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COAL-FIRED FLOW FACILITY**

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PROGRESS REPORT

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PREFACE

The purpose of this report is to provide the status of a multitask 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. 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, the environmental baseline and analysis of test data on the convective heat transfer components (superheater and air heater). For this quarter, progress and future plans in testing are discussed. In this report the results of a 252 hours coal-fired proof-of-concept test of steam bottoming plant components are summarized. Detailed data analysis 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 proof-of-concept (POC) testing and development of the components for a magnetohydrodynamic (MHD) steam bottoming plant.

The primary activities discussed are results of a 252 hour, coal-fired test in the Department of Energy Coal Fired Flow Facility (CFFF). The performance of the upstream components, which simulate the MHD topping cycle for the generation of test gases with the correct time-temperature history, was significantly more reliable than in previous tests. In the bottoming cycle, tests continued on candidate superheater test module (SHTM) tube materials in three different temperature zones. The test achieved all objectives in this area. Difficulties continued in keeping the accumulation of deposits sufficiently blown-off on the high temperature tubes of the first test section and the following cooling section. During the test, a higher pressure mobile compressor was rented to evaluate the effects of increased air pressure to remove these deposits. Additionally, the sootblower nozzle was replaced with a smaller one to increase the blowing velocity. The results of these changes were encouraging but need further evaluation. Particulate loading samples were taken to evaluate the effectiveness of the baghouse and electrostatic precipitator (ESP). Results of varying the flow rate through the ESP to determine the minimum specific collection area (SCA) to meet the New Source Performance Standard (NSPS) particulate emission standards are reported.

Reports of on-going studies and analyses are summarized. Results of utilization of advanced diagnostics by both UTSI and MSU are included. Data and analyses from stack gas analysis, water quality, ambient air sampling and terrestrial ecology programs are summarized and future plans are outlined.

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"Heat and Mass Transfer Calculations for Recirculating Laminar and Turbulent Flows in an Abrupt Pipe Expansion," First National Fluid Dynamics Congress, July 1988, Cincinnati, Ohio.

"Sensitivity Study of the Effects of PDF Models on the Predicted Structure of Turbulent Combustion Flow," First National Fluid Dynamics Congress, July 1988, Cincinnati, Ohio.

"Bench Scale Evaluation of Formate Process Based MHD Seed Reprocessing Option," 23rd Annual IECEC Meeting, July 1988, Denver, Colorado.

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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 (1) 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) operating conditions and procedures and equipment to meet pollution requirements.

The overall scope of work contains eight tasks summarized under each of the following task headings.

1. Task 2 - Design and Fabrication of the Eight 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 (ESP). All of these components are installed and have been functionally tested.

2. Task 3 - Base Operations for the CFFF

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

3. Task 4 - Operation at Eight 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 FY88) 500 hours at MHD conditions to evaluate 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.

4. Task 5 - Testing of DOE Supplied Components

Provides for the testing of DOE supplied components. No work is programmed at this time.

5. Task 6 - Modifications to the CFFF

Provides for major facility modifications which include conversion to a western coal processing system, auto ash removal system (for superheater test module, air heater, electrostatic precipitator, and baghouse) and an intermediate temperature air heater (ITAH).

Note: As part of the Integrated MHD Bottoming Cycle Test Program a contract was awarded to The Babcock & Wilcox Company to perform the design, fabrication and installation of the western coal processing system and automated seed/ash handling system, and the design only of the intermediate temperature air heater. Procurement, fabrication and installation of the ITAH is an option on the contract. UTSI will support this effort through necessary facility modifications to integrate and accommodate the new equipment.

6. Task 7 - MHD Technology Development Program

Provides for additional technology development services on a task order basis as approved by DOE. No work is planned at the present time in this task.

7. 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.

8. Task 9 - Program Management

Provides for effective overall management in performance of the contract through planning, organizing, scheduling, directing, coordinating and controlling of resources. Specific staff functions of project control, reporting, accounting and financial affairs, government property administration, and contract administration are included.

SECTION II

SUMMARY OF TECHNICAL PROGRESS

This Section addresses the technical progress of work according to a grouping of six product or mission oriented activities: A. Testing, B. Studies/Analyses/Reports; C. Component Development and Test Facility Modifications, D. Facilities Operations, Maintenance and Repair, E. Environmental Control, and F. Management and Administrative Support. The breakdown of work as structured in this manner is compatible with and supports the objectives and scope of work outlined in Section I.

A. TESTING

UPSTREAM COMPONENTS

During the quarter one proof-of-concept (POC) test of 252.1 hours on coal was completed in the CFFF. 111.5 hours of this total were continuous on coal. This represents the longest recorded sustained test operation on coal.

Research during the past quarter concentrated on maintaining engineering support for on-going CFFF POC testing of the downstream test train. Hardware and design modifications that were reported in the previous two quarterly reports were completed and implemented into the test train for the POC test completed in September 88 (LMF4-0). Spare hardware, and in some cases, complete components were fabricated for the plasma generator, nozzle, aerodynamic duct sections one and two, and the constant area diffuser. The complete upstream configuration as assembled for the test is shown in Figure 1. The new ring construction constant area diffuser was installed for the first time as shown in Figure 2.

Only minor problems were encountered with the upstream hardware during the test run. These problems consisted of a hot spot in the combustion chamber (see Figure 3), which required replacement of this component during the test, and minor water leaks within the aerodynamic duct. The water leaks were localized and occurred in only one ring of the aerodynamic duct at two points in the test. The first leak was repaired by replacement of aerodynamic duct section number one. The final water leak was not observed during testing and is believed to have occurred either very late in the run or even possibly at shutdown.

The condition of all hardware and components in the upstream configuration was considered excellent after the test. No significant wear of internal surfaces was observed for any component which would require repair action prior to the next scheduled test. In general, the design and material modifications made to these components during the past year have resulted in more durable test train components which are capable of supporting long duration proof-of-concept testing.

Performance evaluations of these components will continue during testing. To date no anomalies in the experimental data have been observed. Operation was maintained at or near design parameters. Heat flux levels through the supersonic flow train were maintained below 200 watts/cm² for the major coal-fired portion of the test. A relatively thick (2-3 mm) slag coating of the aerodynamic replacement duct was observed in post test inspections.

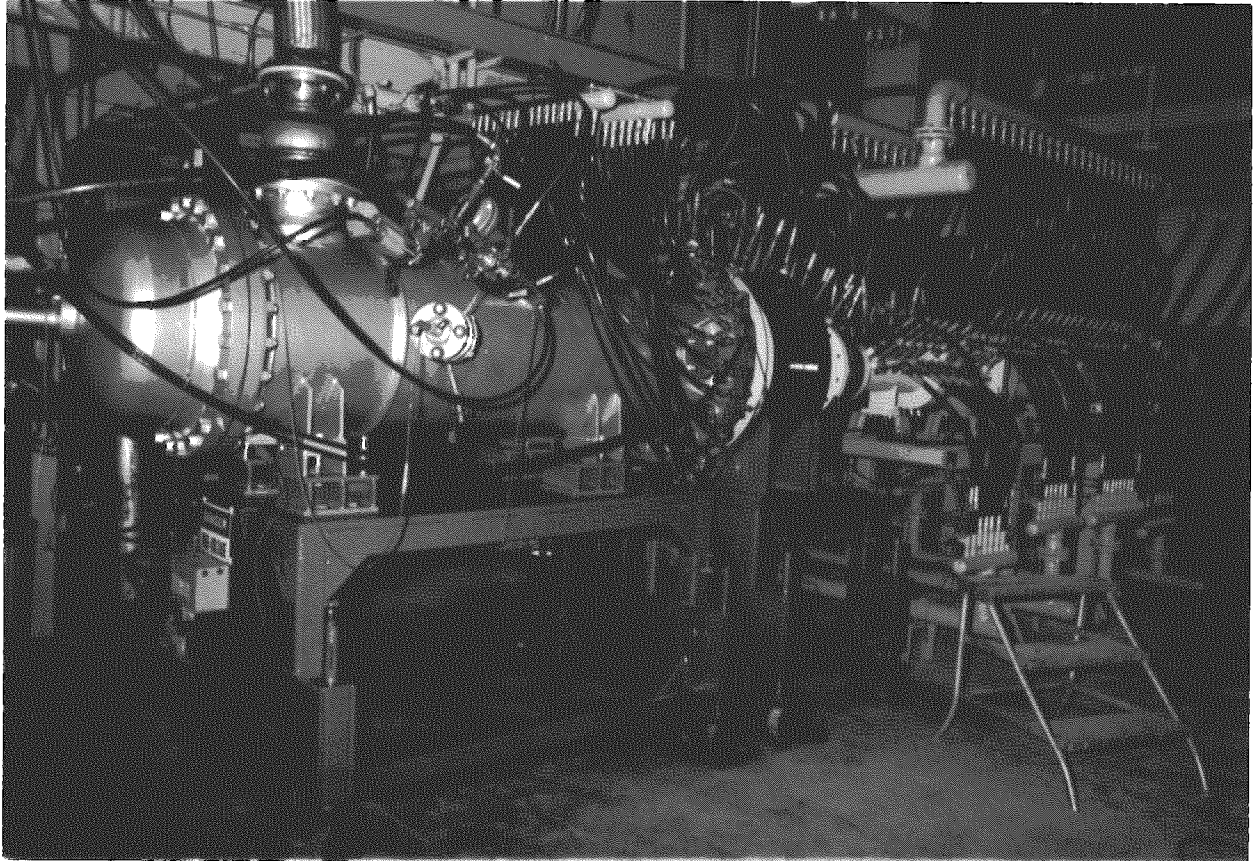


Figure 1. Upstream Components Prior to September 1988 Test

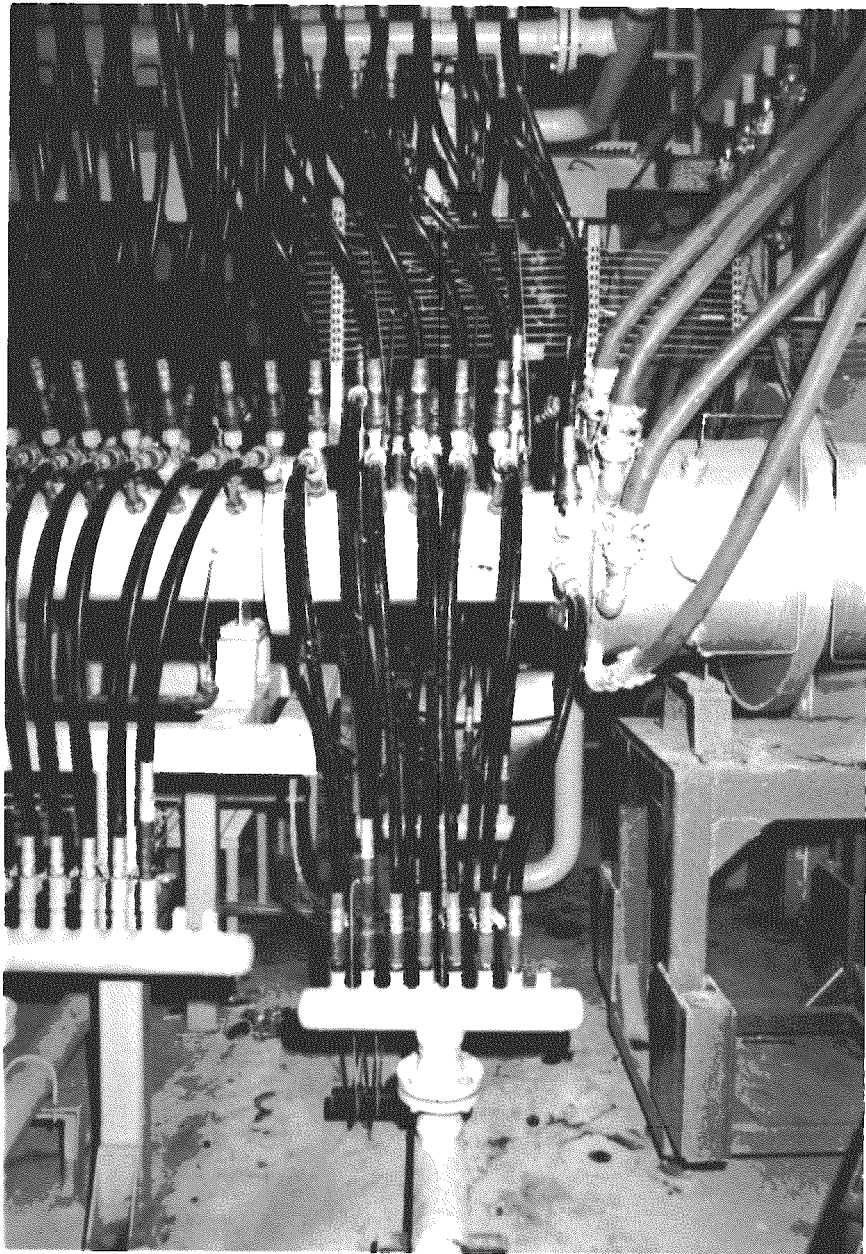


Figure 2. New Constant Area Diffuser Installed in Flow Train

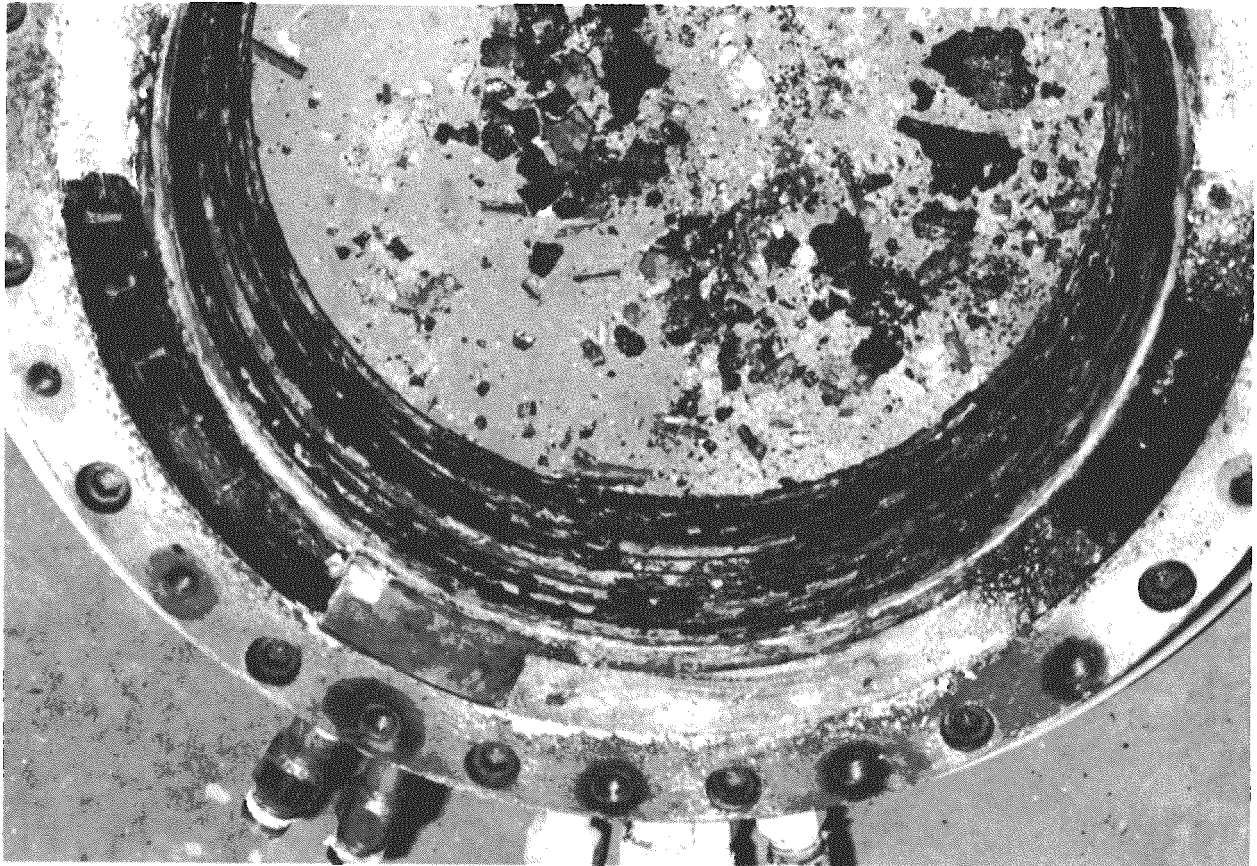


Figure 3. Tube Lined Combustor Module Showing Refractory
Voids Which Resulted in Combustor Hot Spots
(Replaced by ring-lined module during the test)

DOWNSTREAM COMPONENTS

Performance of the downstream components during the August-September 88 POC test was good. During a shutdown to repair upstream components after about 35 hours on coal, a water leak was discovered in the wall of the primary furnace around a spacer pin in the water wall (Figure 4). The leak appeared to be caused by corrosion of the pin weld to the interior water wall. The leak was repaired and no further leaks were observed in this area during or after the test. The refractory opposite the diffuser outlet in the primary furnace (Figure 5) was about 2-3 inches thick, only slightly less than the original four inches. This area of the refractory appears to achieve an equilibrium thickness of about one inch, as that was the thickness of refractory which remained at the end of the test.

After the test, the drum module refractory was found to be spalled and irregular as expected. The drum module will be scheduled for refractory replacement after the next test. The majority of the deposits remaining at the secondary combustion air ports were in the NE and NW corners. These areas were the most difficult to reach with tools to dislodge deposits during the test. Removal of the secondary combustor deposits during testing appears to reduce fluctuations in carbon monoxide content.

Refractory replacement in the superheater test module (SHTM) inlet and the test section 1 (TS1) walls will be required after the next test. Most of SHTM cooling section 4 and the 180 degree elbow were rebuilt (Figure 6) with 1.0 and 1.5 inch thick high density aluminosilicate fiber board in an effort to eliminate failure of the lining during testing. The new lining was in good condition after the last test. All of the new SHTM sections scheduled for installation during FY89 will be constructed with this lining design. Several hot spots were evident on the SHTM outer wall in the older fiber lining area, and these will be repaired with the thicker material before the next test.

A project was reinitiated this quarter to characterize the performance of the secondary combustor. Gas temperature profiles and gas composition were measured in and around the secondary combustor. The initial step was to obtain a more reliable high velocity thermocouple (HVT) to monitor gas temperatures and take gas samples in order to determine the rate of secondary combustion. Modifications thus far entailed using a longer S-type thermocouple and replacing the ceramic insulators in cooler areas with insulated thermocouple wire. For future tests a longer and larger diameter probe will be used and the minor modifications made during the August/September 88 test will be incorporated in the new probe.

Baghouse (BH) and Electrostatic Precipitator (ESP)

During the test this quarter, particulate samples were taken at the common inlet to the BH, ESP and venturi scrubber, and at the outlets of the BH, ESP, and ID Fan. All mass loading samples were taken using Environmental Protection Agency Method 17 sampling procedure. Test objectives were to determine the collection efficiency of the BH and ESP and to determine the effluent particulate concentrations. Twenty-eight mass loading samples were taken at the various sampling locations. Larger thimble filters were used to eliminate several problems encountered during earlier tests. None of the new thimbles ruptured during use. This allowed the entire sample to be taken with one thimble which eased sample recovery, improved the accuracy of the data, and reduced the amount of work and time involved in obtaining the sample.

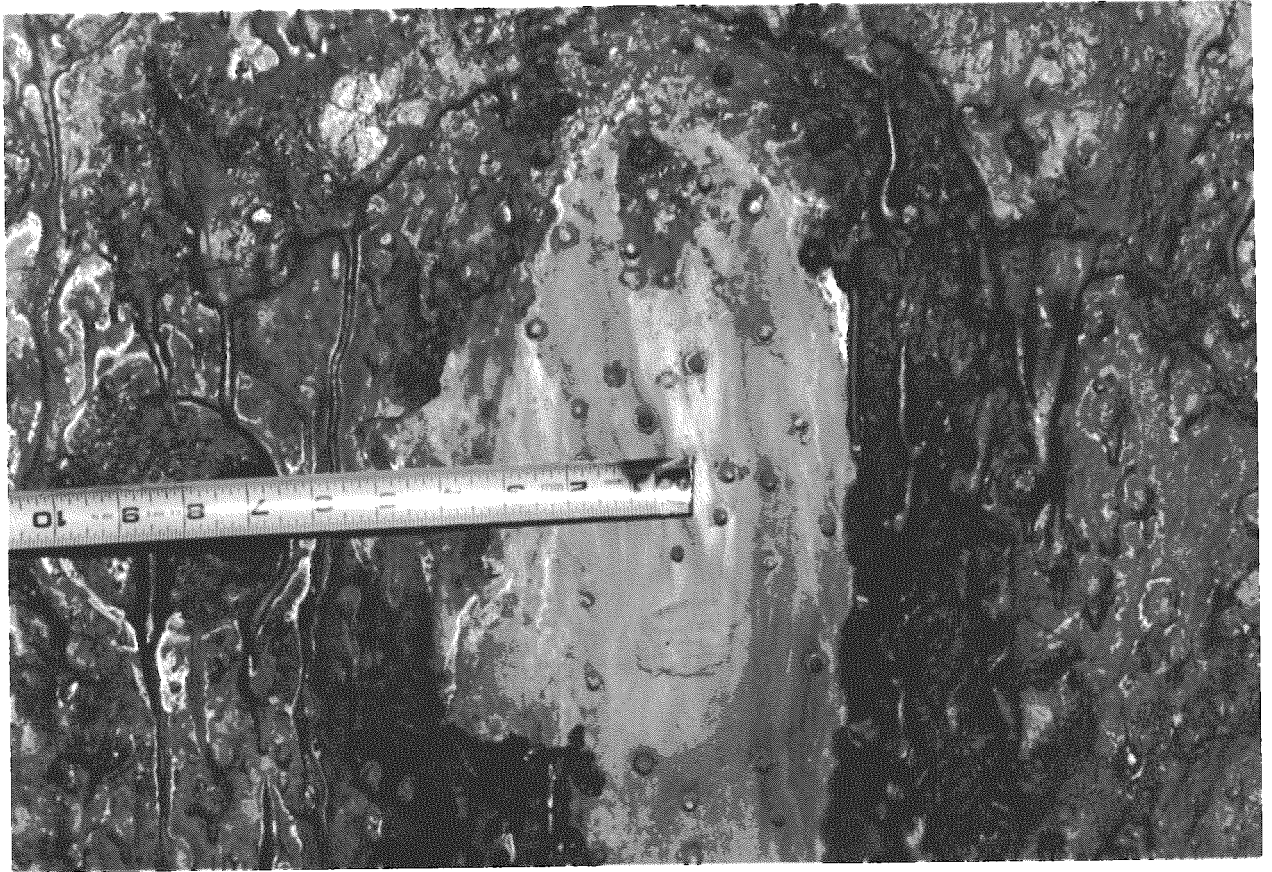


Figure 4. Failure of Pin Weld in Primary Furnace Wall



Figure 5. Primary Furnace Rear Wall Refractory



Figure 6. Installation of Aluminosilicate Fiber Refractory in SHTM

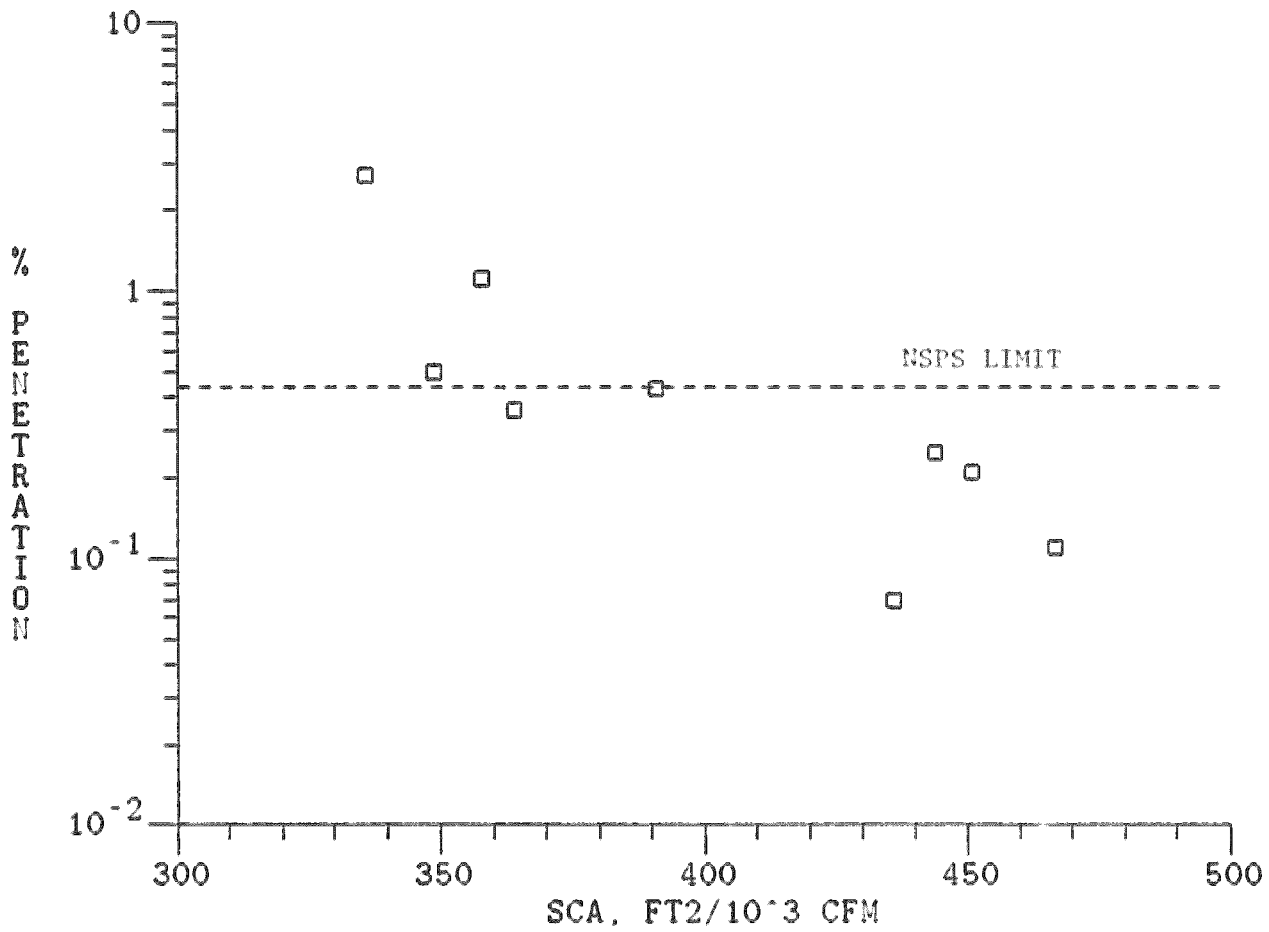
Flue gas flow through the BH was regulated at approximately 4950 scfm throughout the test to maintain a filtration velocity of about 1.8 ft/min. The BH performance was consistent with performance during previous tests. Cleaning cycles were performed using sonic horns when the pressure drop across the bags exceeded 10 in. H₂O, to assist the reverse gas cleaning system. Time between cleaning cycles averaged about 90 minutes. Particulate collection efficiency, as measured by EPA Method 17 testing, was greater than 99.95% throughout the test. The highest measured (of three samples) baghouse particulate emission was 0.0032 lb/MMBTU which is well below the 0.03 lb/MMBTU limit set by NSPS.

The gas flow rate through the ESP was varied in a series of steps to determine the effect of specific collection area (SCA) on particulate collection efficiency. SCA ranged from about 330 to 470 ft²/10³cfm were tested, with each set point being maintained for a minimum of 24 hours. Resulting ESP particulate emission data, based on EPA Method 17 results, are plotted in Figure 7. Results indicate that the New Source Performance Standard (NSPS) particulate emission limit of 0.03 lb/10⁶ Btu can be met when the SCA is greater than 400 ft²/10³ cfm. The Tennessee particulate emission limit of 0.19 lb/10⁶ Btu was also met for the entire plant during most of the test by shutting off the venturi scrubber/cyclone system and passing all of the flue gas through the ESP and BH. The ESP was taken off-line to remove ash build up in the hoppers which caused field 1 to short-circuit. While the ash was removed, flow was diverted through the venturi and baghouse. Due to the low collection efficiency of the venturi, the state emission limit of 0.19 lb/MBTU was exceeded until the ESP was on-line.

During the early part of the test, all ash collected by the ESP was successfully discharged from the Field 1 hopper dump, which is necessary for the automated ash handling system that will be installed next year. During the latter part of the test, ash plugged in the Field 1 hopper on three occasions as indicated in Figure 8. This problem appears to result from ash bridging over the screw conveyer. Therefore, it is planned to increase the size of the Field 1 discharge and add a vibrator on the hopper prior to the next test. No purges were used in the ESP insulator housings during the test, and no problems were experienced with condensation on the insulators. Minimal damage occurred to the Field #4 access door as a result of a malfunction of the fuel oil fired pre-heat burner support system. Figure 9 shows the damage and the burner in operation. The fuel oil burner was used because of a failure of the standard electric resistance heater system. This electric resistance heater brings the ESP temperature above the dewpoint of water to minimize the forming of condensation which would be absorbed by the spent seed material. The damage will be repaired prior to the next test.

Venturi Scrubber and Cyclone

Since corrosion was observed during the prior test, the venturi scrubber/cyclone slurry pH was monitored at regular intervals by both pH paper and by pH electrode measurement. In the previous test, cyclone slurry pH as low as 2.7 was reported. During the test, the pH was raised by chemical addition when the slurry pH dropped below 4.0. Initially, the slurry pH was to be raised by manually adding CaO (which would immediately slake to form Ca(OH)₂), but only limited improvement was noted. The calcium oxide may have been entrained in the gas stream, preventing it from entering and neutralizing the slurry. Subsequently, a 50 weight % sodium hydroxide solution was pumped into the cyclone. Based upon neutralization experiments, estimates of the quantity of caustic required were determined and added.



ESP SCA VS. % PENETRATION DURING TEST LMF4-0

Figure 7. ESP SCA vs. % Penetration During September 1988 Test



Figure 8. Ash Plugging ESP Field 1 Hopper

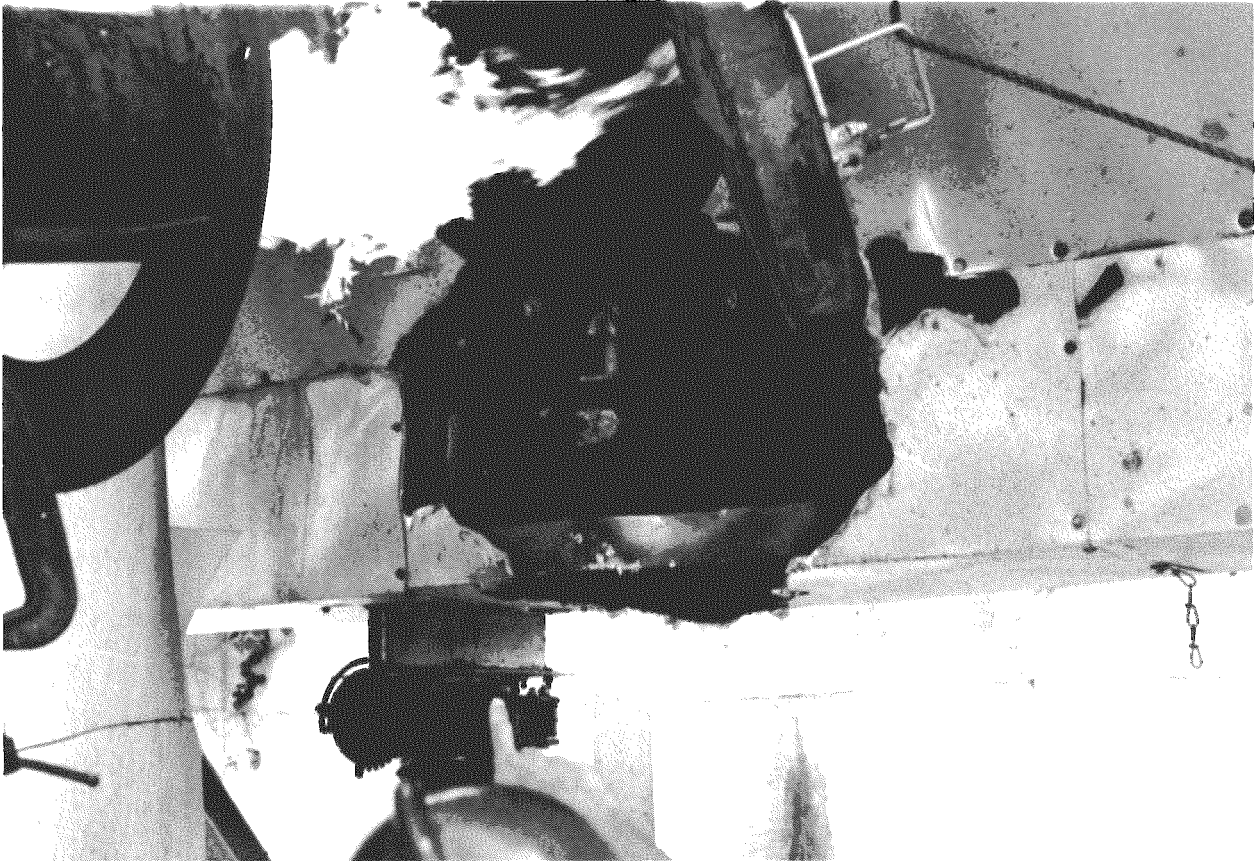


Figure 9. ESP Field 4 Access Door and Preheat Burner

In future testing a continuous pH monitoring system for the cyclone slurry will be utilized. This system will also include a control system for automatically adding caustic when the slurry pH falls below a predetermined level. If the above system does not provide adequate pH control, a pH buffer may be added to the slurry in subsequent tests.

Leaks found in the venturi scrubber, caused by the acidic water from the cyclone, will be repaired prior to the next test. Simulations of venturi scrubber performance, using the ASPEN program, are being conducted with existing and more optimum throat dimensions which may be required to improve the collection efficiency of the wet venturi scrubber. After completing this study, a decision will be made regarding changes to be made in the present system.

Superheater Test Module and Air Heater

Activities focused on analysis of TSI ash/seed tube deposits from the May 88 test, utilizing quantitative energy dispersive X-ray (EDX) techniques. This technique continued during the August/September 88 test.

The general character of the May 88 test tube deposits was described in last quarter's report. Views of deposits shown in Figures 10 and 11 illustrate the diversity of deposit appearance. Deposit samples were cut at 6 inch intervals along the tubes and sections were ground and polished for optical and scanning electron microscope (SEM)/EDX examination. The concentrations of Si, Al, S, K, and Fe were measured by quantitative EDX at increments through the frontal portion of the deposit. These measurements were made at 1 foot intervals along the length of each of the four TSI tubes that were removed from the flow train after the prior test. Plots are being made of concentration with respect to deposit thickness, and also with respect to both distance and metal temperature along the tubes. As with all sections, the concentration of K and S (K_2SO_4 constituents) decreases markedly with distance from the tube, whereas the concentration of Si, Al and Fe (the fly ash constituents) increases, as indicated on Figure 12. The elemental distribution is quite independent of vertical location on the tube. Data indicates that the shift in concentrations throughout the thickness of TSI deposits results primarily from K_2SO_4 flowing off the deposits after they have reached sufficient thickness where the surface temperature is above the melting point. The sulfate appears to flow in a very thin layer over the surface so that there is rarely flow or dripping observable through the view ports. Deposits continue to increase in size while this liquid flow is occurring and the material collected in the hopper has hardly any ash. It is evident that the ash either does not flow along with the K_2SO_4 and remains for the most part where it is originally deposited from the gas, or that it is deposited out on the solid surface as it flows over it. There is as yet no conclusive evidence to establish which alternative is occurring or if both which is more prominent. However, the formation of fine, sharp needles and fins would appear to indicate that much of the ash remains at the point of original deposition. Additional analyses are also planned to confirm the composition of a yellow deposit on the outer surface of deposits from portions of TSI.

After approximately 157 hours on coal, the August 88 test was interrupted because the SiTM cooling section 2 had an excessively high pressure drop. This was caused by plugging of the tube lanes with ash deposits. Because TSI was the only location equipped with a camera to observe sootblower effectiveness, an attempt was made to improve TSI sootblowing and to evaluate the feasibility of proposed modifications to achieve greater sootblowing effectiveness through increased air pressure and capacity. Rented portable

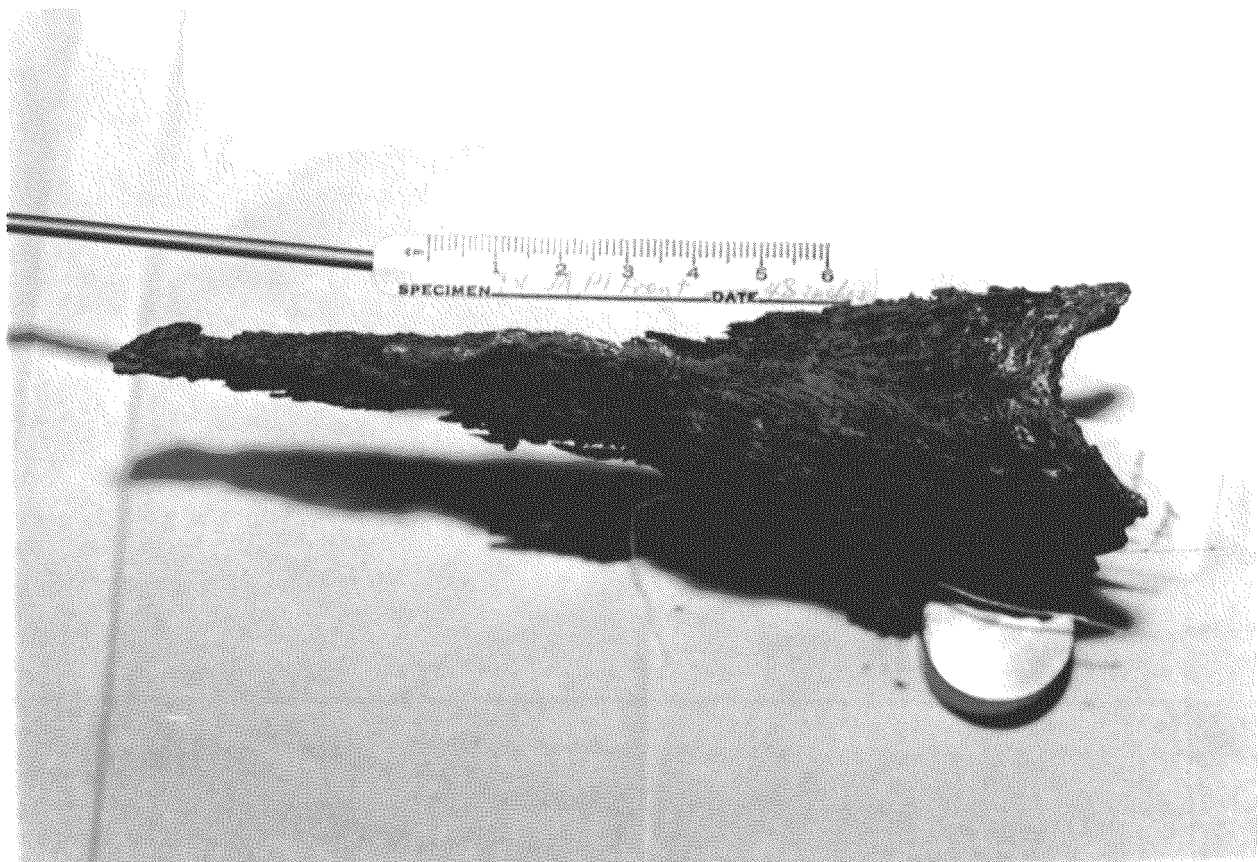


Figure 10. Elongated SHTM Test Section Deposit

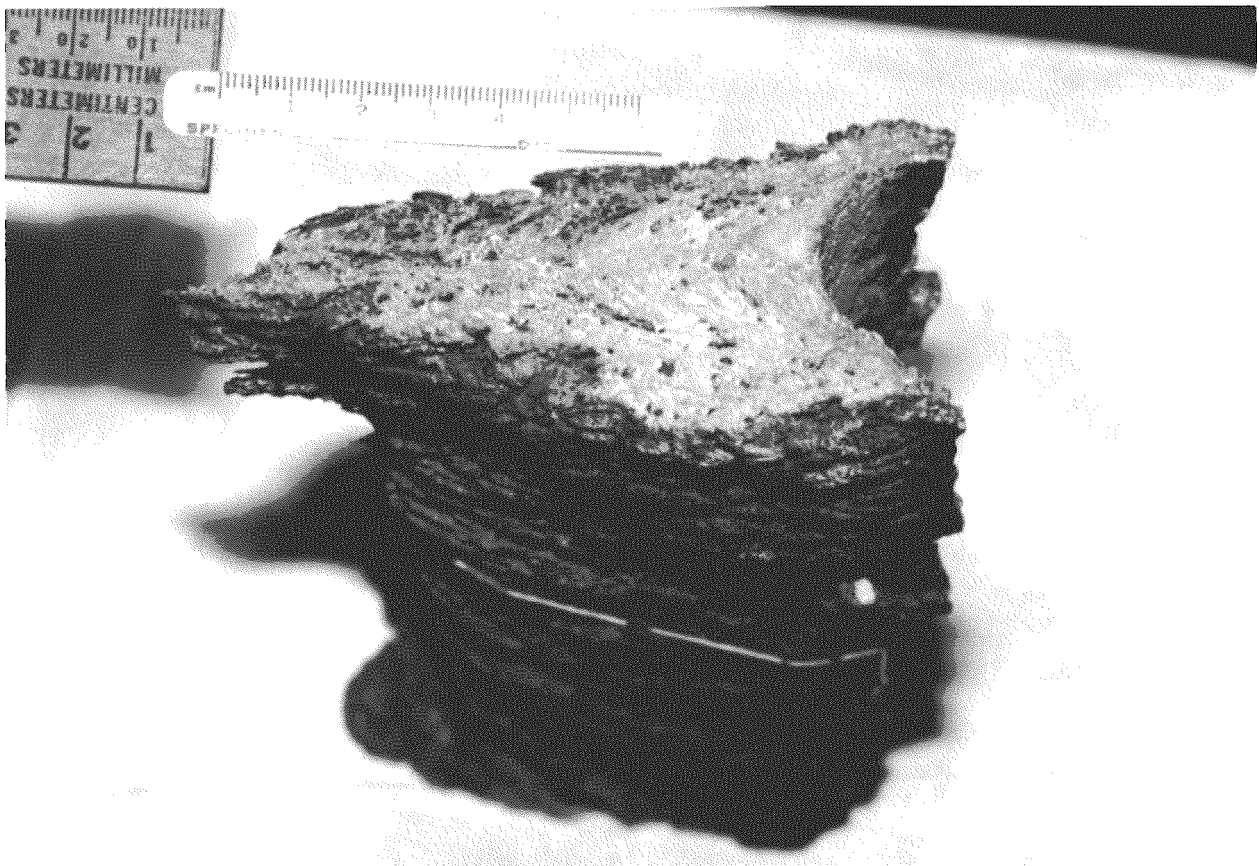


Figure 11. Shortened SHTM Test Section Deposit

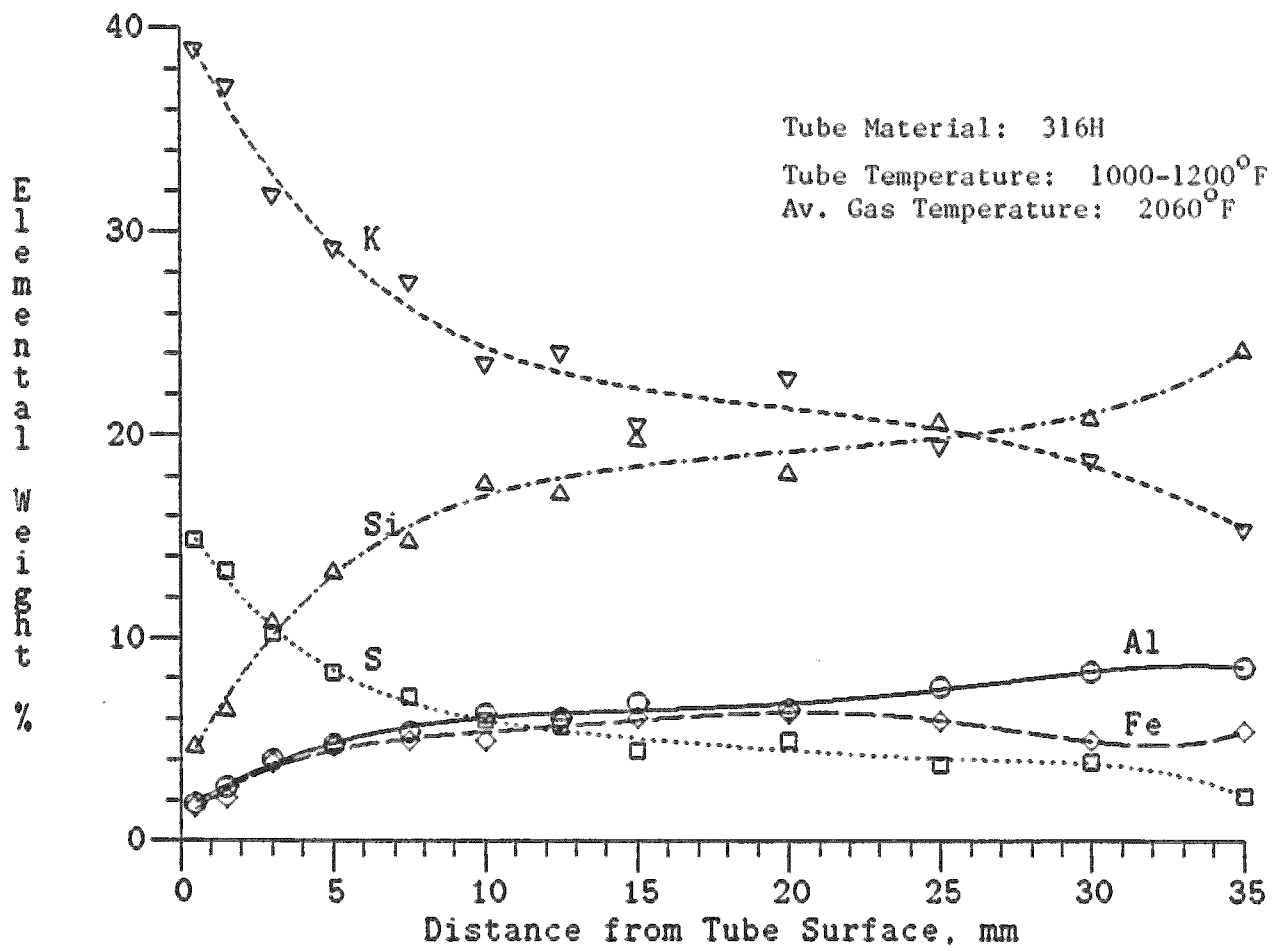


Figure 12. Elemental Distribution of SHTM TS1-2 P2 Frontal Tube Deposits

compressors delivered up to a nominal 225 psi during blowdown. This pressure was more effective in removing deposits. Sootblowing at a higher pressure, in combination with reduced nozzle size from 3/4 inches to 1/2 inches, appeared to be a significant improvement over the use of the existing process air system. However, deposit thicknesses of 1-2 inches were still evident after about three days at this condition. It appeared that the increased pressure slowed down, but did not prevent, deposit buildup. Alternatives for further defining TSI sootblower requirements during the next scheduled test are being studied.

ADVANCED MEASUREMENT SYSTEMS

The advanced measurements effort this quarter concentrated on preparations for and conducting the August-September 88 test. The regularly employed LMF4 University of Tennessee Space Institute (UTSI) and Mississippi State University (MSU) advanced measurement systems were installed and operated. Table 1 provides a performance summary. The listed UTSI systems were again operated continuously for the entire 252 hours on coal. Validation and analysis of both the UTSI and MSU data has been initiated.

Three UTSI and two MSU line reversal systems were operated during the test, providing reliable gas temperature and emissivity measurements. Periodic slag blockage of the line reversal optical ports prevented continuous data availability for all five systems. However, port modification designs to alleviate this problem are being reviewed. This port modification should reduce the purge nitrogen required to keep the ports open. Additional nitrogen use reduction was achieved during the test by changing furnace line reversal system operation from continuous to periodic. The system at the diffuser was still operated continuously, with plans to bring the other four systems into operation if a significant change in the diffuser gas temperature was indicated. This would have allowed monitoring of any gas temperature changes, if they had occurred. Future tests will employ periodic operation schedules to reduce purge use.

The effort to assemble a CFFF stand-alone line reversal system continued this quarter. This system will reduce the load on the CFFF digital data acquisition system (DDAS), and will also provide improved environmental protection and allow expansion of current systems capabilities. It can provide, for example, on-line potassium levels in the gas stream and comparative evaluation of system design improvements. The stand-alone system, once available, will be employed at the diffuser to measure the furnace entrance gas temperature which is used as a primary test control parameter. The system will interface with the CFFF DDAS while eliminating extensive computations which have slowed the DDAS data scan rate.

In addition to measurement systems, the UTSI wide band data acquisition and analysis system was used to record and process, on-line, some of the dynamic data provided by CFFF instrumentation. This principally involved Coriolis meter coal mass flow, Auburn meter coal volume fraction and coal line pressures along with the UTSI high frequency line reversal systems. However, during this test a lightning strike damaged the IRIG time code generator used to correlate tape recorded and DDAS data. Therefore all of the data that was acquired was recorded digitally on the wide-band analysis system hard disk. When dynamic data was not being recorded, the wide-band analysis system was used to monitor the three high frequency line reversal systems to improve their dependability. The wide-band analysis system was also used to evaluate software developed for the on-line K monitoring system. The additional memory

TABLE 1

Advanced Measurement System Test Summary

System	Measurement	Location	Provider	Performance
He bleed	dynamic P	combustor	UTSI	Port appeared blocked.
K line reversal	bulk avg. gas T (high freq.)	diffuser 6, exit	UTSI	Good, but PMT power supply fluctuating.
photo. line reversal	bulk avg. gas T (high freq.)	diffuser 6, exit	UTSI	Excellent, stray light prob. corrected.
LDV (laser velocimeter)	gas velocity, V' profiles	diffuser 6, exit	MSU	Excellent, verified previous measurements.
Black Body experiment	Evaluation of MCP 3- λ transmissivities	diffuser 6, exit & furnace 2	"	Inconclusive (black body T maybe too low).
MCP (2- λ pyrometer)	surface T & emissivity	furnace 1	"	Good, consistent with other measurements.
"	"	furnace 2	"	"
SLR (Na line rev.)	particle corrected bulk gas \bar{T}	furnace 2	"	Good, interfaced with CFFF DDAS by mid-test.
" (mini system)	"	furnace 3	"	"
SLR Probe	localized gas \bar{T}	furnace 3	"	Installation evaluated.
photo. line reversal	bulk gas \bar{T} (w/o chopper)	furnace 3	UTSI	Good, amp. drift problems corrected.
Pyrometer probe	tube surface T and emissivity	superheater TSI	MSU	Good.
TCLT (2- λ transmissometer)	Particle loading & mean size	B/H outlet & ESP outlet	MSU	Good.
"	"	ESP outlet	"	Good.

received for the system this quarter allowed monitoring of the line reversal systems in conjunction with the K monitoring software evaluations.

During the non-test time at the start of this quarter, additional analysis of the coal feed system performance was accomplished with the wide-band analysis system. The pressure transducer at the base of the coal feed tank was installed, the Auburn meter was installed, and both new and serviced Coriolis meters were installed. The wide-band system was used during the test calibrations providing some of the most accurate dynamic data yet acquired on the coal system. Analysis of this data was initiated following the test, but detailed results are not yet available.

In addition to the line reversal systems, MSU systems installed at the CFFF for the next scheduled test will include two multicolor pyrometers (MCP), an optical pyrometer light probe, two two-color transmissometers (TCLT), and a laser Doppler velocimeter (LDV). The LDV optical system, installed on the LMF flow train is shown in Figure 13. The two MSU MCP's were again successfully operated at the primary and secondary furnace levels. Both systems provided wall temperatures similar to those previously recorded, as long as the detectors remained cool. Wall emissivities near 0.65 on the primary furnace rear wall, and near 0.9 in the secondary furnace were measured. Deviations from these values are possible indicators of water leaks upstream of the secondary furnace and further evaluations are being made. Cooling will be provided in the future so these pyrometers can be operated for longer intervals without overheating.

The MSU intrusive light probe was installed to scan the first superheater tube bank, and again measured surface temperatures between 635°C and 800°C on the center tube. These compared reasonably well to calculations based on UTSI tube and steam temperature measurements. Attempts to install this probe in the secondary furnace will be initiated in future tests. The two MSU TCLT systems were installed at the BH and ESP outlets. These systems provided loading data and particle size indications in reasonable agreement with expectations. The on-line near-real-time operation of this technique is an advantage over extractive techniques, particularly when monitoring effects of changing conditions. Finally, the MSU LDV system was again employed to measure diffuser exit velocity profiles. The LDV measurements verified the previous results obtained with the spectrum analyzer processor, indicating that the associated improved noise rejection is required for velocity measurements in the CFFF environment.

Plans for the next scheduled test include operation of most of the UTSI diagnostics, with the microprocessor line reversal system being tested. MSU plans to support this test with a number of their instruments. Furnace modifications are expected to be completed to allow furnace evaluations with the MSU probes in the next test. Preparations for installation of the larger MSU portable laboratory were also initiated this quarter. The laboratory is expected to be employed during the November test.

TEST CONTROL AND SUPPORT

During FY88 a total of 556.59 hours of testing on coal was achieved compared with a planned 500 hours specified in the FY88 Management Plan.

During this quarter, primary emphasis was given to activities associated with facility system preparation, check out, and conduction of the August/September 88 POC test. Prior to the test, individual facility systems and

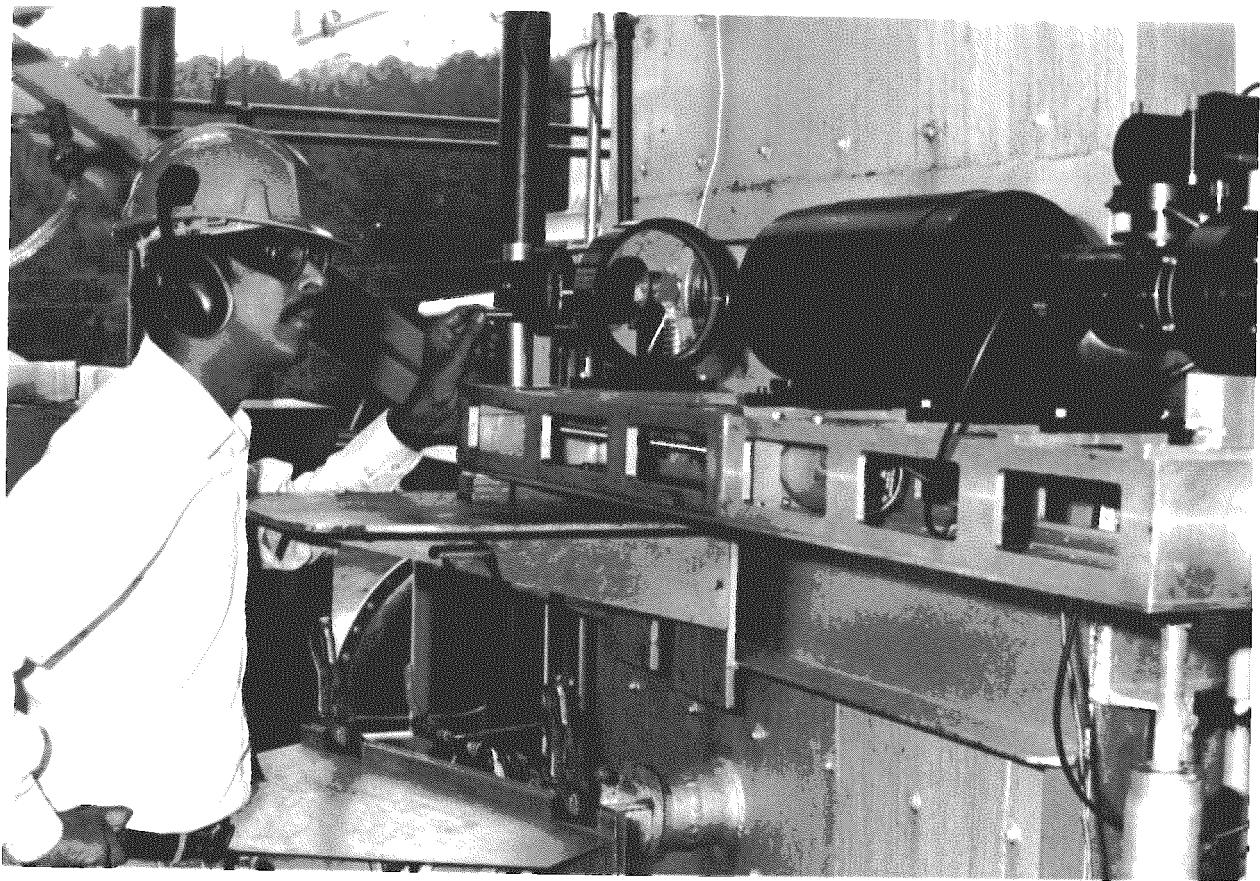


Figure 13. MSU LDV Optical System

the data acquisition system were activated and checked for proper operation. Extensive coal flow tests were performed to calibrate two Coriolis meters and verify the reliability of these meters over time.

A major change to the facility control system was implemented this quarter. Virtually all of the non-critical, timed, on-off sequencing control tasks were removed from the Macsym computer used for burner management. A second Macsym computer was installed and software developed to control these types of sequencing tasks. Proportional integral differential (PID) control loop software was also added to this computer to control the temperature of several air cooled corrosion test probes installed in the radiant furnace. The second computer will also control the venturi scrubber, electrostatic precipitator, and baghouse dampers to regulate the amount of flow through these components. This will allow for a much simpler and more manageable software code for the Burner Management Program, as well as increased flexibility in programming the sequencing of equipment such as sootblower cycling and baghouse cleaning.

New closed circuit television facility monitoring equipment was installed during this quarter. This system consists of four weatherproof, color cameras mounted to view major areas of the test facility. New large screen color monitors with switches to enable test engineers to view each area separately, or all areas simultaneously, have greatly enhanced the ability of test personnel to monitor the status of facility hardware during testing.

Preheat burner remote controllers were installed which will permit control of downstream component temperatures from the control room during refractory preheat.

Other activities this quarter included the compilation and filing of all data reduction constants, the investigation of pulse thermocouple technology for the measurement of radiant furnace temperatures, and the investigation into using gas sampling data to calculate a backup coal flow. A vibration data maintenance computer program for rotating machinery was completed.

The Arnold Engineering Development Center (AEDC) lightning monitoring system was utilized during actual testing. However, during a non-testing period, extensive damage occurred to some facility equipment from a lightning strike.

B. STUDIES/ANALYSES/REPORTS

The mass balance data input file for the December 87 test was completed during this quarter, and data was added to the mass balance input files for the February and May 88 tests. These mass balance calculations are nearing completion.

Work to create an expert system for analysis of CFFF data continued. A summary of the preliminary approach and background work was described in earlier reports.

A version of a machine learning program was implemented. This version was based on an initial dictionary of features. This dictionary is constantly being updated, so that faults can be better represented. Work is progressing on part 2 of A Data Reduction Expert System (ADRES). Data reduction was attempted, using raw data for a pitot probe periodic purge fault analysis, with good results. For certain other faults data reduction was attempted with

simulated data and also yielded satisfactory results. The machine learning, which generalizes and forms a concept about a data pattern, is being refined. Part 3 of the program, an updating module which will perform learning from experience, is in the conceptual stage.

C. COMPONENT DEVELOPMENT AND TEST FACILITY MODIFICATIONS

The primary objective this quarter was the continued effort to increase the reliability of facility systems and components in preparation for future long duration testing. A summary of the progress made toward the fulfillment of this objective is presented below.

A recurring problem during recent tests has been the development of water leaks caused by corrosion from the water side of the radiant furnace. Several steps were taken to alleviate this problem for future tests. The furnace Top Drum Module, water walls, and downcomer pipes have all been thoroughly cleaned, and an automatic blowdown system added. The installation of a softened water system to monitor and control water quality has been completed. During the August/September 88 test, only two minor leaks at water wall stay pins were discovered, and the calcium sludge buildup encountered on previous tests was absent. Inspection of the interior furnace walls in high stress areas to identify weak stay pin welds is planned.

Modifications to the chemical treatment system for the 600 hp boiler makeup water, started last quarter, have been completed. A new steam control valve was installed in the feed water preheater to improve water temperature control. Replumbing of the fuel oil supply system has eliminated the sooting problems normally experienced during boiler start-up.

Coal flow throughout the test was significantly smoother and more consistent than in recent, previous tests. This was due, in part, to the replacement of Synflex hoses in the coal supply line with steel tubing. The use of steel tubing eliminated the step changes in flow area caused by the pipe thread hose end connections.

An improved system for Pitot tube pressure measurement of cyclone, BH, and ESP gas flows has been installed. The previous installation was subject to frequent plugging due to particulate matter in the gas stream. The location of the Pitot tube differential pressure transducers was changed and the transducers recalibrated. Automatic purging of the Pitot tubes was implemented to inhibit blockage.

Personnel and equipment safety has been enhanced as a result of the construction of two concrete slabs near the facility lab office building for the storage of compressed gas cylinders. These cylinders were previously stored inside the building.

A cement block partition was built inside the test building to provide a protected area for the fabrication and assembly of hardware during tests.

D. FACILITIES OPERATION, MAINTENANCE, AND REPAIR

The principal emphasis this quarter was on the completion of normal preventive maintenance procedures and the repair of damaged facility equipment caused by a lightning storm. Major facility maintenance and repair activities are summarized below.

The automatic oilers on the process air compressor were rebuilt and calibrated, and a new set of intake valves and valve unloaders were installed in the second stage cylinder.

Repairs were made to the SHTM refractory and insulation in the area of the 180 degree elbow, the inlet transition, and manway doors. The hoppers were cleaned and the SHTM exterior painted. In order to protect personnel from the rupture of cooling system expansion joints, safety shields were fabricated and installed around the joints.

A direct lightning strike, sustained during a period when testing was suspended, caused extensive damage to the Data Acquisition System. Repairs were made to critical equipment items, enabling the test to continue.

E. ENVIRONMENTAL CONTROL

ANALYTICAL AND CHEMISTRY LAB SERVICES

During this quarter, the chemistry lab completed analysis of all samples submitted from the May 88 test. Twenty-four hour analytical support was provided during August/September 88 test with feedtank, baghouse, and pulverizer samples being analyzed every two hours. More than 400 coal, ash, and slag samples have been received from this test and the chemistry laboratory started analysis of the samples. Soil samples collected during the last quarter have been acid-digested and analyzed for selected anions and cations.

Work is continuing to install the X-ray diffraction unit and develop the system for analysis. The unit should be operational within the next quarter. The Perkin-Elmer Plasma 40 Ion Coupled Plasma Spectrometer (ICP) has been received and efforts are underway to install the system. As soon as the system is operational, method development for coal, ash, and water analysis will begin.

Presently, plans are being made to increase the scope of this project to include gas-phase priority pollutants and particulates collected downstream of the baghouse and electrostatic precipitator.

A quality control round-robin coal sample from Standard Laboratories was analyzed for ultimate and elemental constituents. All results compared favorably with other participating labs and all values were within ASTM limits. We are obtaining EPA drinking water and wastewater quality control round-robin samples which will expand the quality control program for the lab.

Water Quality

The holding ponds were monitored in support of the test. The new instrumentation for remotely monitoring the holding ponds was installed on a temporary line and interfaced to a computer in the control room to evaluate instrument performance. Data collected by the instrument was compared with samples collected at the instrument location and analyzed with lab instrumentation. Response was consistent with lab measurements and the overall performance was encouraging. Lightning damaged the holding pond instruments, but repairs have been completed.

Terrestrial Ecology

Soil samples were collected and preparation was completed for all of the study areas. Chemical analyses were entered into the database. Leaf sampling for CY 88 was completed and sample preparation was initiated. Digestion methodologies for leaf materials was evaluated using National Bureau of Standards (NBS) reference materials. The deionized water digestion methods were found to be adequate for the extraction of potassium and sulfate from ground leaf tissues. Work continued on assembling data from past years and adding these items to the database.

Ambient Air Monitoring

The ambient air monitoring network was operated in support of the test. Ambient particulate sampling again included upwind and downwind 5 stage cascade impactor samples. Preliminary examination of the 5 stage data indicates a bimodal distribution of ambient particulate at both the upwind and downwind remote sites. Samples were submitted for chemical analyses. Monitoring locations downwind of the CFFF during testing displayed a 20-30 ppb excursion from background SO₂ concentrations. During the August/September 88 test the meteorological instrumentation located on top of the coal tower and the associated data logger were damaged extensively by lightning. Repairs were completed on most of the instrumentation and reinstallation is scheduled before the next test. During this test several Industrial Hygiene particulate samples were collected to assess human exposure to dust levels associated with testing activities. The results of these samples will be included in the annual, "Site Environmental Report".

A quarterly audit of our instrumentation and procedures was conducted by The State of Tennessee Division of Laboratory Quality Assurance. The results of the audit indicated all instrumentation to be within EPA guidelines with the exception of the mid range point on the SO₂ analyzer located at Impact 2, which will be repaired.

POLLUTION CONTROL

During the August/September 88 test the primary gas sampling objectives included:

- Providing test operators with continuous CO and O₂ measurements for safety reasons
- Continuing continuous monitoring of CO, CO₂ and O₂ at the secondary combustor outlet and the BH/ESP outlet, and opacity monitoring for ESP performance assessment
- Establishing methods for water leak detection; and dewpoint measurement

During the February 88 test the upstream and downstream sampling positions were operated for a period of approximately 30 minutes with all of the nitrogen purges OFF to determine the effect on NO_x levels. This N₂ OFF period lasted for approximately 40 minutes. Calculations completed this quarter show the average stoichiometric ratio during this time period was approximately 0.85. Although the gas temperature in the secondary furnace rose slightly more than 50°F, no significant change in NO_x was observed (see Figure 14). Additional testing and evaluation are planned.

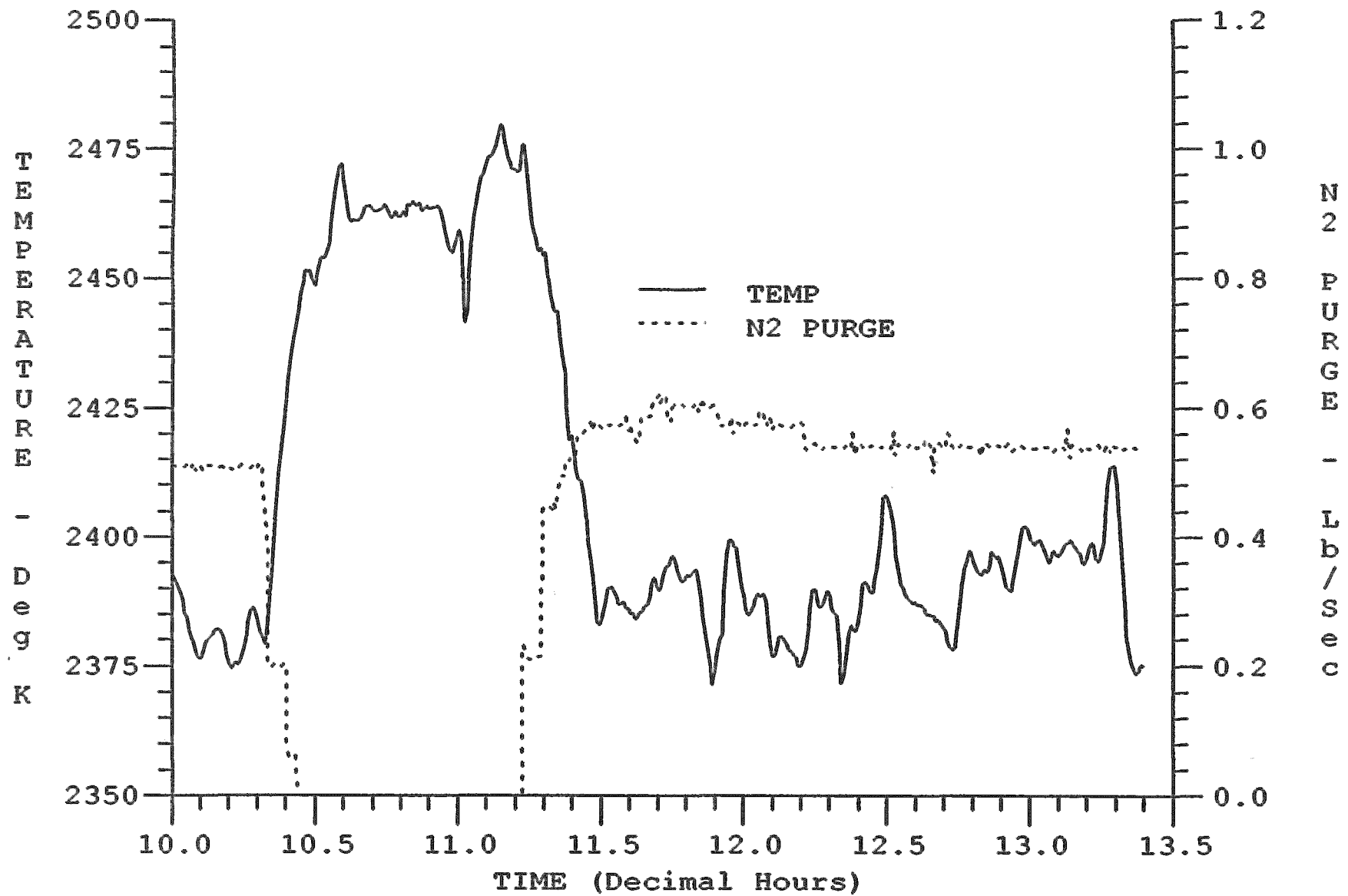


Figure 14. Temperature in the Secondary Furnace During N₂ Purge OFF Test Period

The General Eastern dewpoint analyzer was put in line with the outlet gas of the PermaPure dryer during the entire test except the last 24 hour period. The dewpoint recorded was then a relative measurement of the mixture of moisture extracted from the flue gas by the instrument air used as the dry air source. The instrument air dewpoint, which was recorded at -15° F, appeared to remain relatively constant, except during times when it appeared that large quantities of instrument air were being used and the compressor "chiller" could not capture the moisture due to the large flow rate. The largest usage of instrument air appeared to be during the operation of the ash/spent seed hopper system. The dewpoint analyzer sensed the changes in moisture from the instrument air.

No water leakage was detected from the LMF test train during the test. A post-test inspection of the test train confirmed that only a few small water leaks existed.

Attempts were made to determine N₂O concentration by gas chromatography using the Perkin-Elmer gas chromatograph (GC). The GC detected the N₂O calibration standard well, but NO/NO₂ interfered when the sample gas from the test was injected. A new column is being ordered which will separate the N₂O from the NO/NO₂. Additional samples will be analyzed from the secondary combustor outlet during the next test.

Clearing of the secondary combustor deposits appears to have helped the large CO fluctuations seen at the SCO sampling position during previous tests, with O₂ concentrations of 3% and above. Additional measurement will be made at lower O₂ concentrations.

F. MANAGEMENT AND ADMINISTRATIVE SUPPORT

Dr. J. Muehlhauser and Mr. N. Johanson met with the PETC MHD program officials during the week of September 12, 1988 to review FY89 testing plans. A 450-hour test program for FY89 was agreed to, consisting of two 100-hour and one 250-hour test runs.

The FY89 MHD Work Plan and budget requirements were prepared and sent to Mr. J. Mavec, DOE/CH.

An exit conference was held with auditors of the Cotton & Company on the interim audit of the contract for UTSI fiscal years 1982-1987. Auditors reviewed preliminary findings and recommendations and will prepare their final report.

Mr. J. Hunvald, DOE Property Security Manager, conducted a property security audit of UTSI's Government property system, and submitted a list of recommended changes to CFFF practices and procedures in this area. All of the action items are being addressed and reported to DOE/CH on a monthly basis until completed.

REPORTS SUBMITTED TO DOE IN FINAL FORM

A report on building accessibility for the physically impaired was prepared and sent to DOE/CH.

The Quarterly Small/Minority Business Subcontracting Report for April-June 88 was submitted to DOE/CH.

REPORTS SUBMITTED TO DOE IN DRAFT FORM

The April-June 88 Quarterly Technical Progress Report was submitted to DOE in draft form and is awaiting approval/comments.

TECHNICAL PUBLICATIONS

"Heat and Mass Transfer Calculations for Recirculating Laminar and Turbulent Flows in an Abrupt Pipe Expansion," presented at the First National Fluid Dynamics Conference, Cincinnati, Ohio, July 1988.

"Sensitivity Study of the Effects of PDF Models on the Predicted Structure of Turbulent Combustion Flow," presented at the First National Fluid Dynamics Conference, Cincinnati, Ohio, July 1988.

"Bench Scale Evaluation of Formate Process Based MHD Seed Reprocessing Option," presented at the 23rd Annual IECEC Meeting, Denver, Colorado, July 1988.

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
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
ECF	- Energy Conversion Facility
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
HVT	- High Velocity Thermocouple
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
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 used 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

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APPENDIX A
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