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ABSTRACT

The Component Development and Integration Facility (CDIF) is a Department of Energy (DOE) test facility operated by MSE, Inc. MSE personnel are responsible for the integration of topping cycle components for the national coal-fired magnetohydrodynamics (MHD) development program. Initial facility checkout and baseline data generation testing at the CDIF utilized a 50-MW_t, oil-fired combustor (with ash injection to simulate coal slag carryover) coupled to the 1A supersonic channel. In the fall of 1984, a 50-MW_t, pressurized, slag rejecting coal-fired combustor (CFC) replaced the oil-fired combustor in the test train. In the spring of 1989 a coal-fired precombustor (CFPC) was added to the test hardware. In addition, significant progress and developments were made by MSE in the areas of the solid suspension injection system, the stack gas analysis system, and temporary fine coal transport.

Testing during the last year emphasized baseline testing, including oxygen injection for effective mixing, fine coal testing, duration testing, and iron oxide slurry injection testing accomplished.

MSE activities in test hardware included the fabrication and assembly of an entire $1A_1$ channel and the repair and refurbishment of the channel that has been in test service since July 19, 1989. MSE has also designed and fabricated several developmental projects that include the MSE nozzle, the triple port walls in the diffuser and a post-nozzle test section for combustor-only testing. This paper discusses the involvement of these pieces of hardware in the test program during the last year.

Facility modification and installation of current controls, the permanent solid suspension injection system, and modifications for a temporary fine coal system are addressed. Also, projects on the horizon such as installation of the continuous slag rejection and removal system, and testing to address hardware candidate materials and design for the prototypic channel are discussed. Long-term plans for new installations are also addressed.

INTRODUCTION

The Component Development and Integration Facility (CDIF) is operated for the Department of Energy (DOE) by MSE, Inc. MSE is chartered with integrated testing of coal-fired MHD topping cycle components. Currently under evaluation are a 50-MW_t coal-fired combustor (CFC), developed by TRW, and a linear generator, diffuser, and a full compliment of current control units, all supplied by AVCO Research Laboratory, Inc.

Previous CDIF SEAM papers have detailed the initial oil-fired, ash-injected power tests, as well as the CFC and coal-fired precombustor (CFPC) checkout and initial power generation testing at the CDIF. This paper provides the status of CDIF coal-fired power generation testing since the 27th SEAM (June 1989). During the past year, test activities have concentrated on technical issues of coal-fired MHD, addressing cathode wall shorting phenomena, second-stage mixing, and duration testing, all in the interest of additional data to support Proof-of-Concept hardware decisions. Efforts to install the new AVCO-supplied current controls have also been completed.

TEST SYSTEM DESCRIPTION

Since August 1985 when the first electrical power tests with the CFC were conducted, CDIF test activities have focused on coal-fired MHD power generation. The 50-MW_t CFC in its current test configuration is depicted in Figure 1. The oil-fired vitiator (OFV), sometimes referred to as the air preheater, receives the incoming air from a high-volume compressor and heats this air to 1,200 ^oF after oxygen is added to obtain the desired enrichment. The CFPC uses a portion of the preheated air from the OFV to combust coal and produce air heated to 2,900 ^oF that is then introduced to the first-stage combustor. Preheated air enters the cylindrical first stage tangentially and entrains pulverized coal particles injected from the endplate. Operating substoichiometrically, coal is gasified and slag particles are driven to the combustor wall. A concentric baffle guides the molten slag into a water-filled tank below. The gas stream passes through the deswirl section of the combustor (where dry potassium carbonate may be added) and enters the second stage. Additional oxygen, and sometimes nitrogen (to simulate a prototypical oxidizer product) are injected in the second stage to bring the plasma to near-stoichiometric conditions. Baseline operating conditions used for the majority of the testing during the last year are:

Thermal Throughput	50 MW
Mass Throughput	17.4 lb/s
OFV Preheat	1,200 ^oF
CFPC Preheat	2,900 ^oF
Oxidizer Enrichment	39.2%
CFPC Equivalence	1.09
First-Stage Equivalence	0.55
Second-Stage Equivalence	0.95
Global N/O	0.70

With the completion of CFPC combustor checkout testing, the channel was installed. The channel that was identified as the $1A_1$-C1 provided almost all of the test service since the 27th SEAM. That channel was comprised of anode wall elements capped (top and upstream side) with type 446 stainless steel, cathode wall elements with 75 percent tungsten/25 percent copper leading edge sidecaps, peg-style forward sidewalls, and diagonal bar-style aft sidewalls. The details of these elements have been described in a previous SEAM paper.[1]

A full compliment of AVCO-supplied current controls were installed and checked out. On-line testing of the current controls began in May, and results will be discussed at SEAM 28. Figure 2 shows the arrangement of the current controls in conjunction with the channel.

Major CDIF plant support systems are shown in Figure 3. Compressed air, gaseous oxygen and nitrogen, fuel oil, pulverized coal, iron oxide/oil slurry, and dry seed are the process flow delivery systems. Medium pressure, deionized cooling water maintains the desired test train component temperature. The magnetic field is provided by a 2.9 tesla iron core magnet. Conversion of the dc to ac power, transmission to the commercial power grid, and variable generator loading are provided by an Electric Power Research Institute (EPRI)-supplied inverter system. Channel electrical configuration and measurements are achieved in a room containing the required numerous termination blocks and voltage/current transducers. A data acquisition system (DAS) records and stores over 2,000 measurements and calculated values each second (1,500 of these are electrical parameters). Since the combustor operates at a voltage potential of up to 9,000 volts, all process flow, cooling water, and instrumentation attachments to ground must meet stringent isolation criteria.

TEST RESULTS

Major programmatic and technical objectives have been met in the last year. From July 1989 through April 1990, 65 test starts occurred with a coal burn time of 125:32 hours and electrical power generation of 77:59 hours. Significant test accomplishments are detailed in Table 1.

The test program over the last year at the CDIF was designed to support the overall effort to acquire more and longer duration data to aid vendors responsible for design of the Proof-of-Concept hardware. Major technical accomplishments during the year were:

- completed second-stage oxygen injection configuration testing, within the limits of the second-stage configuration options;
- completed fine coal testing;
- completed testing of varied rates of iron oxide injection on anode and cathode walls; and
- completed more tests for longer continuous duration periods.

Second-Stage Oxygen Injection Testing

Second-stage oxygen injection testing was accomplished during the last year. The second stage was configured for testing using an effective length/height (L/H) ratio of 0.7 and 2.7. Oxygen injection configuration and injector port sizes were also modified. The following listing outlines the oxygen injector frame configurations and some results for the tested configurations:

L/H	Injector Configuration	Injector Size	Peak Power Achieved	N/O Ratio, Phi 1, Phi 2
0.7	12-port vertical*	0.363 inches	1.76 MW_e	0.70, 0.55, 1.00
0.7	8-port horizontal			
0.7	20-port			
2.7	8-port vertical			
2.7	12-port horizontal*	0.363 inches	1.86 MWe	0.75, 0.57, 0.95
		0.363 inches	1.73 MW_e	0.75, 0.55, 0.95
		0.363 inches	1.65 MW_e	0.70, 0.55, 0.90
		0.300 inches	1.69 MW_e	0.70, 0.55, 0.95
2.7	20-port (10-port noninmpinging)*	0.363 inches	1.52 MW_e	0.75, 0.56, 0.95

Since SEAM 27, those configurations designated * have been tested.

Also tested was a temporary arrangement to inject a mixture (by weight) of 10 percent N_2/90 percent O_2, and 20 percent N_2/80 percent O_2. This option was tested to determine the impact of prototypic second-stage oxygen injection. The limited testing accomplished indicated no detrimental impact would be experienced.

Fine Coal Testing

Fine coal testing was completed when fine coal from the CDIF baghouse was reintroduced into the normal coal product used at the CDIF. The fines were reintroduced at a 15 to 20 percent mix of fines. Results from the tests confirmed that no dramatic changes in power level occur when fine coal is introduced to the combustor.

Varied Rate Iron Oxide Injection Testing

During the course of testing, varied rate iron oxide injection was tested. The flow rates were varied so that iron oxide sent to the cathode and anode walls varied from 2 to 8 lb/min slurry. The flow rate delivered to the channel appeared to have an impact on power production due to the loss of effect of iron oxide over time on cathode wall shorting. Immediately before the February 1990 testing shutdown, the last tests indicated that very low flow rates of iron oxide may be most effective and cathode shorting may not reappear over time.

Duration Testing

One of the goals for FY90 was to accomplish steady-state combustor testing and long-duration power testing. Efforts were made to operate testing for a 24-hour duration. Although a 24-hour test was not accomplished, record continuous test duration lengths were achieved. The old record for continuous test length was established October 2, 1986, with 8 hours 29 minutes of coal-fired MHD testing and 7 hours 10 minutes of power production. This record was surpassed twice during the quarter, and the final CDIF record established for continuous testing at the CDIF was achieved February 6, 1990, with 12 hours 50 minutes coal burn time and 12 hours 36 minutes of continuous power run time.

TEST HARDWARE SUPPORT ACTIVITIES

During the last year, several test hardware activities, in support of the test program have been accomplished. These activities, as agreed upon with the TRW and AVCO vendor representatives have included the following significant accomplishments:

- Completed the CFC modification as specified by TRW to enhance first-stage reliability and lower heat loss and to alter second-stage oxygen injection configurations with minimal impact on test schedule.

- Completed installation and checkout of the newly installed, AVCO-supplied current controls and prepared for MHD testing in conjunction with the units.

- Continued a program of 1A channel refurbishment, fabrication, and assembly necessary to support testing at the CDIF.

- Initiated the supporting designs to install the TRW-supplied continuous slag rejection system and the MSE-designed slag removal system.

- Supported developmental projects that included the MSE nozzle and various components designed to support diagnostic measurements of the plasma.

TRW Combustor Modifications

Following the checkout of the new CFPC, which was completed in the fall of 1989, the combustor, configured with a smooth-walled air inlet filler section was used to continue the testing program. During this time, the TRW second stage was configured with oxidizer injection ports located at an L/H ratio of 0.7 and 2.7. The 0.7 L/H provided oxidizer injection options of 12-port vertical, 8-port horizontal, and 20-port injection. The 2.7 L/H ratio provided oxidizer injection options of 8-port vertical, 12-port horizontal, and 20-port. This combustor was used for testing until February 1990 when a shutdown began.

During the shutdown, refurbishment of the combustor resulted in a new baffle, a refurbished exit endplate, and removal of the coal adapter and replacement with a hot sleeve. Also, the second-stage was reconfigured to obtain oxidizing capabilities at three locations. The three locations enable oxidizer to be added at L/H ratios of 0.8, 1.9, and 2.7, and are capable of 12-port horizontal, 8-port vertical, or 20-port mixing. New frames were also added to the second stage to test new materials for prototypical applications. Figure 4 shows the second stage and the arrangements of the alternative configurations.

Current Control Installation and Checkout

Four AVCO-supplied current control cabinets were recently installed at the CDIF. Checkout testing and electrical configuration wiring were completed for MHD testing, which is scheduled to resume in May 1990.

Channel Refurbishment, Fabrication, and Assembly

On July 19, 1989, the channel identified as the $1A_1$-C1 channel was placed into test service. With the exception of the forward anode wall section and the two cathode wall sections, (each which had 7 hours 40 minutes of power generation service) the channel was in new condition. This channel was the first one that contained all components that had been manufactured and assembled by MSE. On February 12, 1990, the channel was removed from test service because of internal water leaks on peg sidewalls and electrical arc burning of the G-9 frame material. While in service, the $1A_1$-C1 channel accumulated a total of 125 hours 32 minutes of coal combustion service and 77 hours 59 minutes of electrical power generation time. Total energy generated during this period was 96.5 MWhr. The anode wall (wall sections 25 and 26) was severely damaged by this test service and has been scrapped.

During the testing of the $1A_1$-C1 channel, MSE fabricated and assembled the $1A_1$-C2 channel, which was to consist of the following wall sections:

anode wall sections 33 and 34,
cathode wall sections 27 and 28,
right sidewall sections 37 and 22, and
left sidewall sections 39 and 48.

However, in February 1990, it was decided by the integrated topping cycle (ITC) contractor that the next series of tests would be materials related. The next channel to be put into test service (in May 1990) would contain components that would be prototypic in design and would include the new 0.7-inch electrode pitch. Test electrodes were placed on the anode and cathode and left sidewall. This Materials Test Channel, scheduled for May 1990 test service, was comprised of the following wall sections:

anode wall sections 33 and 34 -- new
cathode wall sections 19 and 20 -- 85 hrs 36 min electrical
right forward peg sidewall 37 -- new
right aft diagonal sidewall 30 -- 77 hrs 56 min electrical
left forward diagonal sidewall 31 -- new
left aft diagonal sidewall 32 -- 77 hrs 56 min electrical

A list of all the 1A channels wall segments that were available for test service as of April 1, 1990, are shown in Table 2, along with their hours of test service.

Slag Rejection and Removal System Installation

The project to install the TRW slag rejection test equipment and the MSE-designed slag removal system was initiated. Design packages for the installation were completed. The hardware will be installed in phases to minimize test interruption. Between phases, the newly installed equipment will be used as batch slag containers, much the same as the previous equipment was used. The last phase, scheduled to occur in the fall of 1990, will tie all of the equipment together to finalize installation of the continuous slag rejection and removal system.

Development Projects

The MSE designed and fabricated nozzle was placed in test service in January 1988. Since that time, it has experienced 234 hours 37 minutes of coal combustion time and 114 hours 3 minutes of electrical power generation time. The exit end of the nozzle is now starting to show some deterioration (see Figure

5). As can be seen from Figure 5, there has been some cracking and erosion of the capping material (type 446 stainless steel). This type of cracking is typical of a ferrous material that is experiencing carburization/sulfidation. However, the cracking is not serious because it does not extend beyond the cap. The amount of erosion that was observed on the cap indicates that the life of the nozzle should be in excess of 500 thermal hours.

After MHD test 90-DIAG-13, the nozzle was partially disassembled and two materials test coupons (bar elements) were placed at the exit end on the bottom. The coupons were supplied by AVCO and consisted of a solid molybdenum element and a tungsten capping on copper element.

MSE has designed and fabricated two devices that allow instrumentation to be attached to the test train to perform diagnostic measurements on the plasma. The devices are the post-nozzle test section, which is attached to the outlet of the second-stage nozzle, and the diffuser triple port walls, which are located horizontally in the forward subsonic section. In the past, these components have been used by Mississippi State University (MSU) to accommodate their diagnostic equipment.

During the year, the portal size of the triple port walls was reduced from 3 inches in diameter to 2 inches in diameter in an effort to improve the nitrogen purge efficiency of these walls. Figure 6 is a photograph of the modified portal. The modified wall sections were placed into test service in May 1990.

PLANT SUPPORT SYSTEM ACTIVITIES

Major improvements in plant system operation yielded longer duration tests and higher quality experimental data. Many plant activities improved system reliability while others satisfied changing requirements of the test program. Major improvements in plant system operations are listed below:

- completed temporary modification to the coal system to support fine coal testing;
- completed various improvements to the coal system for enhanced operation;
- installed a new, permanent solid suspension injection system to support testing; and
- initiated modifications to the stack gas analysis system.

Fine Coal Testing Support

Temporary modifications were made to the coal system to mix and inject coal fines that are normally removed by the baghouse for MHD testing of fine coal. These temporary modifications proved the ability of the injection system to handle fine coal as it naturally occurs during the grinding process of the final coal product.

Coal System Improvements

Numerous improvements were made in the coal system to enhance operation. A new type of flow control valve was installed for the CFPC pinch valve. Sleeve life of this new pinch valve is projected to match that of the first-stage coal pinch valve.

A screen was installed in the coal primary injector to trap particles capable of plugging the CFPC pinch valve. Since the screen was installed, the CFPC pinch valve has not plugged, and inspections of the screen have shown it traps particles that could have plugged the valve.

To support duration test efforts, steps were taken to accomplish on-line coal processing during MHD testing. Prior to the effort, test duration was limited by the batch coal capacity.

The coal filter receiver was recently replaced because the original equipment was undersized and damaged. Timely replacement during a testing shutdown provided the opportunity for installation without interference to the test program.

Permanent Solid Suspension Injection System

The solid suspension injection system was designed to mix, store, and inject slurry additives into the test train. The current slurry, a 50/50 percent by weight mixture of iron oxide and gear oil is being added to mitigate the effects of erosion caused by interelectrode shorting. The new, permanent system was installed in the fall of 1989, replacing a temporary system used in the initial investigation of the effects of iron oxide on channel longevity. Flow rates for the new system are from 2 to 8 lbs per minute slurry. Figure 7 shows the configuration of the system. Following the initial installation, a mix/storage tank was added for increased capacity for duration testing.

Initial operation used a slurry of agricultural-grade iron oxide; however, particles of silica and grinding media found in the material caused system failures. An upgrade to pigment-grade iron oxide rectified the failures. Additionally, recent additions of CAB-O-SIL at 0.25 percent by weight have curtailed the iron oxide from falling out of suspension. Since the beginning of calendar year 1990, these changes have been in effect, and system dependability has increased. The final hurdle to be overcome involves occasional plugged iron oxide injectors at the channel.

Stack Gas Analysis System Enhancements

The thermoelectron wet gas analysis system was modified and became operable for SO_2, CO and NO_x monitoring.

A new stack gas analysis facility and a compressed gas storage facility are being designed. Construction is scheduled to be complete in the fall of 1990. This new facility will provide permanent facilities for analysis and also adds some automation and expanded capabilities to the process. The new facilities will include a programmable logic controller.

Two additional modifications to enhance stack gas data collection include an autosampler for the gas chromatograph and a remote calibration manifold. The autosampler for the gas chromatograph will change the mode of operation from batch to continuous.

FUTURE PLANS AT THE CDIF

Long-term plans at the CDIF include a new DAS and additional liquid oxygen storage. Support for the prototypic hardware installation is also planned. All activities are scheduled to occur in the early 1990s.

Testing with the workhorse hardware will continue until the arrival of the prototypic test hardware. To support this requirement, a total of 15 new channel wall sections will be fabricated and assembled by MSE. Additional wall sections will be refurbished and reassembled peg sidewalls.

REFERENCES

1. Glovan, R.J., "Status Report of 1A Test Train Hardware Performance and Development," 27th SEAM Conference, Reno, NV, June 1989.

ACKNOWLEDGEMENT

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TABLE 1 -- 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
7/25/89	89-CFC-14	1) Demonstrate functional performance of seed and iron oxide slurry systems and consumable process flow delivery into the combustor before conductivity and power testing. 2) Continue to establish baseline fouling condition for redesigned, smooth-walled filler assembly at nominal stoichiometry. Evaluate dependence of individual filler panel heat loss on fouling condition. 3) Obtain baseline heat flux data for second-stage individual frames and the entire CFC at nominal power operating conditions. 4) Achieve smooth startup and shutdown and maintain combined-stage operation at 50 MWt for a minimum duration of 7 hours, consumables limiting. Operation will vary N/O (global) from 0.76 to 0.70. 5) Obtain baseline stack gas emission data for carbon closure prior to power conditions. 6) Continue evaluating additional system variables including oil burner performance, filler heat flux, refractory performance, and sleeve heat flux. 7) Provide thermal test of rebuilt channel and obtain channel operation heat flux and channel pressure data. 8) Support MSU diagnostic equipment measurement.	02:25	N/A	N/A	N/A	Test objectives were partially met. Startups were smooth, and systems generally operated well. However, incorrect slag tank thermocouple readings for vent line coolant temperatures resulted in the hose overheating and melting. Shutdown of the test was required for repair.
8/10/89	89-CFC-15	Initially: 1) Verify the ability of the coal system to flow coal to the CFPC. Subsequently: 1) Accomplish initial testing of the channel in conjunction with the CFPC for both plasma conductivity measurement and power generation operations. 2) Evaluate the performance of power take-off current consolidation circuits. 3) Obtain baseline heat flux and power data with N/O = 0.70; Phi 1 = 0.55; Phi 2 = 0.90, 0.95, 1.00, and 1.05 (without iron oxide); and mixing of L/H = 2.7. 4) Continue evaluation of the filler section fouling, plant systems operation, and CFPC flame stability using the flame detector. 5) Support MSU diagnostic equipment measurements.	05:00	4.42	1.430	4:12	Test objectives were partially met. Combustor startup was smooth. As the test continued, several operational problems were discovered that required post-test evaluation, including the CFPC coal flow, the conductivity power supply, the seed flow, and the iron oxide slurry flow. For the first time, the new power take-off configurations were checked and appeared to work well. After the test, an internal inspection of the channel revealed a low-level leak at anode 56; therefore, the channel was converted to low-pressure cooling so testing could continue without having to remove the channel for repair. Testing was shutdown when adequate seed flow could not be maintained.

TABLE 1 -- MHD TESTS (CONT'D)

DATE	TEST NO.	TEST OBJECTIVES	COAL BURN TIME (hr min)	ENERGY GENERATED (KW hr)	PEAK POWER (MWe)	POWER RUN TIME (hr min)	COMMENTS
8/16/89	89-DIAG-6	1) Obtain baseline heat flux and power data with N/O = 0.70; Phi 1 = 0.55, 0.53, and 0.50; Phi 2 = 0.90, 0.95, 1.00, and 1.05; mixing of L/H = 2.7; 12-port horizontal oxygen injection. 2) Continue evaluation of the filler section fouling, plant systems operation, and CFPC flame stability using the flame detector. 3) Support MSU diagnostic equipment measurements. 4) (Optional) Evaluate reduced CFPC flame temperature operations.	06:22	N/A	N/A	N/A	Test objectives were met. Systems generally operated well. Although somewhat erratic early in the test, coal flow was maintained at the requested flow rate during the power portion of the test. Iron oxide slurry injection on the cathode worked well.
09/06/89	89-DIAG-9	1) Obtain baseline heat flux and power data with N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, mixing of L/H = 2.7, 12-port horizontal oxygen injection; varied iron oxide injection on cathode wall, and varied seed flow rates. 2) Continue evaluation of the filler section fouling, plant systems operation and CFPC flame stability using the flame detector. 3) (Optional) Evaluate seed velocity considerations at L/H = 2.7. 4) (Optional) Evaluate reduced CFPC flame temperature operations	05:04	3.72	1.89	03:54	Test objectives were partially met. All systems operated well. For the first time, coal was processed on-line during this test. The processing went well, and newly processed coal was used during the test. This sequence was planned to check out some aspects that are required for the upcoming 16- to 24-hour test. A new record peak power level--1.89 MWe--was achieved during this test.
9/18/89	89-REST-1	1) Checkout the wiring of the aft power take-off in the resistively consolidated configuration. 2) Obtained reduced CFPC flame temperature startup heat flux data. 3) Determine maximum seed flow rate.	01:02	02.24	1.07	00:33	Test objectives were met. All systems and the reduced flame temperature startup operated well. The repaired conductivity power supply was checked out. Wiring anomalies were noted in the resistively consolidated configuration and will be repaired before the next test.
09/20/89	89-DIAG-11	1) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, mixing of L/H = 2.7, 12-port horizontal oxygen injection, and varied iron oxide injection on cathode wall. 2) Obtain reduced CFPC flame temperature startup heat flux data. 3) Continue evaluation of the filler section fouling, plant systems operation, and CFPC flame stability using the flame detector. 4) Support MSU diagnostic equipment measurements. 5) (Optional) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, mixing of L/H = 2.7 12-port horizontal oxygen, and varied seed flow rates. 6) (Optional) Evaluate seed velocity considerations at L/H = 2.7. 7) (Optional) Obtain Phi sweep data at reduced CFPC flame temperature operations. 8) (Optional) Evaluate iron oxide injection on the anode wall. 9) (Optional) Obtain baseline data at N/O = 0.80.	06:21	6.88	1.74	05:01	Test objectives were partially met. All systems operated well with the exception of the seed system. Iron oxide was run for a five-hour duration with no noticeable decrease in power output.
9/28/89	89-DIAG-12	1) Obtain heat flux, conductivity, and power data with varied iron oxide flow rates on the cathode wall and the anode wall.	05:31	2.46	1.89	02:35	Test objectives were partially met. All systems operated well with the exception of the seed system. Seed flow rates were not consistent and will be investigated before further testing.

TABLE 1 -- 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
9/28/89	89-01AG-12	2) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95; mixing of L/H = 2.7, 12-port horizontal oxygen injection, and iron oxide injection on cathode wall. 3) Obtain reduced flame temperature startup heat flux data. 4) Continue evaluation of the filler section fouling, plant systems operation, and CFPC flame stability using the flame detector. 5) Support MSU diagnostic equipment measurements. 6) (Optional) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, mixing of L/H = 2.7, 12-port horizontal oxygen, and varied seed flow rates. 7) (Optional) Evaluate seed velocity considerations at L/H = 2.7. 8) (Optional) Obtain Phi sweep data at reduced CFPC flame temperature operations. 9) (Optional) Obtain data at increased N/O ratios and L/H = 2.7. 10) (Optional) Evaluate increased iron oxide injection on the cathode wall.					
10/05/89	90-01AG-1	1) Obtain heat flux, conductivity, and power data with varied iron oxide flow rates on the cathode wall and the anode wall. 2) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, and Phi 2 = 0.95, mixing of L/H = 2.7, 12-port horizontal oxygen injection, and iron oxide injection on the cathode wall. 3) Obtain reduced flame temperature startup heat flux data. 4) Continue evaluation of filler section fouling, plant systems operation, and CFPC flame stability using the flame detector. 5) Support MSU diagnostic equipment measurements. 6) (Optional) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, mixing of L/H = 2.7, 12-port horizontal injection oxygen, and varied seed flow rates. 7) (Optional) Evaluate seed velocity considerations at L/H = 2.7. 8) (Optional) Obtain Phi sweep data at reduced CFPC flame temperature operations. 9) (Optional) Obtain data at increased N/O ratios and L/H = 2.7.	6:36	6.49	1.80	04:09	Test objectives were met. Test startup was smooth, and the systems operated well. A reduced flame temperature startup resulted in CFPC heat fluxes remaining low at the startup. Seed flow consistency was improved from previous tests. Shutdown was required when the oxygen supply was depleted.
10/13/89	90-01AG-2	1) Obtain heat flux, conductivity, and power data with varied iron oxide flow rates on the cathode and anode wall. 2) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, and Phi 2 = 0.95, mixing of L/H = 2.7, 12-port horizontal oxygen injection, and iron oxide injection on the cathode wall. 3) Obtain reduced flame temperature startup heat flux data.	07:13	5.05	1.66	03:39	Test objectives were partially met. The larger seed particles recently included in seed deliveries were causing seed flow difficulties. During the test, procedures for flowing the larger seed were developed. Varied iron oxide additions on the anode and cathode walls were tested. Shutdown was required when the combustor was brought to a reduced thermal throughput to conserve consumables until troubleshooting of an inverter problem could be done. The reduced CFPC coal flow for the lower thermal throughput could not be maintained, and the combustor tripped. Inverter troubleshooting was not complete, and the test was shutdown.

TABLE 1 -- 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
10/13/89	90-DIAG-2	4) Continue evaluation of filler section fouling, plant systems operation, and CFPC flame stability using the flame detector. 5) (Optional) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, mixing of L/H = 2.7, 12-port horizontal oxygen, and varied seed flow rates. 6) (Optional) Evaluate seed velocity considerations at L/H = 2.7. 7) (Optional) Obtain Phi sweep data at reduced CFPC flame temperature operations. 8) (Optional) Obtain data at increased N/O ratios and L/H = 2.7. 9) (Optional) Obtain load sweep data using increased seed flow rate.					
10/24/89	90-DIAG-3	1) Obtain heat flux, conductivity, and power data with steady-state combustor operations, cathode iron oxide flow rates, and varied anode iron oxide flow rates. 2) Obtain conductivity and power data at both 1.75 and 2.25 percent potassium 3) Obtain long-duration evaluation in support of the proof-of-concept prototypic design review as follows: a. CFPC filler section fouling; b. plant systems operation; and c. channel performance. 4) Support MSU diagnostic equipment measurements.	06:59	4.06	1.84	02:42	Test objectives were partially met. Other than the failed items requiring immediate repair, the plant systems operated well. Process flows were stable. Testing was shutdown when the magnet power supply tripped, and troubleshooting efforts revealed no quick repair method. Although the duration objective was not accomplished, data to support other objectives was gathered.
10/26/89	90-DIAG-4	1) Obtain heat flux, conductivity, and power data with steady-state combustor operations, cathode iron oxide flow rates, and varied anode iron oxide flow rates. 2) Obtain conductivity and power data at both 1.75 and 2.25 percent potassium 3) Obtain long-duration evaluation in support of the proof-of-concept prototypic design review as follows: a. CFPC filler section fouling; b. plant systems operation; and c. channel performance. 4) Support MSU diagnostic equipment measurements. Subsequently: 1) (Optional) Obtain baseline heat flux, conductivity, and power data with N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, mixing of L/H = 2.7, 12-port horizontal oxygen injection, and varied seed flow rates. 2) (Optional) Obtain data at increased N/O ratios and L/H = 2.7.	06:17	6.16	1.86	04:08	Test objectives were partially met. Midway through the test, consumables were depleted to the level that a duration test could no longer be accomplished. Because the staff and consumables were available, it was decided to continue testing. Two optional test objectives were addressed. Other than the failed items requiring immediate on-line repair, the plant systems operated well. Process flows were stable.
11/08/89	90-DIAG-5	1) Obtain heat flux, conductivity, and power data with second-stage mixing ratio L/H = 0.7, and 12-port vertical oxygen injection at nominal oil-fired vitiator peak power conditions (N/O = 0.70, Phi 1 = 0.55, Phi 2 = 1.00, and potassium = 1.50 percent). 2) Obtain heat flux, conductivity, and power data with second-stage mixing ratio L/H = 0.7, 12-port vertical oxygen injection, at Phi 2 = 0.95, and potassium = 2.00 percent.	05:35	3.84	1.76	02:48	Test objectives were partially met. Main-stage coal flow problems were encountered when coal flow could not be delivered at the desired rate. The decreased coal flow was attributed to a plugged screen in the primary injector. Primary injector pressure was raised throughout the test, and as the screen plugged more, the necessary pressure for maintaining flow was too high to allow coal transfers. Testing was shutdown when coal transfers were no longer possible.

TABLE 1 -- 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
11/08/89	90-DIAG-5	3) (Optional) Obtain heat flux, conductivity, and power data with second-stage mixing ratio L/H = 0.7, 12-port vertical oxygen injection at varied seed flow rates to determine seed utilization.					
		4) (Optional) Evaluate seed velocity considerations at L/H = 0.7.					
		5) (Optional) Obtain power and conductivity data with L/H = 0.7, at increased N/O.					
11/15/89	90-DIAG-6	1) Obtain heat flux, conductivity, and power data for steady-state combustor operation with iron oxide on the cathode and anode walls using a second-stage mixing ratio of L/H = 2.7 with 10-port nonimpinging oxygen injection (N/O = 0.75, Phi 1 = 0.56, Phi 2 = 0.95, and potassium = 1.75 percent).	07:50	2.89	1.52	02:58	Test objectives were partially met. The plant systems operated well, and coal and seed flows were stable. Although the duration objective was not accomplished, data to support other objectives were gathered. Open circuits on the anode wall appeared and disappeared during the course of testing. When troubleshooting of this problem required opening the magnet and consumables were depleted to the point that the duration test objectives could not be accomplished, testing was shutdown. Post-test inspection of the anode wall electrical connections revealed widespread failures, which were repaired before the next test.
		2) Obtain heat flux, conductivity, and power data at Phi 1 = 0.54 and N/O = 0.75.					
		3) Obtain long-duration evaluation in support of proof-of-concept prototypic design review as follows: a. CFPC filter section fouling; b. plant systems operation; and c. channel performance.					
		4) (Optional) Obtain heat flux, conductivity, and power data with second-stage mixing ratio L/H = 2.7 with 10-port nonimpinging oxygen injection at varied seed flow rates to determine seed utilization.					
		5) (Optional) Obtain decreased N/O conductivity and power data at L/H = 2.7 with 10-port nonimpinging oxygen injection.					
11/21/89	90-COAL-1	1) Obtain heat flux, conductivity, and slag rejection data with CDIF baghouse coal fines reintroduced into the normal coal product used for testing at the CDIF; the fines were reintroduced at a 15 to 20 percent mix of fines. Testing with second-stage mixing ratio of L/H = 2.7 and 10-port horizontal oxygen injection (N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, and potassium = 1.75 percent).	02:16	1.76	1.73	01:21	Test objectives were met. All plant systems operated well. Coal flow to the combustor with the coal fines introduced posed no flow problems. The test was shutdown with a soft shutdown when the fine coal mixture developed for the test was depleted.
11/30/89	90-ELEC-1	1) Obtain voltage spike data as requested by AVCO to aid in current control/inverter troubleshooting.	01:52	0.0002	0.05	00:03	Test objectives were partially met. Many of the plant systems operated well. Coal flow and seed flow from the blue vessel were stable. The inverter rectification data was collected; however, the rest of the data could not be collected because the magnet power supply would not operate. Testing was shutdown when all rectification data had been collected.
		2) Obtain heat flux and power data with steady-state combustor operation and iron oxide on the cathode wall for a second-stage mixing ratio of L/H = 2.7 20-port (12 horizontal and 8 vertical) oxygen injectors, and with 0.25-inch inside diameter injectors (N/O = 0.70, Phi 1 = 0.55, Phi 2 = 0.95, and potassium = 1.00 and 1.75 percent).					
12/01/89	90-ELEC-2	1) Same as 90-ELEC-1.	02:59	1.64	1.57	02:04	Test objectives were partially met. The plant systems operated well, and coal flows were stable. The seed system failure, which shutdown the test, was attributed to the low requested seed flow. However, seed flow from the blue vessel was stable, however, at seed flows of 1.0 percent potassium and above.

TABLE 1 -- 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
12/12/89	90-01AG-7	1) Obtain heat flux, conductivity, and power data with steady-state combustor operation and iron oxide on the cathode and anode walls configured with 90 percent O_2, 10 percent N_2 oxidizer in the second-stage, a mixing ratio of L/H = 2.7, and 12-port horizontal oxygen injection (N/O = 0.75, Phi 1 =0.55, and Phi 2 = 0.95).	07:50	4.25	1.71	03:27	Test objectives were partially met. With the exception of the magnet power supply, the plant systems operated well. Process flows were stable. When the magnet power supply failed to restart, conductivity data was collected at the N/O level of 0.75 with a second-stage oxidizer stream composition of 80 percent O_2 and 20 percent N_2. Testing was shutdown when the magnet power supply failed to restart.
		2) (Optional) Obtain increased N/O conductivity and power data at L/H = 2.7 and 12-port horizontal oxygen injection (N/O = 0.80, 80 percent O_2, 20 percent N_2 oxidizer in the second stage).					
		3) (Optional) Obtain decreased N/O conductivity and power data at L/H = 2.7 with 12-port horizontal oxygen injection.					
		4) (Optional) Obtain data for N/O increase in the first stage at the same operating conditions or increase N/O to 0.80 in the second stage.					
		5) (Optional) Obtain low thermal (30 MW) operation heat flux, conductivity, and power data.					
12/19/89	90-01AG-8	1) Obtain heat flux, conductivity, and power data with fine seed by breaking the seed using eight in-line elbows prior to injection into the CFC with normal-sized seed.	02:47	1.28	1.60	01:03	Test objectives were partially met. Testing was shutdown when the solid suspension injection system, which is used to inject iron oxide slurry, failed. Because of the high intercathode voltages, the test could not continue without the iron oxide because of risk of channel damage.
		2) Obtain heat flux, conductivity, and power data with steady-state combustor operation and iron oxide on the cathode and anode walls. The second stage is configured with 90 percent O_2 and 10 percent N_2 oxidizer with a mixing ratio of L/H = 2.7, 12-port (0.30-inch inside diameter injectors installed), and horizontal oxygen injection (N/O = 0.70 and 1.75, Phi = 0.55, and Phi 2 = 0.90 and 0.95).					
		3) (Optional) Anode iron oxide variations during steady-state conditions.					
		4) (Optional) Obtain data for N/O increase in the first stage at same operating conditions.					
		5) (Optional) Obtain low thermal (30 MW) operation heat flux, conductivity, and power data.					
1/18/90	90-01AG-10	1) Obtain heat flux and power data with fine seed by breaking the normal-sized seed material using eight in-line elbows prior to injection into the CFC.	03:07	1.92	1.58	02:11	Test objectives were partially met. Test startup was smooth. When power conditions were achieved, it was determined that some of the iron oxide injectors were plugged. When one anode and one cathode injector were unplugged, the magnet power supply would not respond for restart.
		2) Obtain heat flux and power data with steady-state combustor operation and iron oxide injection on the cathode and anode walls. The second-stage is configured with 90 percent O_2 and 10 percent N_2 oxidizer with a mixing ratio of L/H = 2.7, 12-port (0.30-inch ID injectors installed) horizontal oxygen injection, and N/O = 0.70 and 0.75, Phi 1 = 0.55, and Phi 2 = 0.90 and 0.95.					
		3) (Optional) Anode iron oxide variations during steady-state conditions.					
		4) (Optional) Obtain data for N/O increase in the first-stage at the same operating conditions.					
		5) (Optional) Obtain low thermal (30 MW) operation heat flux, conductivity, and power data.					

TABLE 1 -- 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
1/19/90	90-DIAG-11	1) Obtain heat flux and power data with steady-state combustor operation and iron oxide injection on the cathode and anode walls. The second stage is configured with a mixing ratio of L/H = 2.7, 12-port (0.30-inch inside diameter injectors installed) horizontal oxygen injection, and N/O = 0.70 and 0.75, Phi 1 = 0.55, and Phi 2 = 0.90 and 0.95. 2) (Optional) Anode iron oxide variations during steady-state conditions. 3) (Optional) Obtain data for N/O increase in the first-stage, at same operating conditions. 4) (Optional) Obtain low thermal (30 MW) operation heat flux, conductivity, and power data. 5) (Optional) Obtain heat flux and power data with fine seed by breaking normal-sized seed using eight in-line elbows prior to injection into the CFC.	04:29	4.10	1.54	03:38	Test objectives were partially met. Test startup was smooth. After steady state was achieved, the magnet tripped, was restored, and after achieving steady state again, the inverter tripped. Process flows were stable. Iron oxide flow experienced no problems using the pigment-grade rust. Testing was secured when the inverter would not restart.
1/23/90	90-DIAG-12	1) Obtain heat flux and power data with steady-state combustor operation and iron oxide injection on the cathode and anode walls. The second stage is configured with 90 percent O_2, 10 percent N_2 oxidizer with a mixing ratio of L/H = 2.7, 12-port (0.30-inch inside diameter injectors installed) horizontal oxygen injection, and N/O = 0.70, Phi 1 = 0.55, and Phi 2 = 0.95. 2) (Optional) Anode iron oxide variations during steady-state conditions.	09:42	11.75	1.69	09:04	Test objectives were partially met. Plant systems operated well, and process flows were stable until near the end of the test. The iron oxide system experienced no problems using the pigment-grade rust. Post-test inspection did show that one injection tube was plugged. An external channel hose leak required shutdown of the test. This test exceeded the previous continuous test duration records with 9 hours 42 minutes coal burn time and 8 hours 26 minutes of continuous power run time. The previous records were set October 2, 1986, and were 8 hours 29 minutes of coal-fired MHD testing and 7 hours 10 minutes of power production.
02/06/90	90-DIAG-13	1) Obtain long-duration electrical power data with steady-state combustor operation and iron oxide injection on the cathode wall. The second stage is configured with a mixing ratio of L/H = 2.7, 12-port (0.363-inch inside diameter) horizontal oxygen injection. Operating conditions are N/O = 0.70, Phi 1 = 0.55, and Phi 2 = 0.90 and 1.75 percent potassium. 2) (Optional) Obtain heat flux, conductivity, and power data with 90percent O_2 and 10 percent N_2 in the second-stage at Phi 1 = 0.55, Phi 2 = 0.90, and N/O = 0.75.	12:50	16.49	1.65	12:36	Plant systems operated well, and process flows were stable. The iron oxide system experienced no problems using the pigment-grade rust and a single-pump-to-single-injector configuration. The test was shutdown with a manual emergency shutdown to freeze the slag layer on the channel walls. A minor pre-existing leak in the channel was noted and evidence of arcing was also present on the electrical lug of anode 279; the channel will be pulled for repair. This test exceeded the previous continuous test duration records with 12 hours 50 minutes coal burn time and 12 hours 36 minutes of continuous power run time. The previous records were set during the last test and were 9 hours 42 minutes of coal-fired MHD testing and 8 hours 26 minutes of power production.

TABLE 2 -- CHANNEL WALL SECTIONS AVAILABLE FOR TEST SERVICE (APRIL 1, 1990)

Wall Section Number	Description	Coal Hours	Power Hours
17	Forward Pt Capped Anode	20:20	9:00
18	Aft Pt Capped Anode	0	0
19	Forward Cathode	142:54	85:36
20	Aft Anode	142:54	85:36
30	Right Aft Diagonal Sidewall	125:31	77:56
32	Left Aft Diagonal Sidewall	125:31	77:56
22	Right Aft Peg Sidewall	0	0
27	Forward Cathode	0	0
28	Aft Cathode	0	0
31	Left Forward Diagonal Sidewall	0	0
33	Forward 446 Capped Anode	0	0
34	Aft 446 Capped Anode	0	0
37	Right Forward Peg Sidewall	0	0
39	Left Forward Peg Sidewall	0	0

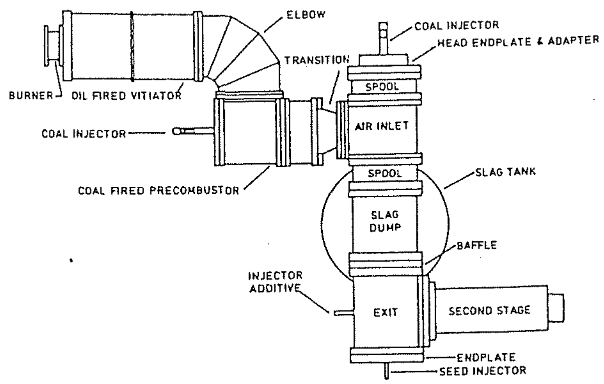

FIGURE 1 -- 50-MW$_t$ CFC IN CURRENT TEST CONFIGURATION

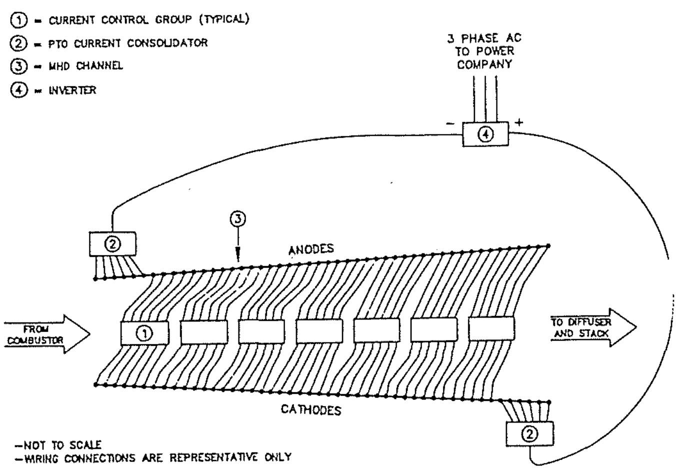

FIGURE 2 -- ARRANGEMENT OF CURRENT CONTROLS IN CONJUNCTION WITH THE CHANNEL

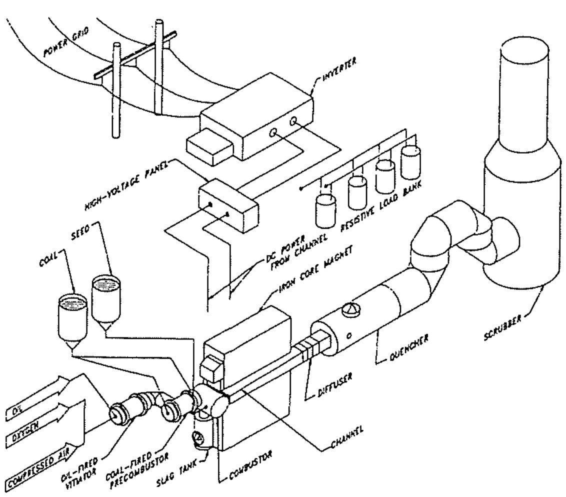

FIGURE 3 -- CDIF TEST TRAIN SUPPORT SYSTEMS

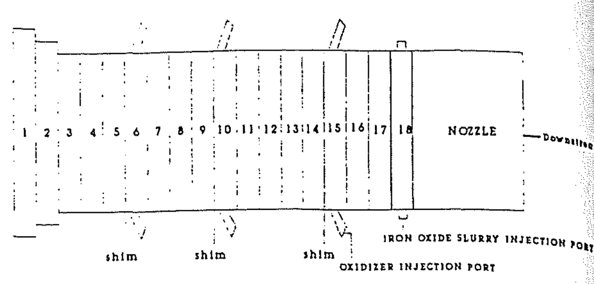

FIGURE 4 -- CFC SECOND-STAGE CONFIGURATION

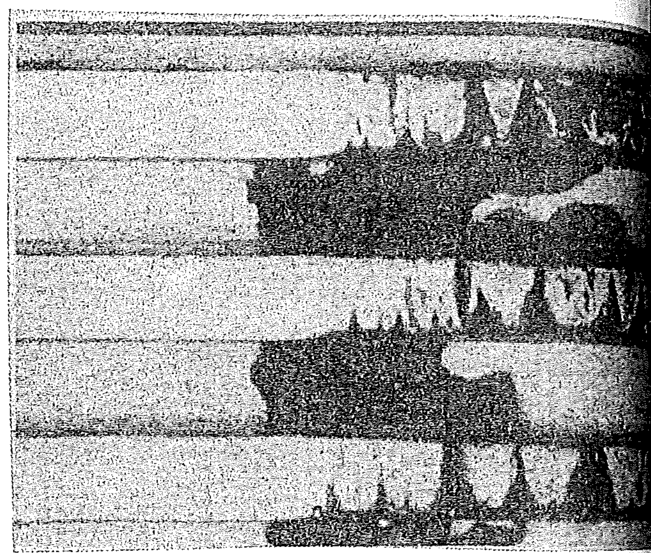

FIGURE 5 -- PART OF A BAR FROM THE MSE NOZZLE. THE PHOTOGRAPH SHOWS A PORTION OF AN EXPOSED AREA (RIGHT SIDE) AND AN ADJACENT UNEXPOSED AREA. FLOW IS FROM BOTTOM TO TOP.

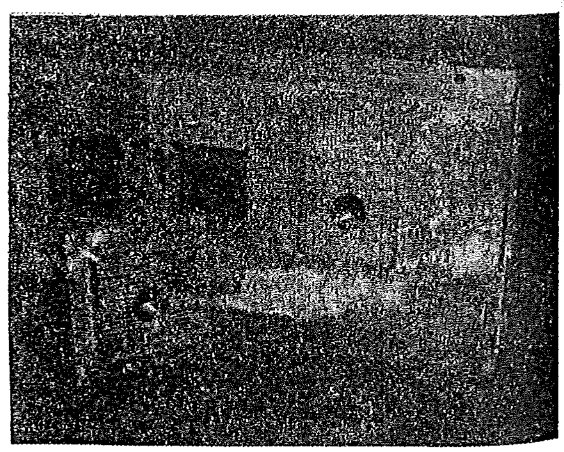

FIGURE 6 -- VIEW OF A TRIPLE PORT DIFFUSER WALL SHOWING THE RECENTLY FABRICATED 2-INCH DIAMETER INSERTS THAT REPLACED THE 3-INCH DIAMETER OPENINGS.

FIGURE 7

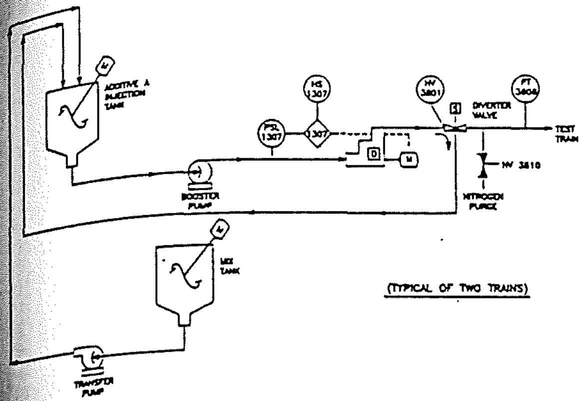

FIGURE 7 -- CONFIGURATION OF THE PERMANENT SOLID SUSPENSION INJECTION SYSTEM