3/6
8/3/81
Eh

(2)

NTIS-25
Bms-218

D. 2892

DOE/ET/10790-T1

MASTER

MHD GENERATOR COMPONENT DEVELOPMENT

Quarterly Report, July–September 1980

November 1980

Work Performed Under Contract No. AC01-77ET10790

Avco Everett Research Laboratory, Inc.
Everett, Massachusetts

U. S. DEPARTMENT OF ENERGY

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

"This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A04
Microfiche A01

MHD GENERATOR COMPONENT DEVELOPMENT
Quarterly Report for July 1980 - Sept. 1980

AVCO EVERETT RESEARCH LABORATORY, INC.
a Subsidiary of Avco Corporation
2385 Revere Beach Parkway
Everett, Massachusetts 02149

November 1980

prepared for
U.S. DEPARTMENT OF ENERGY
Contract No. EF-77-C-01-2519

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
	List of Illustrations	iv
1.0	PROGRAM OBJECTIVES AND SCOPE OF WORK	1
2.0	SUMMARY OF PROGRESS TO DATE	5
3.0	CDIF RELATED HARDWARE	7
3.1	CDIF Generator 1B ₂ , Task C	7
3.1.1	Background	7
3.1.2	Status	7
3.1.3	Electrode Design	9

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
2-1	Program Performance Schedule	6
3-1	CDIF 1B ₂ Channel Schedule	8
3-2	CDIF 1B ₂ Channel Assembly	11
3-3	Sectional Detail of Peg Wall	12
3-4	Pegs in Assembly Fixture	13
3-5	Pegs in Assembly Fixture	14
3-6	Complete Peg Row in Assembly Fixture	15
3-7	Hydrostatic Testing of Assembled Peg Row	16
3-8	Installation of Peg Row on Channel Wall	17
3-9	Installation of Peg Retaining Screws on Channel Wall	18
3-10	CDIF 1B ₂ Channel Electrode Design	19
3-11	Anode Erosion Data in High Sulfur Environment	21
3-12	1B ₂ Channel/SC Magnet Interface Layout	22

1.0 PROGRAM OBJECTIVES AND SCOPE OF WORK

The overall objectives of this program are the design, fabrication and delivery of test channels (nozzle, channel, diffuser, instrumentation and controls, and all necessary facility service connections) to the CDIF for MHD generator tests. These CDIF test channels will be driven by a coal combustor which is under development in parallel with this program. The program schedule has the following major milestones:

Deliver - Diagnostic Test Section to PERC-----January 1978

Deliver - Diagnostic Tst Section to CDIF-----April 1979

Deliver - 1st CDIF Test Channel-----October 1979

Deliver - 2nd CDIF Test Channel-----October 1980

Amendments to the contract resulted in the following actual CDIF hardware delivery schedule:

1A Ash Injected Combustor and Nozzle Sept. 78

1A1 MHD Channel/Diffuser March 79

The CDIF diagnostic test section was cancelled and the second CDIF channel, designated the 1B2, was slowed down to coincide with the facility construction schedule.

The overall program consists of a series of interrelated tasks whose individual requirements are the following:

Task A-1

Conduct basic engineering tests and perform necessary analytical work to define preferred design configuration of the CDIF channel in relation to fluid dynamics and electrodynamic performance.

Task A-2

Conduct basic engineering tests and perform necessary analytical work to define preferred electrode module design, sidewall construction, wall materials, and fabrication methods for a high performance, durable MHD channel.

Task A-3

Conduct basic engineering tests and perform necessary analytical work to define instrumentation and controls and preferred inverter systems and/or channel electrical controls in relation to inverter requirements and operating stability.

Task A-4

Determine basic performance capability of the disk generator design under conditions simulating an open cycle MHD plasma. Under such conditions, minimum performance goals are 15% enthalpy extraction at an isentropic efficiency of 60%.

Task A-5a

Maintain continuous design and engineering liaison with the Pittsburgh Energy Research Center (PERC) in the development of the two-stage CDIF coal combustor. Ensure design compatibility of the integrated combustor-generator system. Design, build, and deliver to PERC an instrumented test section to assist in the design and performance evaluation of the PERC subscale 5 MW(t) experimental combustor. Obtain quantitative chemical and physical data on relevant coal slags with the PERC experimental combustor.

Task A-5b

Conduct necessary bench tests to establish essential design information on fluid dynamic, heat transfer, and current transfer characteristics of selected MHD coal slags.

Task A-5c

Design, build, and deliver to the CDIF site an instrumented test section to assist in the initial test evaluation of the PERC CDIF combustor. This diagnostic section shall be capable of measuring plasma characteristics of first order importance to design considerations and performance of the generator.

Task B

Successively design, construct, and test two "reference design" channels of the Mark VI scale. Design will be based upon criteria determined through Tasks A-1 through A-3.

Task C

Design, construct, perform preliminary quality checks, and deliver the first and second CDIF test generator to the test site at Butte, Montana.

Design and prepare drawings and documentation for a scaled-up ash injection combustor suitable for initial checkout testing of the first and second CDIF generators. Fabricate and deliver an ash injection combustor to the CDIF.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

2.0 SUMMARY OF PROGRESS TO DATE

Program status and projected performance schedules are shown in Fig. 2-1. A task progress summary follows:

Task C - CDIF Related Hardware

The Data Package required for the Critical Design Review was completed and forwarded to DOE. Trial assembly of one peg wall section was initiated.

[illegible]

Fig. 2-1 Program Performance Schedule

3.0 CDIF RELATED HARDWARE

3.1 CDIF GENERATOR 1B₂, TASK C

3.1.1 Background

The B test cell of the CDIF will be equipped with a 6 T superconducting magnet to provide a test bed for long duration performance evaluation of MHD flow trains in the high interaction subsonic regime which may be typical of future large-scale commercial generators.

The CDIF 1B₂ generator, the first to be operated in the B test cell, incorporates those design features which will allow a detailed characterization of its operating regimes and performance, specifically, separable electrode and peg sidewalls and provision for adjustments in channel (and diffuser) loft. This design allows operation in the single load diagonal as well as in the Faraday mode.

Nondissipative electrode consolidation and current control circuitry for two terminal diagonal connection will be supplied as a separate deliverable item. These devices will be configured for operation with both the A and B series channels.

Initially, the 1B₂ channel will be driven by an ash-injected combustor but may later provide the initial coupling to the first CDIF coal combustor. Electrical loading of the 1B₂ can be provided by either the existing A cell resistive load bank (RLB) or a future EPRI-supplied dc/ac inverter.

Delivery of the 1B₂ flow train to the CDIF is scheduled for September 1982. A bar chart schedule of the channel/diffuser design, fabrication and assembly is shown in Fig. 3-1.

3.1.2 Status

Detail design and initiation of long lead procurement was authorized on January 4, 1980, with DOE approval of the preliminary design.

The Data Package (Dwg. #A643-4186) required for the critical Design Review was completed and forwarded to DOE on August 27. The CDR was subsequently scheduled for October 22.

J6854

Fig. 3-1 CDIF 1B₂ Channel Schedule

Table 3-1 reviews the major operating parameters and calculated performance characteristics of the $1B_2$ flow train when driven by either an AIC or a typical coal combustor.

Figure 3-2 is a cross section of the channel assembly with identification of the major elements of construction, and shows how the four separable channel walls are held together and sealed. The nonconducting insulator walls are made of copper pegs similar to those operated successfully in the Mk VI 500 hr duration test. Figure 3-3 is a detail of this construction. Trial assembly of one peg wall section was initiated in this period to determine the necessary fixturing and the proper sequence and technique for the assembly procedure.

Figures 3-4 through 3-6 are photos of the individual pegs of a peg row in a universal fixture used for assembly, pressure testing and installation of peg rows on the structural fiberglass channel wall. Figures 3-7 through 3-9 are photos of the testing and installation operations. Hydrostatic tests are conducted on each row both before and after installation on the wall.

3.1.3 Electrode Design

Recent experiments with Avco's Mk VI and Mk VII generators have resulted in some non-noble metal electrode cap designs which have moderately long life even in a high sulfur environment simulating coal combustion. The plain copper anodes proposed for the $1B_2$ channel in the PDR would meet the channel lifetime requirement of 100 hr when operated with low sulfur fuel oil. However, the proposed channel characterization test plan would require ~100 hr of operation and could result in a situation in which refurbishing of the channel might be necessary before any subsequent testing could be performed. The revised electrode designs will have a considerably greater life and will permit a prolonged and more flexible test program. For instance, it should be possible to complete the proposed test plan using the ash injection combustor and K_2CO_3 seed and then repeat the test plan using a coal combustor.

The new electrode designs are shown in Fig. 3-10.

Cathodes contain tungsten-copper reinforcement pieces positioned only on the upstream corner. This design provides better protection of the anodic surface without the high thermal stress associated with a full width cap. It also permits grooving the copper surface for slag retention. The boron nitride insulation extends to the gas surface to minimize interelectrode erosion from the local leakage currents in the cathode wall slag.

TABLE 3-1

CDIF 1B₂ OPERATING CHARACTERISTICS

<u>Combustor</u>	<u>#2 Oil</u>	<u>Rosebud Coal</u>
Total Mass Flow	10 kg/sec	10 kg/sec
Assumed Efficiency	0.9	0.9
Thermal Output	48.2 MW	47.5 MW { 35.5 - Coal 11.0 - Oil, 2900°F Vitiator 5.5 - 1200°F Oxidizer Preheat
Oxidizer N/O (Volume)	1.1	1.175
Stagnation Pressure	3.35 atm	3.31 atm
Stagnation Temperature	2820°F	2824°F
Seed	50/50 K ₂ CO ₃ +H ₂ O	50/50 K ₂ CO ₃ +H ₂ O
		<u>Fuel Oil</u> <u>N/O = 1.1</u>
<u>Channel (Diagonal)</u>		<u>Coal</u> <u>N/O = 1.175</u>
Inlet Mach Number		0.75
Inlet Area (cm ²)		472
Inlet Conductivity (mho/m)		10.3
Maximum Hall Parameter		2.86
Maximum Core Current Density (A/cm ²)		1.04
Maximum Axial Field (V/m)		2170
Maximum Transverse Field (V/m)		3850
Exit Area (cm ²)		1294
Hall Potential (kV)		6.79
Diagonal Load Current (A)		500
Total Channel Heat Loss (MW)		6.21
Electric Power Out (MW)		3.39
Channel Isentropic Efficiency (%)		43.8
Enthalpy Extraction (%)		7.0

Fig. 3-2 CDIF 1B₂ Channel Assembly

H4938-1

Fig. 3-3 Sectional Detail of Peg Wall

Fig. 3-4 Pegs in Assembly Fixture

Fig. 3-5 Pegs in Assembly Fixture

Fig. 3-6 Complete Peg Row in Assembly Fixture

Fig. 3-7 Hydrostatic Testing of Assembled Peg Row

Fig. 3-8 Installation of Peg Row on Channel Wall

Fig. 3-9 Installation of Peg Retaining Screws on Channel Wall

CDIF $1B_2$ ANODE

Fig. 3-10 CDIF $1B_2$ Channel Electrode Design

The anodes will be capped with EB 26-1 stainless steel. This material has demonstrated erosion rates of as low as 1% of bare copper in channel tests which simulate high sulfur coal combustion. Figure 3-11 shows measured erosion rates of various types of stainless steel as compared to plain copper. These tests were with combustion products containing 0.45% sulfur which approximates the combustion with a high sulfur coal such as Illinois No. 6. The anodes are reinforced on the gas face and upstream side. The boron nitride insulator is recessed to provide space for castable refractory to promote slag retention.

Fabrication and assembly of the electrode walls will start after the approval of the CDR in the forthcoming period.

The 1B_2 channel interface with the warm bore liner of the superconducting magnet is shown in Fig. 3-12, a typical section at the exit end. A channel support structure on wheels mates with tracks located in the corners of the rectangular magnet aperture. The support structure also serves as an attachment for water manifolds and piping and incorporates cable trays for the electrical power leads. The structure is fabricated with aluminum and fiberglass members to afford the maximum degree of electrical isolation between channel wall elements and from the channel to the grounded magnet dewar.

Fig. 3-11 Anode Erosion Data in High Sulfur Environment

J2807

Fig. 3-12 1B₂ Channel/SC Magnet Interface Layout