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MAGNETOHYDRODYNAMIC PROJECTS AT THE CDIF

Quarterly Technical Progress Report
for
July 1 - September 30, 1990

PREPARED BY

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PREPARED FOR

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Approved by:

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ABSTRACT

This quarterly technical progress report presents the tasks accomplished at the Component Development and Integration Facility during the fourth quarter of FY90. Areas of technical progress this quarter included:

- coal system development;
- seed system development;
- test bay modification;
- channel power dissipation and distribution system development;
- oxygen system storage upgrade;
- iron core magnet thermal protection system checkout;
- TRW slag rejector/CDIF slag removal project;
- stack gas/environmental compliance upgrade;
- coal-fired combustor support;
- 1A channels fabrication and assembly;
- support of Mississippi State University diagnostic testing;
- test operations and results;
- data enhancement;
- data analysis and modeling;
- technical papers; and
- projected activities.

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1.0 INTRODUCTION

The Component Development and Integration Facility (CDIF) is a major U.S. Department of Energy magnetohydrodynamic (MHD) test facility in Butte, Montana. The CDIF is operated by MSE, Inc. Within the national MHD program, MSE personnel are responsible for performing integration testing of vendor-supplied MHD power train components at the CDIF to support the goal of commercialization.

During the fourth quarter of FY90 on-line current control testing and testing using the materials test channel, which contains coupons to obtain material and design information, continued. Testing also addressed inverter voltage spike testing and on-line current control checkout. At the end of the quarter, testing was shutdown for channel repairs.

2.0 TASK DEFINITION

- Task 1 -- Facility;
- Task 2 -- Test Hardware/Support; and
- Task 3 -- Test Operation.

2.1 TASK 1 -- FACILITY

This task encompassed modifications and enhancements to plant systems that support testing, including checkout, testing, and characterization.

Subtasks for the facility task were:

- Subtask 1A -- Coal System Development;
- Subtask 1B -- Seed System Development;
- Subtask 1C -- Test Bay Modification;
- Subtask 1D -- Channel Power Dissipation and Distribution System (CPDDS) Development;
- Subtask 1E -- Unassigned;
- Subtask 1F -- Unassigned;
- Subtask 1G -- Oxygen System Storage Upgrade;
- Subtask 1H -- Iron Core Magnet (ICM) Thermal Protection System Checkout; and
- Subtask 1I -- TRW Slag Rejector/CDIF Slag Removal Project.

2.1.1 Subtask 1A -- Coal System Development

A CDIF coal system review was held to solicit recommendations on system reliability and performance. Consultants from several firms, who have experience in coal drying and processing, evaluated the system and participated in discussions with CDIF personnel. The consensus was that the basic components of the CDIF coal system are sound, but there is room for some improvements in the scalping screen and transport line.

A statement of work specification to have an outside vendor provide the tailored coal was completed.

2.1.2 Subtask 1B -- Seed System Development

The following progress has been made during seed system development.

- An investigation continues into using loadcells and nuclear level measurement devices for determining the seed level in the storage injector.

- A task force was formed to investigate problems in the seed system. A strategy for implementing the recommendations of the task force has been sent to DOE.

On the recommendation of the seed system task force, investigation on an upgrade for the bottom of the seed storage silo was suspended. If any modifications are done, installation of a new feeder and fluidizers will be reconsidered.

2.1.3 Subtask 1C -- Test Bay Modification

This subtask is an ongoing effort to support the CDIF Test Program. Test bay modification will continue to evolve as testing progresses, new objectives are set, and new tests are defined.

Iron oxide injection support activity performed this quarter follows.

- Iron oxide was injected into the channel cathode wall for a total of 30 hours.

- Installation of the two progressive cavity pumps for replacements/backup for the existing diaphragm metering pumps will occur next quarter.

2.1.4 Subtask 1D -- Channel Power Dissipation and Distribution System (CPDDS) Development

The CPDDS consists of the resistive load bank, high-voltage room, inverter, voltage limiting device, and wiring from the high-voltage room to the MHD channel connectors. The following progress was made in the CPDDS this quarter.

- The N+11 resistive configuration was removed, and the high-voltage room was reconfigured to a N+15 configuration with current control circuits installed only in the midchannel region.

- Work packages and/or engineering support for the Avco-TRW circuit tests were provided. Support included providing special/extra current control circuit instrumentation and short/open circuit MHD test configurations.

- Work packages and/or engineering support for TRW-Westinghouse's inverter spike characterization test were provided. Support included installing a test filter network and the accompanying instrumentation. Test results demonstrated a 1/2-amplitude reduction coupled with a greatly reduced frequency of the transient waveform. Subsequently, the filter network was installed temporarily until a permanent solution can be installed.

- TRW-Westinghouse's effort to provide an independent evaluation for using the resistive load banks in a series-parallel combination to replace the inverter as a load on the channel was supported. Results of this evaluation have not been received.

- Troubleshooting efforts to determine the cause of arcing in the high-voltage room, which was observed during MHD Test 90-CC-4, were initiated. The configuration was an N+15 with current controls used only in the midchannel region. Observations revealed that arcing occurred on all midchannel high-voltage room panels between the terminal blocks of the anodes and the associated adjacent resistive load bank resistors of the terminal blocks. The resistive load bank resistors were not connected in this configuration, and the current was bled off through the primary cooling water circulating through the resistive load bank tanks. The arcs occurred in the airspace between adjacent terminals. To eliminate arcing, the anodes and resistive load bank resistors were connected.

  Additionally, meggor tests were conducted randomly and selectively on the resistive load bank resistors; two resistors had considerably lower resistance to ground readings and were removed from the circuit. This arcing did not occur in previous current control tests (as these tests were unsuccessful), and the inverter never reached the potentials realized in this test.

- The cause of the static volts-amp reactive (VAR) generator out-of-specification alarm activation was identified. The problem was traced to existing incompatibilities between the VAR transducer and the range-change circuit board. An isolation amplifier was inserted between the two circuits until a permanent solution can be engineered.

- Additional work packages were released to: 1) increase the current handling capabilities of the interconnecting bus bar cables to current controls 7 and 8 (current consolidators), 2) distinctively mark each high-voltage room panel from its neighbor, 3) identify cable trays, and 4) remove hardware that had been installed for special test efforts.

2.1.5 Subtask 1E -- Unassigned

2.1.6 Subtask 1F -- Unassigned

2.1.7 Subtask 1G -- Oxygen System Storage Upgrade

The Title II design effort was completed. The initial review was held on July 19 with a followup review conducted on August 8 for clarification of construction specifications and safety analysis considerations. Modifications to the contract were completed and included in the construction subcontract. Construction subcontract assembly is underway and will be issued for a construction period encompassing April through August 1991. This construction period will correspond with the data acquisition system installation, thereby limiting the actual facility shutdown periods required for major project installations.

2.1.8 Subtask 1H -- Iron Core Magnet (ICM) Thermal Protection System Checkout

Iron core magnet (ICM) thermal protection system checkout is continuing, and new developments will be reported as they occur.

2.1.9 Subtask 1I -- TRW Slag Rejector/CDIF Slag Removal Project

The TRW slag rejector consists of a slag grinder assembly, a pressurized receiver tank, and an atmospheric collection tank with interconnecting valves and piping. As it is currently being designed, the CDIF slag removal system will consist of equipment that dewaters, weighs, and transports slag out of the combustor pit and then disposes of the slag. When installed, the slag rejector/removal equipment will provide batch removal and slag weighing from the TRW 50-MW_t coal-fired combustor (CFC) to support extended duration testing.

Activities this past quarter included:

- Work on the integrated Title II design for the project was initiated.
- Structural steel modifications (as far as practicable in support of the Phase I installation of the TRW slag rejector equipment) were completed.
- The slag grinder was installed in the slag tank and tested on a preliminary basis. Further tests will be done in conjunction with the upcoming Phase I installation.
- The work package for the completion of the Phase I installation was issued.
- Procurement specifications were issued, and bids were received on all major equipment items.

2.2 TASK 2 -- TEST HARDWARE/SUPPORT

Test hardware is supplied under a Department of Energy contract and is tested at the CDIF. During the test program, hardware design modifications and repairs are accomplished by MSE personnel at the request of the component developer. Facility test hardware interface refinements are also part of this task. Subtasks for the test hardware/support task were:

- Subtask 2A -- Stack Gas/Environmental Compliance Upgrade;
- Subtask 2B -- Coal-Fired Combustor (CFC) Support;
- Subtask 2C -- 1A Channels Fabrication and Assembly;
- Subtask 2D -- Unassigned;
- Subtask 2E -- Unassigned; and
- Subtask 2F -- Support of Mississippi State University (MSU) Diagnostic Testing.

2.2.1 Subtask 2A -- Stack Gas/Environmental Compliance Upgrade

This upgrade provides a permanent facility for collecting and analyzing off gases from any process tested at the CDIF. It will also give the CDIF the needed modification to comply with the required safety standards for storing and dispensing compressed gases and to comply with the Environmental Protection Agency's and the State of Montana's need to know of the actual stack emissions of nitrogen oxides (NO_x), sulfur dioxides (SO_2), and carbon monoxide (CO).

Procurement is continuing on the purchase of two facilities: the stack gas analysis facility (SGAF) and the compressed gas storage facility (CGSF). Both of these buildings are preengineered. The CGSF is a turnkey facility, and the SGAF is a metal building. Construction is scheduled to be completed during January 1991.

A draft of the continuous emissions monitoring system (CEMS) Quality Assurance Plan was completed. The final version is scheduled to be issued by January 1991. This document provides details on system design, chain-of-custody, data collection and verification, delegation of responsibility, and a plan for compliance to 40 CFR 60 in accordance with applicable regulations of CEMS design and operation.

On completion of construction, an independent relative accuracy test audit will be performed on the CEMS so system certification can be attained.

Work is continuing on analyzing the off gases for CO, CO_2, and O_2 on a dry basis and SO_2, CO, and NO_x on a wet basis. The use of gas chromatography to analyze N_2, H_2, and O_2 was suspended because some asbestos was found in the gas chromatograph; steps were taken to replace the material. An autosampler valve will be installed in the gas chromatograph so samples can be automatically sampled and analyzed.

2.2.2 Subtask 2B -- Coal-Fired Combustor (CFC) Support

Smooth-wall air inlet filler section testing to reduce coal-fired precombustor fouling continued.

2.2.3 Subtask 2C -- 1A Channels Fabrication and Assembly

Testing with the materials test channel continued throughout the quarter; the channel had test coupons added in anode wall sections 41 and 42 for this testing. The channel is comprised of wall sections 41, 42, 19, 20, 37, 30, 31, and 32. The thermal and electrical power test history of these wall sections is shown in Table 1.

Assembly of the next anode wall (wall sections 49 and 50) has proceeded to the point where the coupons in the existing channel will need to be installed for completion of the wall. Procurement of the bars for the next anode wall (wall sections 57 and 58) was completed. Assembly of right forward diagonal sidewall 29 is approximately 50 percent complete.

The removal and recovery of platinum from anode wall sections 17 and 18 were completed.

TABLE 1 -- CHANNEL WALL SECTIONS IN SERVICE DURING QUARTER

WALL SECTION NUMBER	DESCRIPTION	COAL HOURS	POWER HOURS
41	FORWARD ANODE	45:07	15:38
42	AFT ANODE	45:07	15:38
19	FORWARD CATHODE	213:10	120:30
20	AFT CATHODE	213:10	120:30
37	FORWARD RIGHT SIDEWALL	70:16	34:54
30	AFT RIGHT SIDEWALL	195:47	113:00
31	FORWARD LEFT SIDEWALL	70:16	34:54
32	AFT LEFT SIDEWALL	195:47	113:00

In-house fabrication of replacement diffuser sections continues. Replacement sections for the aft subsonic section are approximately 75 percent complete.

2.2.4 Subtask 2D -- Unassigned

2.2.5 Subtask 2E -- Unassigned

2.2.6 Subtask 2F -- Support of Mississippi State University (MSU) Diagnostic Testing

During the quarter, CDIF personnel supported MSU with a series of diffuser plasma diagnostic tests, which produced preliminary temperature and electron and potassium number density data. This data is being compared to MHD computer models.

2.3 TASK 3 -- TEST OPERATION

The subtasks for the test operation task were:

- Subtask 3A -- Test Operations and Results;
- Subtask 3B -- Data Enhancement; and
- Subtask 3C -- Data Analysis and Modeling.

2.3.1 Subtask 3A -- Test Operations and Results

On-line current control testing continued, and inverter voltage spike testing was completed. A new hot-walled filler, CFC pintle, and slag rejection system grinder were also tested; these tests were

initiated with the materials test channel in place. Test objectives addressed during the quarter included:

- Checking out the newly installed, hot-walled filler section and CFC coal pintle.
- Checking out the slag grinder and slag tank modifications for the continuous slag rejector.
- Confirming the proposed 1A4 channel element materials, pitch, and braze design on both plasma side and water side using the materials test channel.
- Checking out long-duration test data on power degradation with iron oxide injection and precombustor fouling during 22- to 24-hour duration testing.
- Obtaining voltage spike data from the inverter.
- Obtaining minimum iron oxide flow during actual test train operation.
- Obtaining test data at a lower current density and higher N/O condition with second-stage nitrogen addition.
- Diagnosing current controls operation.
- Checking out facility systems operability.
- A new section, Test Analysis, was added to the preliminary test reports generated for each successful MHD test. The purpose of this section is to discuss aspects of the test that do not fit elsewhere in the report, especially conclusions or results that were obtained. Some of the key points are described below.
- The difficulty of operating the Avco-supplied current controls was determined to be a combination of noise and droop on the 480-V ac supply, which caused the cabinet clock boards to stop sending pulses to the gate-driver board. Consequently, the gate-driver boards signaled the gate turn-off thyristors (GTOs) to conduct all the time and resulted in loss of control of the channel electrode currents. After determining the cause of the operational difficulties, an MHD test was run with power brought in from another source on a temporary basis. Various electrical test conditions were obtained to verify correct operation under stressing conditions. Conditions included short circuit, open circuit, and inverter operation at various voltage levels. With the temporary power run, all the current controls operated within normal parameters.
- An investigation of the voltage transient on the positive inverter bus was conducted because of concern (which proved to be unfounded) that this might be causing the current controls to fail. This transient occurs at 180 Hz and is associated with thyristor stack switching. An MHD test was conducted to

determine the effectiveness of a resistor-capacitor (RC) filter from the positive bus to ground. The test was conducted in three stages: 1) without the filter (baseline case), 2) with the RC filter, and 3) with the resistor part of the RC filter jumpered out but with the capacitor left installed. Data showed the RC filter reduced the magnitude of the voltage (and current) transient to one-half of its baseline value. It also decreased the frequency of oscillation caused by the transient. Operation with only the capacitor resulted in more oscillation; therefore, it was concluded the resistor is beneficial.

- Voltage spikes on the anode wall of the channel corresponded to ends of regions where nonslagging test electrodes were installed. The spikes were caused by a power generation depression over the test electrodes and were accompanied by a depression in the currents associated with the electrodes. Reasons for this power depression are under investigation.

Testing this quarter included nine tests for a total coal burn time of 45 hours 7 minutes and a total power time of 15 hours 38 minutes. Table 2 outlines the tests run during the quarter. During the quarter, a new record for continuous thermal operation was achieved.

During Test 90-MATL-5, 21 hours 12 minutes of continuous thermal operation was completed. Due to irregular internode voltages, the power portion of the test was discontinued after 38 minutes.

2.3.2 Subtask 3B -- Data Enhancement

No activity is anticipated within this subtask until June 1991; therefore, reporting will be suspended.

2.3.3 Subtask 3C -- Data Analysis and Modeling

The high-voltage spikes in the downstream power take-off region, described in previous reports, are being addressed both experimentally and computationally. Some amelioration of the voltage spikes was realized in more recent tests, and modified power take-off circuit designs will be tested in the future.

3.0 TECHNICAL PAPERS

A CDIF status paper was presented at the IECEC Conference in Reno, Nevada, on August 15, 1990. The paper was authored by I. Stepan, A. Hart, R. Glovan, T. Rivers, and A. Viall and was presented by R. A. Carrington.

TABLE 2 -- MHD TESTS

DATE	TEST NO.	TEST OBJECTIVES	COAL BURN TIME (hr:min)	ENERGY GENERATED (MW hr)	PEAK POWER (MWe)	POWER RUN TIME (hr:min)	COMMENTS
07/31/90	90-WEST-1	1) Obtain voltage spike data from the inverter. 2) Check out operation of the slag grinder. 3) Obtain minimum iron oxide flow during actual test-train operations. 4) (Optional) Obtain heat flux, conductivity, and power data at Phi 1 = 0.55, Phi 2 = 0.95, and N/O = 0.70. 5) (Optional) Obtain heat flux and power data with a high N/O (0.75) and 10 percent N_2 in the second-stage oxidizer stream. 6) (Optional) Gain operational experience at low (30 MW) input.	00:00	0.000	0.00	00:00	Test objectives were not met. Precombustor ignition set point temperatures could not be achieved.
08/01/90	90-WEST-2	1) Same as 90-WEST-1.	:27	0.041	0.73	00:11	Test objectives were not met. The test was secured with a manual emergency shutdown because an arc path from ground to the CFC test stand developed, causing a loss of isolation to the test stand. The stand's fiberglass insulators will be repaired before the next test.
08/02/90	90-WEST-3	1) Same as 90-WEST-1.	03:18	1.172	1.41	01:20	Test objectives were met, and all systems operated well. The ability to decrease thermal input to the combustor was successfully demonstrated. The slag grinder operated continuously during the test. Westinghouse modifications were in place in the inverter to reduce the inverter voltage spike. Testing was shut down when objectives were completed. Before the test train was secured, low thermal inputs to the combustor were tested. Process flows were reduced in steps to a final condition of 35 MW_t.
08/10/90	90-CHEK-2	1) Check out operation and obtain heat flux data of the newly installed hot-walled combustor filler section and CFC coal pintle. 2) Check out operation of the slag grinder. 3) Check out the facility in anticipation of a 24-hour duration test.	01:46	0.270	1.34	00:27	Test objectives were met, and most systems operated well. However, the seed system experienced plugging in the mix-tee. Test objectives were completed when the number 3 primary cooling water spray pump failed, requiring test shutdown.
08/14/90	90-MATL-5	1) Obtain long-duration test data on power degradation with iron oxide injection and precombustor fouling during a continuous 24-hour thermal/22-hour electrical test. 2) Confirm the proposed IA4 channel element materials, pitch, and braze design on both plasma side and water side using the materials test channel. 3) (Optional) Obtain heat flux, conductivity, and power data at Phi 1 = 0.55, Phi 2 = 0.95, and N/O = 0.70.	21:12	0.397	1.12	00:38	Test objectives were partially met. Building 20 seed system continued to have problems with intermittent flow and plugging. The MHD portion of the test was discontinued after 38 minutes of power generation; however, the thermal portion of the test was continued to check long-term slagging effects in the combustor. The test was shut down when coal and oxygen supplies were depleted. This test established a continuous thermal operation record.
08/28/90	90-CC-3	1) Diagnose current control operations in relation to inverter operation. 2) (Optional) Obtain heat flux, conductivity, and power data at Phi 1 = 0.55, Phi 2 = 0.95, and N/O = 0.70.	01:26	0.147	0.06	00:45	Test objectives were partially met; all systems operated well, and process flows were stable. Enough data was gathered for preliminary troubleshooting of the Avco-supplied current controls. Off-line troubleshooting will continue before more on-line testing is attempted.

TABLE 2 -- MHD TESTS (Cont'd)

DATE	TEST NO.	TEST OBJECTIVES	COAL BURN TIME (hr:min)	ENERGY GENERATED (MW hr)	PEAK POWER (MWe)	POWER RUN TIME (hr:min)	COMMENTS
08/30/90	90-CC-4	1) Same as 90-CC-3.	04:38	1,199	1.38	02:36	Test objectives were met; all systems operated well, and process flows were stable. Once established, seed flow was stable. This test verified current control operation with a temporary power supply from an isolated feeder. Testing included open circuit, short circuit, inverter with resistor-capacitor (RC) filter, and inverter without RC filter configurations.
09/20/90	90-MATL-6	1) Obtain long-duration test data on power degradation with iron oxide injection and precombustor fouling during a continuous 22-hour electrical test. Determine the effect of iron oxide on the anode wall. 2) Confirm the proposed 1A4 channel element materials, pitch, and braze design on both plasma side and water side using the materials test channel.	08:30	7,512	1.26	07:50	Test objectives were partially met. The current controls continued to operate with temporary power from an isolated feeder. Testing was temporarily shut down when a thermocouple arced from the combustor to the support stand. Repairs were immediately completed so testing could continue. Testing was shut down due to a plugged coal scalping screen vent line. Low current to the inverter, when the inverter was operated at 6,000 V, was experienced.
09/27/90	90-MATL-7	1) Obtain long-duration test data on power degradation with iron oxide injection and precombustor fouling during a continuous electrical test. 2) Confirm the proposed 1A4 channel element materials, pitch, and braze design on both plasma side and water side using the materials test channel.	02:50	1,085	0.90	01:51	Test objectives were partially met. The current controls continued to operate with temporary power from an isolated feeder. Testing was temporarily shut down when a leak in the quench water system developed. Repairs were immediately completed so testing could continue. Testing was then shut down due to a high CO reading on the continuous emissions monitor.

4.0 PROJECTED ACTIVITIES

Facility (Task 1) activities planned for the first quarter of FY91 include:

- upgrading the iron oxide slurry system to increase system capabilities and reliability;
- initiating coal system upgrades based on the recommendations of the CDIF coal system review team;
- initiating seed system modifications recommended by MSE-CDIF taskforce; and
- completing Title II design for installing the TRW-supplied slag rejector equipment.

Test hardware support (Task 2) activities planned for the first quarter of FY91 include:

- completing assembly of wall sections 29, 49, and 50;
- initiating assembly of wall sections 57 and 58;
- initiating procurement of channel wall section 40, which is a four-segment left aft diagonal sidewall; and

- completing fabrication of aft subsonic diffuser sections and initiating fabrication of horizontal forward subsonic diffuser sections.

Test operations (Task 3) activities planned for the first quarter of FY91 include:

- completing the 50 hours of cumulative electrical materials testing with iron oxide injection on the materials test channel;
- performing a 24-hour duration test using Rosebud coal;
- initiating the 50 hours of cumulative electrical materials testing with iron oxide injection and current controls on the materials test channel; and
- continuing to support MSU measurements using modified diffuser triple port walls.

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