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**TECHNICAL PROGRESS REPORT
FOR
THE MAGNETOHYDRODYNAMICS
COAL-FIRED FLOW FACILITY**

**For The Period
January 1, 1995 - March 31, 1995**

May 1995

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

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The United States Department of Energy**

**Prepared by:
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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 evaluating technology for the Steam Bottoming Cycle Program. The approach taken was 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 wet and dry electrostatic precipitators), environmental monitoring, and analyses of test data on the convective heat transfer components (superheater and air heater) with eastern, high sulfur coal firing. For this quarter, analyses of the data for previously completed eastern coal testing and western coal proof-of-concept (POC) tests continued on a limited basis due to the loss of personnel in downsizing the organization for program closeout. Detailed data analyses will be contained in test reports, topical reports or technical papers to the extent permitted by resources available.

Also during the quarter activities continued in maintaining the CFFF in standby condition, readying the facility and equipment for disposition, fulfilling site environmental compliance and remediation requirements, and the preparation of data and documentation for archiving.

ABSTRACT

In this quarterly technical progress report, UTSI reports on the status of a multi-task contract to develop the technology for the steam bottoming portion of a MHD Steam Combined Cycle Power Plant. The report describes the facility maintenance and environmental work completed, status of completing technical reports and certain key administrative actions occurring during the quarter.

With program resources at a minimum due to closeout the MHD program, no further testing occurred during the quarter, but the DOE CFFF facility was maintained in a standby status, preventive maintenance and repairs accomplished as needed. Plans and actions progressed for environmental actions needed at the site to investigate and characterize the groundwater. The asbestos in the cooling tower was removed and disposed. Work continued on the preparation for archiving the results of the MHD program.

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SECTION I

OBJECTIVE AND SCOPE OF WORK

Under Contract No. DE-AC02-79ET10815, the overall objective initially was 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) were to resolve experimentally and analytically the key technical areas of concern identified or found to occur in direct coal-fired MHD systems with moderate to high ash carryover. The key areas involved (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) the operation, conditions, procedures and equipment needed to meet pollution control requirements.

In view of the conclusion of the MHD proof-of-concept program and acquisition of data, DOE directed UTSI to take the following actions:

- a) contract closeout;
- b) property disposition;
- c) reporting and archiving of data; and
- d) environmental remediation

In support of the above objectives and the DOE FY1994 MHD Program Plan, a revised contract statement of work (SOW) and management plan were approved by DOE. The technical approach now focuses on the following four (4) tasks described below:

TASK I - Contract Management and Close Out

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

TASK II - Facility and Property Disposition

This task provides for the maintenance of the CFFF in a standby condition until final disposition of the facility is made. All government owned property and equipment will be documented and controlled, and worn or unusable material will be recommended for applicable disposition.

TASK III - Data Reporting and Archiving

The contractor shall collect all data generated during the proof-of-concept testing program and place in a retrievable condition by identifying and documenting in accordance with its nature, format, quantity and repository. Data to be archived will be selected on the basis of certain criteria.

TASK IV - Site Environmental Compliance and Remediation

The Coal Fired Flow Facility site shall be subject to a DOE-directed project environmental characterization whereby site compliance and remediation requirements and actions will be identified and documented. The contractor shall accommodate this effort by providing accessibility to all pertinent areas and relative information and documentation as needed to perform the environmental characterization.

The contractor shall be prepared to perform the tasks necessary for site remediation and site restoration as determined by the site characterization study and as decided upon by the U.S. Department of Energy, and within the limitations of allocated costs.

CFFF PROGRAM GOALS AND SCHEDULE

Figure 1 shows the major program tasks presently scheduled/completed during the January through March 1995 period.

UTSI/CFFF MAJOR ACTIVITIES & SCHEDULE
OCTOBER 1, 1994 - SEPTEMBER 30, 1995

	FY95											
	O	N	D	J	F	M	A	M	J	J	A	S
TASK I - CONTRACT MANAGEMENT & CLOSE OUT												
1. Issue a DRAFT Management Plan for DOE review/approval												
2. Issue Monthly Project Status and Cost Management Reports												
3. Issue Quarterly Technical Progress Report												
TASK II - FACILITY & PROPERTY DISPOSITION												
1. Carry out preventive maintenance programs for the CFFF												
2. Maintain all Government Property for Status and Disposition												
3. Complete and maintain all Facility Engineering Drawings												
TASK III - DATA REPORTING & ARCHIVING												
1. Issue the following Technical/Topical Reports:												
- NOx/SOx Formation & Control-Eastern & Western Coal												
- Western Coal Processing System												
- Western Coal 1000 Hr POC Testing Summary & Final Program Summary Report												
- Superheater/Air Heater Tube Corrosion-Western Coal Testing												
2. Identify Data for Archiving												
3. Prepare data/documentation for archiving												
4. Publish & Maintain Lists of all Technical Reports, Papers, Plans/Manuals												
TASK IV - SITE ENVIRONMENTAL COMPLIANCE & REMEDIATION												
1. Support Site Environmental Characterization												
2. Install/Monitor Additional Groundwater Wells: Study Extent of Contamination												
3. Asbestos Abatement of CFFF Cooling Tower												
4. Maintain Operation of Ambient Air Monitoring Station												
5. Conduct/Report Monthly Discharge Monitoring												
6. Conduct Remedial & Restoration Actions as Identified, Required, Directed & Funded												

■ Planned
 ■ Completed

FIGURE 1. Scheduled Tasks

SECTION II

SUMMARY OF TECHNICAL PROGRESS

This section addresses the technical progress of work conducted during the period January 1 through March 31, 1995, according to the objectives and scope of work tasks outlined in Section I. Figure 2 is an overview of the DOE MHD Coal Fired Flow Facility (CFFF) at UTSI, and Figure 3 is a schematic of the current LMF test train.

TASK I - CONTRACT MANAGEMENT AND CLOSEOUT

The draft October-December 1994 Quarterly Technical Progress Report was issued to DOE.

Monthly Contract Status Reports for December 1994, January and February 1995 were prepared and sent to DOE.

Contract funding modification #A111 in the amount of \$987,291 was received to support operations through June 1, 1995.

A draft Management Plan for FY1995 was submitted to DOE.

Internal project plans and budgets to support FY95 contract tasks were completed.

TASK II - FACILITY AND PROPERTY DISPOSITION

No MHD testing was scheduled or performed during this quarterly period.

Activities this quarter were concentrated on the facility preventive maintenance/repairs required to maintain the Coal Fired Flow Facility in a standby condition. Weekly and monthly equipment maintenance procedures were performed for facility air compressor systems, cooling water pumps, coal processing system motors, steam boiler systems, ID and FD fans, and fire water system equipment.

FIGURE 2. Overview of the Coal-Fired Flow Facility

FIGURE 3. CFFF Integrated MHD Bottoming Cycle Schematic

The reconditioning of the CFFF process water cooling tower continued this quarter. The asbestos containing air baffles were removed and disposed. A purchase order was issued for the installation of an interior protective coating on the bottom of each cooling tower quadrant. This protective coating will be applied during the next quarter.

A program to improve the operation of sump pumps in the coal processing system pit and the test building pit was initiated. Improvements included the installation of new motors, controls, and wiring.

During this period, the following electrical and data system maintenance items were accomplished:

- Installed new electrical power monitoring instrumentation at the CFFF power substation and developed software to log data on a personal computer. Personal computer will alarm in the event of a high billing demand occurrence and also will perform verification of the accuracy of TVA billing data.
- Continued improvement and repair of computer ethernet network for CFFF.
- Performed periodic operational checkout and disk backups on the Data General MV1500 computers to maintain operation in an standby condition.

TASK III - DATA REPORTING AND ARCHIVING

Superheater/ITAH Tube Corrosion Studies

Measurements and evaluations were underway of the extent and type of gas-side surface corrosion which occurred on tubes in the Superheater Test Module (SHTM) during LMF5 testing with firing of low sulfur, high ash content Montana Rosebud coal. Operation with potassium to sulfur ratios greater than one resulted in tube deposits in the SHTM containing a mixture of potassium sulfate, potassium carbonate, and flyash. The three sections of SHTM tubes were steam-cooled to provide metal surface temperatures representative of expected tube temperatures for the secondary superheater, reheater, primary superheater, and intermediate temperature air heater (ITAH) in a first generation retrofit MHD plant. Test Section 1 (TS1) was located in nominally 2250°F flue gas with metal temperatures ranging along the tubes from about 700°F to 1400°F. TS2 was located in nominally 1700°F gas and also 700-1400°F metal temperatures. TS3 was in gas at about 1350°F with metal temperatures of about 650-1100°F.

Corrosion evaluation is being attempted by two methods. One is by measuring tube wall recession as the difference between original tube wall thickness measured by ultrasonic gauging and post-test wall thickness measured either by microscope or by micrometer. The other method is to measure the corrosion scale thickness and depth of sub-surface penetration microscopically from polished tube sections. Both methods have deficiencies as applied to the test section tubes. Since the amount of metal loss was minuscule (below 50 micrometers) for the stainless steels and high alloys in TS1 and TS2 owing to the short exposure time, the metal recession method requires very high precision in measuring the wall thickness and in relocating the original measurement location. So far, 261 retained wall thicknesses have been measured on 87 polished sections from TS1 and TS2 tubes, exercising rather great care in attempting to relocate the original measurement locations. Nevertheless, the resulting data showed too much scatter to be usable. Meaningful interpretation of scale thickness and penetration data requires that all metal consumed is measurable as retained corrosion scale. In the present corrosion situation, this is generally not the case. Microscopic inspection reveals that a considerable amount of the consumed metal is present as other than scale in a diffusion zone within the tube deposit adjacent to the metal surface. Furthermore, the diffusion zone in the deposit is saturated with metal cations, scale oxides and possibly some precipitated sulfides. This zone is often in such a finely divided, dispersed form that the imaging equipment and techniques employed are unable to adequately measure their area. In addition, this dispersal of tube-derived metal into the deposit either in solution or as precipitates is subject to loss by way of deposit removal due to sootblowing or post-test thermal spalling. Thus, neither of the employed evaluation methods appears satisfactory, but further evaluations of the method itself will be conducted and trends in the final data will be analyzed. Most of the difficulty arises from the relatively short exposure time of the tubes and the resultant small amount of corrosion.

Alloys tested in the SHTM and their placement are given in Table 1. So far, post-test evaluations have been confined to TS1 and TS2. The arrangement of alloys in TS1 and TS2 was identical, all those being "high alloys" in that they contained high levels of chromium and/or nickel. A portion of tube 7 was alloy T9 with 9% chromium, but it had been chromized to produce a high surface chromium level. Each tube was composed of two or more alloys welded together, the alloy(s) toward the hotter end expected to be more corrosion/heat resistant. Samples were taken for metallographic examination from 8 locations on each u-shaped tube, four from the first (upstream, hotter) pass and four from the second pass. These locations were identified by their distance from the flange at the top end of the tube, being 33, 57, 81, and 93 inches. These corresponded to approximately 21, 45, 69, and 81 inches from the ceiling of the module duct.

Table 1. Test Section Tube Alloys for LMF5 Testing with Montana Rosebud Coal

	TS1	TS2	TS3
1	556 / 316	556 / 316	316H / SA192
2	RA85H / HR-160 / 253MA	RA85H / HR-160 / 253MA	347H / T11
3	HR3C / 347	HR3C / 347H	T22
4	CR30A / 304H	CR30A / 304H	T9
5	310 / IN 690	310 / IN 690	T9
6	CR35A / Tempaloy A3	CR35A / Tempaloy A3	T22
7	cr ¹ -800H / cr-T9	cr-800H / cr-T9	347H / T11
8	MA956 / 347	MA956 / 347	304H / SA192

cr = chromized

Typical Composition of Alloys (wt %)

	Cr	Ni	Fe	Mo	W	V	Nb	Ti	Mn	Si	P	S	Al	C	N
SA192	-	-	Bal.	-	-	-	-	-	0.45	0.20	0.03	0.03	-	0.15	-
T11	1.25	-	Bal.	0.50	-	-	-	-	0.45	0.75	0.03	0.03	-	0.15	-
T22	2.50	-	Bal.	1.00	-	-	-	-	0.45	0.50	0.03	0.03	-	0.15	-
T9	9.00	-	Bal.	1.00	-	-	-	-	0.45	0.40	0.03	0.03	-	0.15	-
316	17.0	12.0	Bal.	2.50	-	-	-	-	2.00	1.00	0.05	0.03	-	0.07	-
347	18.0	11.0	Bal.	-	-	-	0.70	-	2.00	1.00	0.05	0.03	-	0.07	-
RA85H	18.0	14.0	Bal.	-	-	-	-	-	0.50	3.50	-	-	1.00	-	-
304H	19.0	9.00	Bal.	-	-	-	-	-	2.00	1.00	0.05	0.03	-	0.07	-
MA 956	20.0	-	Bal.	-	-	-	0.50	-	-	-	-	-	4.50	-	-
800H	21.0	32.5	Bal.	-	-	-	-	0.38	0.80	0.50	-	-	0.38	0.08	-
253MA *	21.0	11.0	Bal.	-	-	-	-	-	0.80	1.70	0.04	0.03	-	0.10	0.17
Temp A3	22.0	15.0	Bal.	-	-	-	0.70	-	1.37	0.40	0.03	0.01	-	0.05	0.19
556 **	22.0	20.0	Bal.	3.00	2.50	-	-	-	1.00	0.40	-	-	0.20	0.10	0.20
310	25.0	20.0	Bal.	-	-	-	-	-	2.00	1.50	0.05	0.03	-	0.25	-
HR3C	25.0	20.0	Bal.	-	-	-	***	-	2.00	1.50	0.05	0.03	-	0.08	0.10
HR-160 *	28.0	Bal.	4.0	-	-	-	-	-	0.50	2.75	-	-	-	0.05	-
IN 690	29.0	Bal.	9.0	-	-	-	-	-	-	-	-	-	-	-	-
CR30A	30.5	Bal.	17.7	2.10	-	-	-	0.18	0.20	0.27	-	-	0.14	0.06	-
CR35A	35.0	Bal.	18.2	-	-	-	0.50	-	-	0.07	-	-	-	0.07	-

* Contains 0.05% Ce ** Contains 18.0% Co, 0.6% Ta, 0.02% La, 0.02% Zr *** 1% Nb+Ta * Contains 27% Co

Measurements have yet to be completed on all samples, but available data are shown in Figure 4. The unfilled lower portion of each bar represents scale thickness and the filled portion represents penetration depth. The combination of scale thickness and penetration depth is used as a measure of corrosion extent. Penetration is usually the greater of the two, but as noted above, scale thickness as measured often underestimates the amount of metal consumption. A clear effect of temperature is noted at pass 1, with greater corrosion at higher temperatures, and less effect at pass 2. Generally, the best performer was alloy CR35A, which might be expected from its highest chromium content. However, alloy CR30A, with the second highest chromium content was one of the worst performers. This may be attributed to its molybdenum content, which is detrimental to high temperature ash corrosion resistance. Alloy RA85H, containing aluminum for the formation of an alumina subscale, also performed unsatisfactorily. Alloy HR-160, a highly alloyed material with 27% cobalt performed fairly well, but penetration was considerable. As with conventional coal ash corrosion, chromium content appears to be the principal determiner of performance, with Nb additions being beneficial and Mo additions detrimental.

At the highest exposure temperatures, all of the alloys exhibited metal diffusion into the deposit salt and subsequent precipitation of metal oxides dispersed within that diffusion zone. Under those conditions, none of the alloys produced continuous, non-porous scales at the metal-salt interface so as to provide a good diffusion barrier. Thus, outward cation diffusion to the salt and inward oxygen and perhaps sulfur diffusion resulting in sub-surface penetration are not negligible. Under these conditions, the corrosion rate remains low as long as chromium in the subscale is sufficient to repair and maintain an adequate scale barrier. But in long-term exposure, chromium depletion and subsequent catastrophic attack are to be expected.

Work continued on the evaluation of NO_x decomposition when using both eastern and western coals.

All data and documentation developed thus far on the MHD/CFFF project have been identified for archiving, and such records are ready for archiving storage. Also, those topical reports and technical papers presently under preparation will be included in our archival records.

FIGURE 4. Corrosion Scale Thickness and Penetration Depth (in micrometers) for CFFF Superheater/ITAH Tubes Exposed to 991.4 Test Hours

(Except as noted, under LMF5 conditions (based on incomplete measurements))

TASK IV - SITE ENVIRONMENTAL COMPLIANCE AND REMEDATION

With the completion of the shortened LMF5 POC test series, the MHD related analytical services being conducted are those which support environmental monitoring, evaluation of materials, and maintenance of the Chemistry Laboratory. Monitoring and treatment of the holding pond effluent was conducted to comply with the UTSI water discharge permit. Water was checked for pH, temperature, flow rate, oil and grease content, total dissolved solids, and total suspended solids. The scanning electron microscope (SEM) was serviced this quarter and is in good working order, but the energy dispersive x-ray analysis (EDAX) attachment to the SEM continues to be non-operational due to computer hardware and software problems. An 8-inch floppy disc drive was determined to be broken. Spare drives were located on site, as the drive is obsolete and could not be obtained from commercial vendors. Repair of this device is being investigated as time allows, as the only person capable of operating the SEM and EDAX is also working on the analysis of the SHTM tube corrosion samples. The combination gas chromatograph/mass spectrometer was serviced this quarter and is in good working order. Routine equipment maintenance was also performed.

A subcontract for the drilling of additional groundwater wells to investigate and characterize the groundwater surrounding the CFFF was awarded. Award of a subcontract for preliminary analysis was also to be awarded. Weather permitting, work should start the first part of April 1995.

A contract for removal and disposal of the asbestos-containing cooling tower fill at the CFFF was awarded, and the work was finished the week of February 13, 1995.

UTSI was still awaiting a response from DOE to its letter of March 18, 1994, containing planned action items and cost estimates for the disposal, site remediation and restoration for the CFFF and adjacent areas which was prepared in response to the DOE-conducted site environmental characterization audit held in March 1994.

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