 165°F for all tests.

Raw coal was fed to the pulverizer where grinding and drying occurs. Grab samples were taken at the pulverizer exit. The primary 'air' conveys the pulverized coal to the baghouse which separates the solids from the gas stream. This coal is collected in reservoir tanks until the pulverization has been completed (approx. 10,000 lb). Next, the coal is gravity fed into the feed tank and pressurized with nitrogen. Grab samples were collected as the coal flowed from the feedtank.

The first test was conducted without mixing potassium carbonate (seed) with the coal. Moisture at the pulverizer exit averaged approximately 14%, while the feedtank moisture was only 7% (see Figure 11). Drying does occur between the pulverizer exit and the feedtank, especially since dry nitrogen was used, but some of the observed difference may be caused by sampling technique. The residence time for the gas in the duct between the pulverizer exit and the baghouse inlet was approximately 2 seconds. There is additional residence time for the particles in the baghouse. A heat balance was performed around the pulverizer but nearly 50% of the energy was lost in the pulverizer. Another energy balance was performed between the pulverizer exit and the baghouse. However, the amount of energy required to evaporate the coal from 14% moisture at the pulverizer exit down to 7% moisture at the feedtank would have caused a much greater gas temperature drop than was measured. For this reason it was believed that the pulverizer exit coal sample was biased and the measured moisture was higher than actually present. Two samples were collected for size analysis. These samples were approximately 77% through 200 mesh for a raw coal feed rate of 4500 lb/hr to the pulverizer (see Figures 12 and 13).

In the second test sequence, potassium carbonate was mixed with coal in the pulverizer. The 'dried' mixture contained approximately 10% K_2CO_3. During the first portion of the test, the raw coal feed rate was 4500 lb/hr with an indicated 7 lb/min seed flow. During the last third of the pulverization, the raw coal feed rate was increased to 5000 lb/hr. Pulverized coal moisture content for the pulverizer outlet and the feedtank averaged approximately 15% and 6%, respectively (see Figure 14). Size analysis of pulverized coals averaged 81% through 200 mesh for both 4500 and 5000 lb/hr raw coal feed rates (see Figures 15 and 16). Typical pulverizer pressure drop and primary air flow is shown in Figure 17.

Subsequent flow tests at the CFFF of the pulverized coal were very successful with no recorded flow stoppages. Flow smoothness was observed to be comparable with that of Illinois #6 coal. Flow rates were varied from 0.8 to 1.5 lb/sec with no observable control problems.

Six different process options were developed to dry Montana Rosebud coal at the CFFF. Based on a number of factors (capital cost, operating cost, installation schedule, simplicity, etc.), one option was selected and recommendations were given to PETC. The option selected (see Figure 18) has a closed-loop inerted gas system which is heated indirectly with an oil or gas fired burner. The heated gas is used to dry the coal and carry the coal to the baghouse. The moisture in the gas exiting the baghouse is removed by a water-cooled condenser. The water supplied to the condenser is tentatively cooled with a chiller. The dried gas (dewpoint of 90°F) from the condenser then returns to the heater, thus completing the loop. Oxygen contained in the inert gas loop is maintained below 7%, with nitrogen make-up. Because the primary 'air' to the pulverizer will be 650 to 700°F,

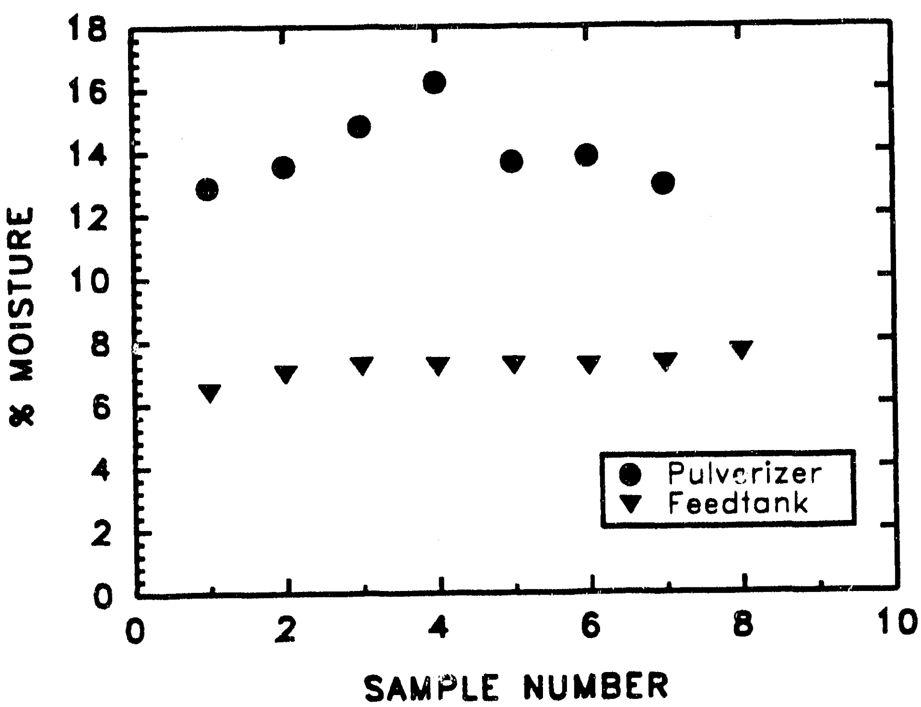

FIGURE 11. Moisture of Montana Rosebud Coal Pulverized at CFFF Without K_2CO_3

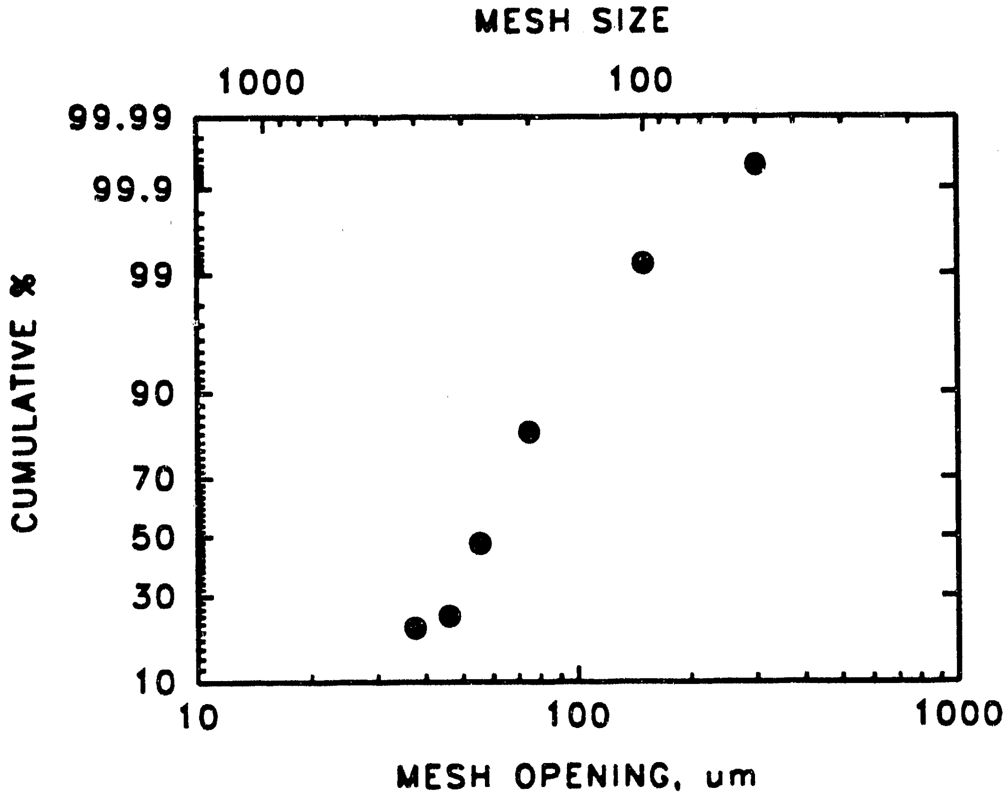

FIGURE 12. Size Analysis of CFFF Pulverized Montana Rosebud Coal Without K_2CO_3 (Sample 1)

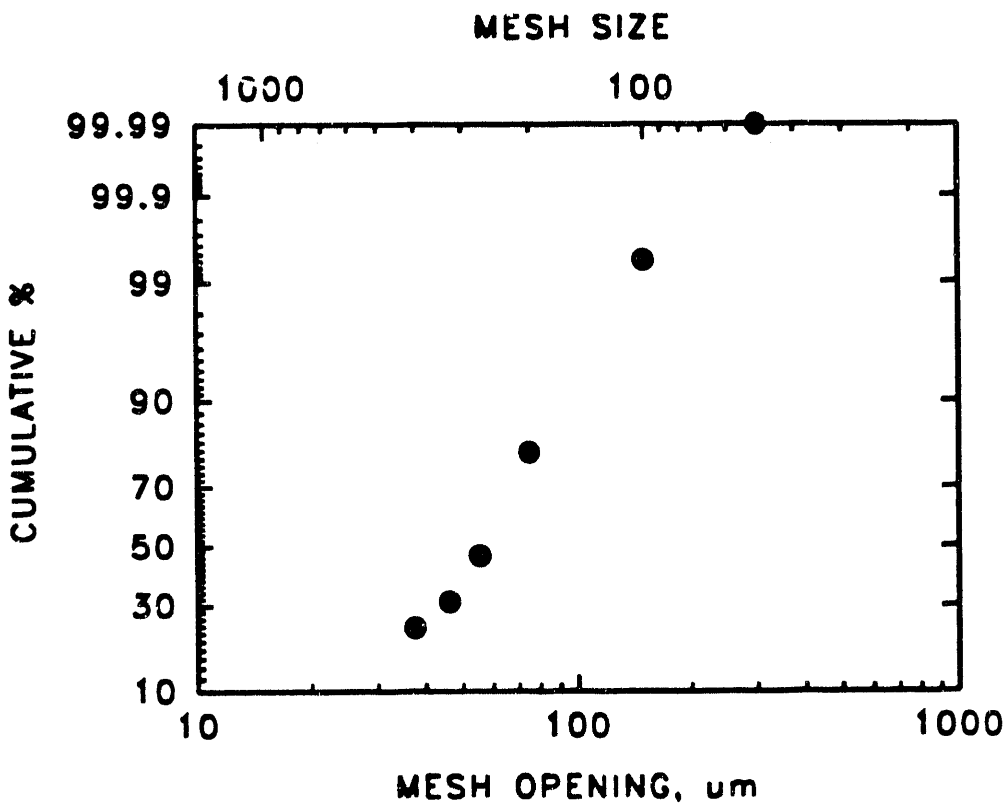

FIGURE 13. Size Analysis of CFFF Pulverized Montana Rosebud Coal Without K_2CO_3 (Sample 2)

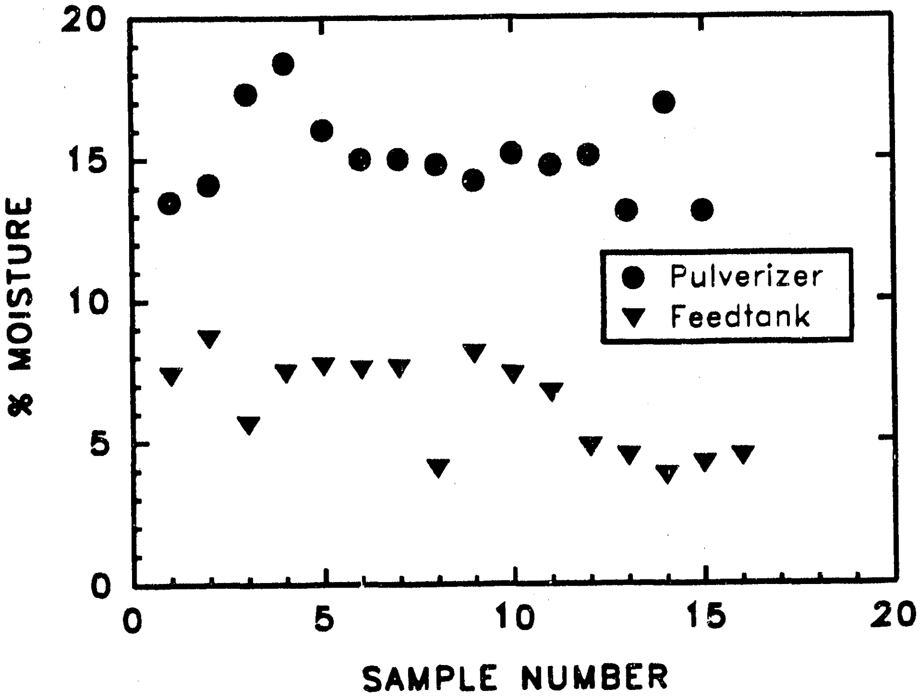

FIGURE 14. Moisture of Montana Rosebud Coal Pulverized at CFFF With 10% K_2CO_3

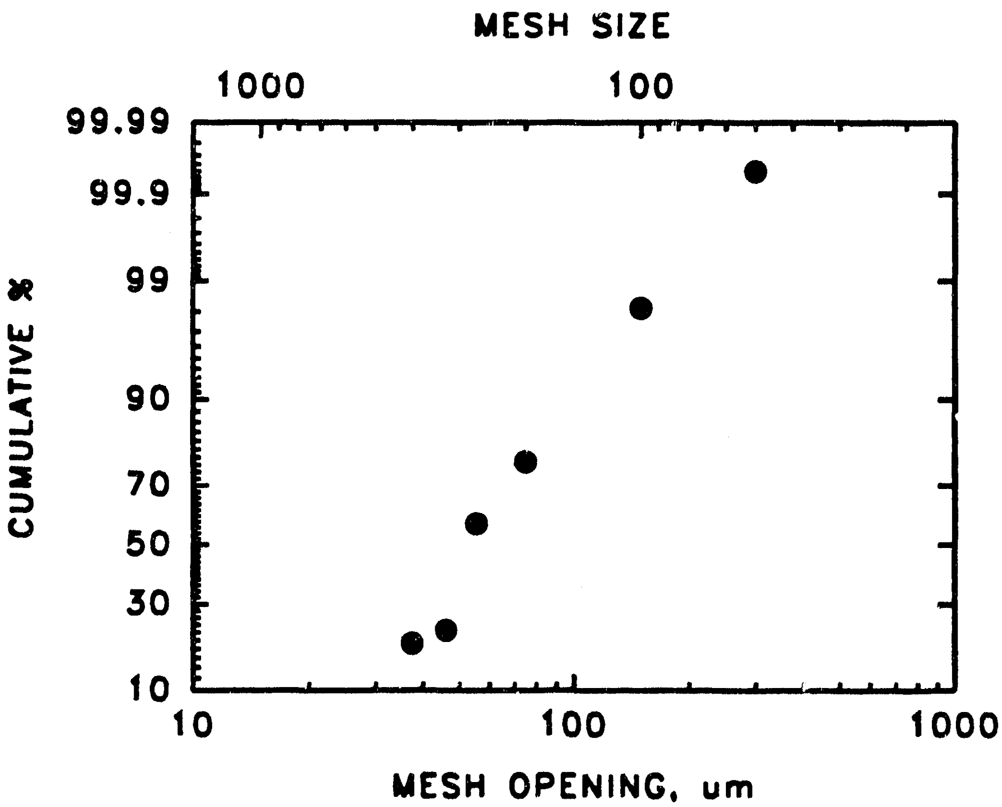

FIGURE 15. Size Analysis of CFFF Pulverized Montana Rosebud Coal With 10% K_2CO_3 (4,500 lb/hr raw coal feed rate)

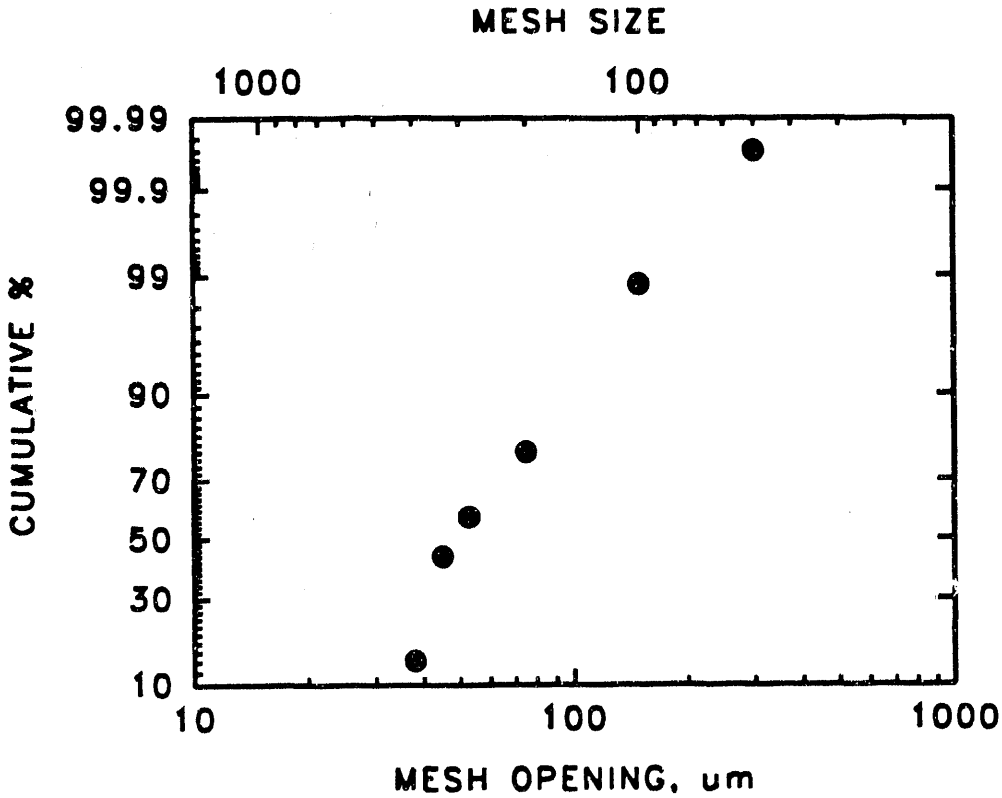

FIGURE 16. Size Analysis of CFFF Pulverized Montana Rosebud Coal With 10% K_2CO_3 (5,000 lb/hr raw coal feed rate)

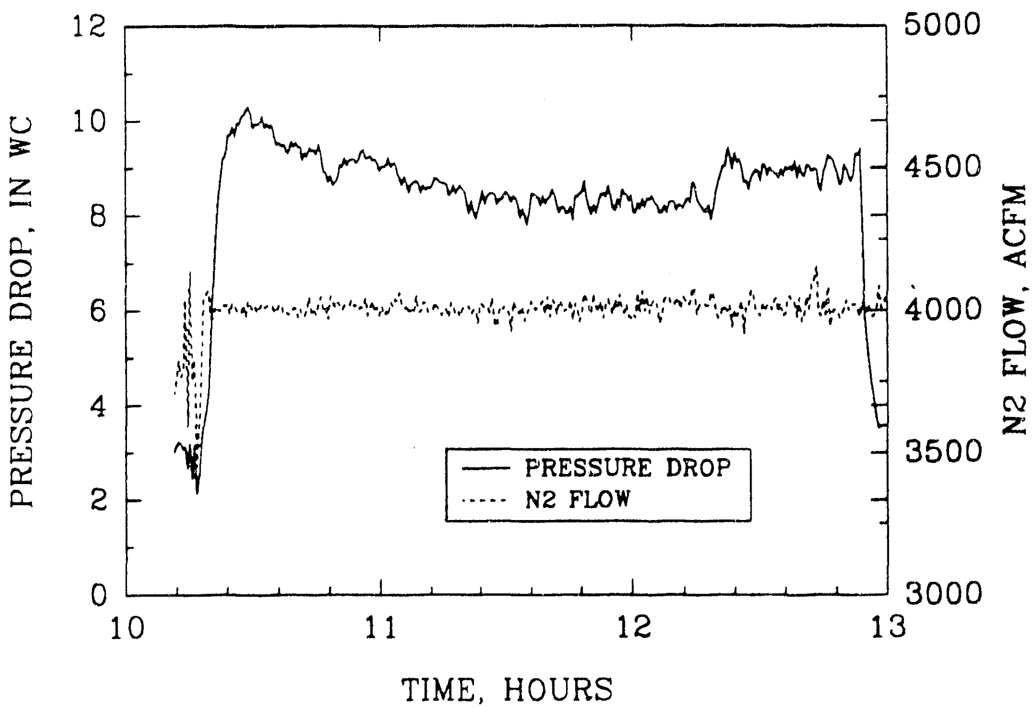

FIGURE 17. Pulverizer Pressure Drop Using Montana Rosebud Coal

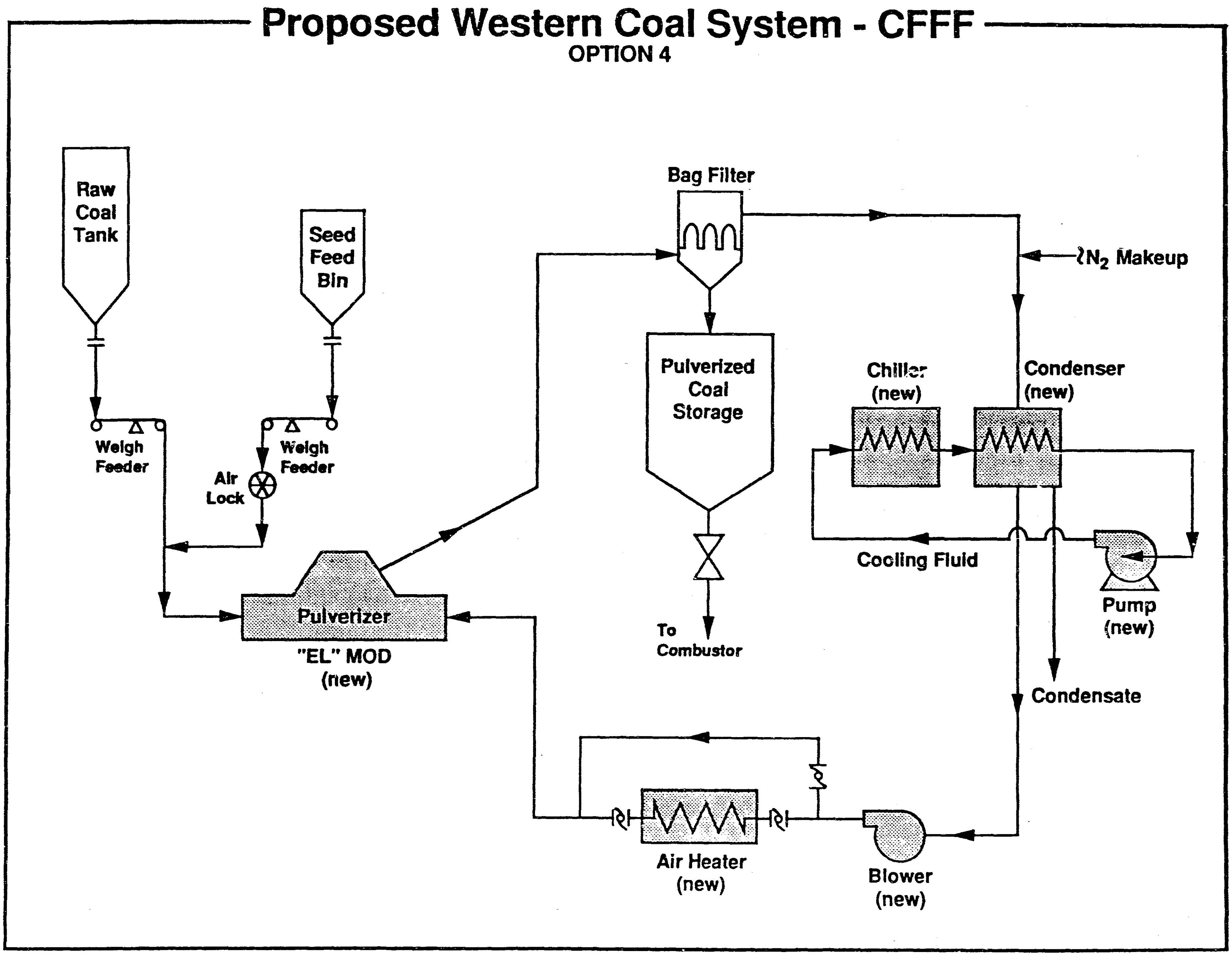

FIGURE 18. Proposed Western Coal System - CFFF

the existing E-35 mill will require an EL modification. The design moisture level for the described system is 6-7%. This is comparable to the moisture level used at the CDIF.

HIGH TEMPERATURE AIR HEATER DEVELOPMENT

The major effort during this quarter was preparing for a high temperature air heater (HTAH) evaluation which will be piggybacked onto the next scheduled CFFF long-duration test. This evaluation will involve a three inch OD, 40 inch long tubular component made from silicon carbide particulate reinforced alumina made via the Lanxide DIMOX TM directed metal oxidation process and purchased from DuPont Lanxide Composites Inc. (This material has previously survived reasonably intact at the temperature zone planned for this evaluation). The tube will be mounted in the CFFF primary furnace and held in place at both ends by water cooled supports. An electric powered preheater will be used to introduce 1200°F ambient pressure air into the top end of the tube. The air will exit the tube from the bottom support. Heat transfer data will be collected as the air temperature and flow rate are varied.

The manufacturer of the composite tube will only use dye penetrant non-destructive tests (NDT) of the tube as the vendor has not yet perfected other NDT techniques for this material. NDT techniques that can apply to the composite are under investigation. Radiography and ultrasonic methods also are currently under consideration.

During the prior test in December 89 (LMF4-S) it was noted that a zirconia test specimen donated by Norton Corporation seemed to resist corrosion in a temperature zone where no other sample has survived. However, the sample was severely cracked, presumably from the effects of thermal shock. It is therefore planned that a zirconia coating be applied to a piece of the SiC/Al_2O_3 composite to determine if it can provide protection in a temperature zone where the composite failed in prior tests. Since the composite is highly resistant to thermal shock and the zirconia is very resistant to corrosion, it appears possible that this could be a good combination.

A topical report entitled "An Investigation into the Feasibility of a Recuperative Magnetohydrodynamic High Temperature Air Heater" was in preparation for submittal to DOE. The general conclusions of this interim technical report were:

- A radiant recuperative rather than regenerative HTAH is the more practical approach, if feasible.

- The most promising material for HTAH heat transfer tubes, as demonstrated by exposure to process gases in the CFFF radiant furnace during long-duration tests, is a reinforced alumina composite made via the Lanxide DIMOX™ process of the DuPont Lanxide Composites Company.

- Analyses to date indicate that a cage wall recuperator consisting of vertical ceramic composite tubes will meet the requirements for a viable high temperature MHD combustion air preheater.

Assuming success with the atmospheric pressure high temperature air cooling during the upcoming LMF4-T test in May 90, the next test will attempt cooling with high temperature (1200°F entering temperature) air that is pressurized to 100 psig.

TASK 7 - MHD TECHNOLOGY DEVELOPMENT PROGRAM

The only activity currently being undertaken in this Task is the System Analyses being performed under subcontract by The Westinghouse Electric Corporation. Topical Reports will be issued at the conclusion of each phase of this activity. Following is the status of major work elements:

Westinghouse representatives reviewed the documentation and participated in the ITC System and Combustor Design Review, January 9-11, 1990. They also reviewed the

Preliminary Design Review (PDR) documentation and attended the Design Review for the ITC MHD Channel Subsystem.

Mr. Joe Lance of Westinghouse attended the POC Integration Task Force meeting on Feb. 27, 1990. He also attended the MHD Contractor's Review Meeting at PETC January 22-24, 1990.

Work continued on modeling the Corrette plant retrofit, including adding the TRW seed regeneration process. Work also continued on adding the TRW seed regeneration process to the existing model of the Scholz plant retrofit.

Westinghouse submitted the subcontract Management Plan to UTSI for review/approval. A meeting has been scheduled for early April to discuss the Management Plan prior to its finalization and approval.

TASK 8 - TECHNICAL SUPPORT AND INTERFACE ACTIVITIES

No activity was planned this quarter.

No activity is planned for next quarter.

TASK 9 - CFFF PROGRAM MANAGEMENT

MANAGEMENT AND ADMINISTRATIVE SUPPORT

Dr. J. W. Muehlhauser, Mr. N. R. Johanson and Mr. R. C. Attig attended the MHD Contractors' Program Review Meeting at Pittsburgh Energy Technology Center on January 22-24, 1990.

A copy of ONR's Property System Survey Report which was conducted on October 23-24, 1989 was received. A satisfactory rating was given in all areas.

Mr. Bob McLlroy and Mr. John Rackley from Babcock & Wilcox visited UTSI on January 18, 1990. This was a meeting to bring John Rackley up to speed on the Bottoming Cycle Plan.

Award of the subcontract to Westinghouse for MHD Systems Engineering Support is now complete with the approval and signature by a University Vice President. A signed copy was sent to Westinghouse.

Seven papers were in preparation and abstracts completed for the 28th Symposium on Engineering Aspects of MHD (SEAM).

Ten personnel from the CFFF participated in a Supervisory Leadership Training Course presented by Leadership Development Associates, Inc.

A letter was sent to the DOE/CH MHD program manager containing projected costs and work plan objectives for a proposed contract renewal period of August 1, 1990 through July 31, 1991.

The final 1988 Site Environmental Report was issued.

Dr. J. W. Muehlhauser and Mr. N. R. Johanson attended the EPRI MHD-Utility Colloquium on March 27-28, 1990 in St. Louis, MO.

REFERENCES

1. Rasnake, D. G. and Douglas, J. R., "Emission Performance Test Report for the Low Mass Flow MHD Combustor," The University of Tennessee Space Institute, February 1990.

2. Winkleman, B. C. and Giel, T. V., "Non-Simultaneous Sampling Error in Modified Line Reversal Temperature Measurements," Proceedings of the 23rd Symposium on Engineering Aspects of Magnetohydrodynamics, Pittsburgh Energy Technology Center, Somerset, Pennsylvania, pp. 292-301, June 1985.

GLOSSARY

AH	- Air Heater
ASTM	- American Society for Testing and Materials
BH	- Baghouse, particulate capturing device using a fabric type filter bag
B&W	- Babcock & Wilcox
CARS	- Coherent anti-Stokes Raman spectroscopy
CFFF	- Coal Fired Flow Facility
CS(n)	- Cooling Section where n = number of section
CDIF	- Component Development Integration Facility
DCW	- Diagonal Conducting Wall
DDAS	- Digital Data Acquisition System
Diagnostic Channel	- A substitute channel in place of generator channel
DNCF	- Dry Normal (i.e. standard pressure and temperature) cubic foot
Downstream	- From exit of diffuser outlet to stack
DFI	- Diffuser inlet probe
DG	- Data General Computer
ε	- Emissivity
ECF	- Energy Conversion Facility
EPRI	- Electrical Power Research Institute
ESP	- Electrostatic Precipitator
EDX	- Energy Dispersive X-ray
Flow Train	- Test facility including all components from the vitiation heater to the stack
GC	- Gas Chromatograph
GC/MS	- Gas Chromatograph/Mass Spectrometer
GIS	- Geographic Information System
HPT	- High Pressure Test
HR/SR	- Heat Recovery/Seed Recovery
HTAH	- High Temperature Air Heater
HVT	- High Velocity Thermocouple
ICAP	- Inductively Coupled Argon Plasma
ITAH	- Intermediate Temperature Air Heater
ITC	- Integrated Topping Cycle
LDV	- Laser Doppler Velocimeter
LMF(n)	- Low Mass Flow Test, where n = number of test
MCP	- Multicolor pyrometer
MHD	- Magnetohydrodynamics
MPS	- Miscellaneous Process Sampling
MSE	- Mountain States Energy
MSU	- Mississippi State University
NPDES	- National Pollution Discharge Elimination System
NSPS	- New Source Performance Standard
ONR	- Office of Naval Research
PAD	- Pulsed Amperometric Detector
POC	- Proof-of-Concept
PTO	- Power Take-Off
SCA	- Specific Collection Area for ESP
SCI	- Secondary Combustor Inlet
SCO	- Secondary Combustor Outlet
SCR	- Silicon Controlled Rectifier
SER	- Site Environmental Report
SEM	- Scanning Electron Microscope
SHTM	- Superheater Test Module
SLR	- Sodium Line Reversal
Sootblower	- Device for removing particulate collection on heat transfer surface
T/C	- Thermocouple
TCLT	- Two Color Laser Transmissometer
TGA	- Thermogravimetric Analyzer
TS(n)	- Test Section, where n = number of section
Upstream	- That part of the Flow Train from the vitiation heater to the exit of the diffuser
UTSI	- The University of Tennessee Space Institute
WBDAAS	- Wide Band Data Acquisition and Analysis System

END

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