Molten Carbonate Fuel Cell (MCFC) Product Development Test

**Annual Report
September 1993 - September 1994**

February 1995

Work Performed Under Contract No.: DE-FC21-92MC28065

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
M-C Power Corporation
Burr Ridge, Illinois

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.

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

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, 175 Oak Ridge Turnpike, Oak Ridge, TN 37831; prices available at (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161; phone orders accepted at (703) 487-4650.

DISCLAIMER

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

Molten Carbonate Fuel Cell (MCFC) Product Development Test

**Annual Report
September 1993 - September 1994**

Work Performed Under Contract No.: DE-FC21-92MC28065

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
M-C Power Corporation
8040 South Madison Street
Burr Ridge, Illinois 60521-5808

February 1995

Abstract

This report summarizes the technical progress that has occurred in conjunction with Cooperative Agreement Number DE-FC21-92MC28065, Molten Carbonate Fuel Cell Product Development Test (PDT) in 1994. A summary of the project status follows:

Change of Site: The fuel cell demonstration project site originally at the Kaiser Permanente Medical Center in San Diego, California was relocated to the Naval Air Station Miramar. The change of site was caused by an increase in the site related costs.

NEPA Documentation: An Environmental Assessment has been prepared to comply with the National Environmental Policy Act of 1969 (NEPA). The Environmental Assessment resulted in a categorical exclusion of the proposed action from all environmental permit requirements.

Active Components Status: M-C Power has completed the tape casting and sintering of cathodes and is proceeding with the tape casting and sintering of anodes for the first 250 cell stack. 453 cathodes were tape cast; 424 were accepted. 435 cathodes were sintered; 358 were accepted. 270 anodes were tape cast; 268 were accepted. 257 anodes were sintered; 151 were accepted.

Separator Plate Status: A new plate design for improved sealing compared to the first 250 cell stack fabricated for the Unocal Demonstration has been developed. A new automated aluminization procedure has been developed. The separator plates are expected to be completed by the end of January 1995.

Non-Repeat Parts: None of the non-repeat parts for the first 250 cell stack are complete. They are scheduled for completion during the first quarter of 1995.

Balance of Plant Status: The Bechtel Corporation has completed the reformer process design coordination, a Process Description, the Pipe and Instrumentation Diagrams (P&IDs), a Design Criteria Document and General Project Requirement Document. Bechtel developed the requirements for the soils investigation report and issued the following equipment bid packages to prospective vendors:

- Inverter
- Reformer
- Desulfurization Vessels
- Hot Gas Recycle Blower
- Heat Recovery Steam Generator
- Recycle Gas Cooler

Table of Contents

	<u>Page</u>
List of Figures	iv.
List of Tables	iv.
Executive Summary	v.
I. Introduction	1
II. Purpose	3
III. Technical Results	4
Task 1 Project Management/Permitting	4
Task 2 Demonstration Design	5
Task 3 Stack Manufacturing	10
Task 4 BOP Fabrication	10
Task 5 Site Work	11
Task 6 Testing	11
Task 7 ARPA Enhancements	13

List of Figures

<u>Figure</u>	<u>Description</u>	<u>Page</u>
1	SDG&E NAS Miramar Fuel Cell Demonstration Compact Plant Layout	6
2	M-C Power SDG&E Product Development Test Project	9

List of Tables

<u>Table</u>	<u>Description</u>	<u>Page</u>
1	Current Status of Balance of Plant Design	7
2	Current Status of Equipment Procurement	12

Executive Summary

M-C Power Corporation and the U.S. Department of Energy (DOE) have entered into Cooperative Agreement Number DE-FC21-92MC28065, Molten Carbonate Fuel Cell Product Development Test (PDT). M-C Power will install, test and evaluate a 250 kW Proof-of-Concept Molten Carbonate Fuel Cell (MCFC) Power Plant.

At the onset of the project activities the plant was to be located at the Kaiser Permanente Medical Center in San Diego, California. The site design work was almost complete when the estimated costs for construction escalated beyond acceptable levels. These escalations were primarily due to previously unidentified underground constraints and increasingly stringent architectural requirements. Based upon these site conditions, the decision was made to seek a more suitable demonstration site.

The plant is to be located at the Naval Air Station Miramar in San Diego, California. The DOE is providing funds for two 250 kW natural gas-fueled IMHEX[®] MCFC stacks to be manufactured and shop tested by M-C Power. The Gas Research Institute (GRI) is providing funds for the balance of plant engineering and construction. San Diego Gas and Electric Company (SDG&E) will host the PDT. The Electric Power Research Institute is providing funds through a tailored collaboration agreement with SDG&E.

M-C Power has formed a team with the Bechtel Corporation and Stewart and Stevenson Services. M-C Power will design and manufacture MCFC stacks. The Bechtel Corporation will perform balance of plant and engineering and administration. Stewart and Stevenson Services will fabricate the balance of plant equipment on to a skid that can be truck transported to the power plant sites.

As host of the PDT, SDG&E will construct and then operate the power plant. SDG&E will coordinate all site related activities including the securing of the necessary construction and operating permits. SDG&E is coordinating the power plant design with the United States Navy who manages and operates the military reservation.

In addition to the funds provided by GRI and EPRI, in-kind cost sharing is provided to the project by the Bechtel Corporation, Stewart and Stevenson Services, and SDG&E.

The PDT project represents the first truly integrated MCFC power plant in a cogeneration application. The power plant will be fueled by natural gas and it will furnish electricity to the SDG&E electrical distribution grid. It will also furnish thermal energy in the form of saturated steam to the Naval Air Station Miramar. Miramar was chosen as the site for the PDT to gain direct experience with an MCFC power plant in a military application.

This report summarizes the technical progress that has occurred in conjunction with this project in 1994. M-C Power has completed the tape casting and sintering of cathodes and is proceeding with the tape casting and sintering of anodes for the first 250 cell stack.

For the new project location at the Naval Air Station Miramar, an Environmental Assessment has been prepared by the Department of Energy (DOE) in compliance with the National Environmental Policy Act of 1969 (NEPA). The Environmental Assessment resulted in a categorical exclusion of the proposed action from all environmental permit requirements.

The Bechtel Corporation has completed the reformer process design coordination, a Process Description, the Pipe and Instrumentation Diagrams (P&IDs), a Design Criteria Document and General Project Requirement Document. Bechtel developed the requirements for the soils investigation report and issued the following equipment bid packages to prospective vendors: Inverter, Reformer, Desulfurization Vessels, Hot Gas Recycle Blower, Heat Recovery Steam Generator, and Recycle Gas Cooler.

Ishikawajima-Harima Heavy Industries (IHI) is in the process of manufacturing and testing a 250 kW plate type reformer specifically designed for use in MCFC applications.

Stewart & Stevenson Services, Inc. has participated in the preparation of bid specifications and in the evaluation of vendor quotations. By being involved in the establishment of equipment specifications, Stewart & Stevenson is able to influence the equipment design for simplified skid installation and maintenance.

The PDT is configured to demonstrate the viability of natural gas-fueled MCFC for the production of electricity and thermal energy in an environmentally benign manner for use in commercial and industrial applications.

I. Introduction

M-C Power Corporation will design, fabricate, install, test and evaluate a 250 kW Proof-of-Concept Molten Carbonate Fuel Cell (MCFC) Power Plant. The plant is to be located at the Naval Air Station Miramar in San Diego, California. The project is defined as "MCFC Product Development Test" (PDT) and has been developed in accordance with Department of Energy guidelines under Cooperative Agreement Number DE-FC21-92MC28065.

As host of the PDT, SDG&E will construct and then operate the power plant. SDG&E will coordinate all site related activities including the securing of the necessary construction and operating permits. SDG&E is coordinating the power plant design with the United States Navy who manages and operates the military reservation.

The PDT project represents the first truly integrated MCFC power plant in a cogeneration application. The power plant will be fueled by natural gas and it will furnish electricity to the SDG&E electrical distribution grid. It will also furnish thermal energy in the form of saturated steam to the Naval Air Station Miramar. Miramar was chosen as the site for the PDT to gain direct experience with an MCFC power plant in a military application.

This report summarizes the technical progress that has occurred in conjunction with this project in 1994. M-C Power has completed the tape casting and sintering of cathodes and is proceeding with the tape casting and sintering of anodes for the first 250 cell stack.

The fuel cell demonstration project site was originally at the Kaiser Permanente Medical Center in San Diego, California. Due to escalating site construction cost estimates, the Kaiser Medical Center location was deemed prohibitive. M-C Power and San Diego Gas and Electric relocated the fuel cell demonstration project to an alternate site at the Naval Air Station Miramar.

For the new project location at the Naval Air Station Miramar, an Environmental Assessment has been prepared by the Department of Energy (DOE) in compliance with the National Environmental Policy Act of 1969 (NEPA). The Environmental Assessment resulted in a categorical exclusion of the proposed action from all environmental permit requirements.

For the new project location at the Naval Air Station Miramar, the Bechtel Corporation has completed the reformer process design coordination, a Process Description, the Pipe and Instrumentation Diagrams (P&IDs), a Design Criteria Document and General Project Requirement Document. Bechtel developed the requirements for soils investigation report and issued the following equipment bid packages to the suppliers for bids: Inverter, Reformer, Desulfurization Vessels, Hot Gas Recycle Blower, Heat Recovery Steam Generator, and Recycle Gas Cooler.

SDG&E has secured necessary site permits, conducted soils investigations, and is working on the construction plan. They are in final negotiations with the U.S. Navy on a site agreement. Site drawings are required for finalization of the agreement.

II. Purpose

The mission of this project is to carry out the planning, coordination, support, management, development, construction, and demonstration of a MCFC power generation facility utilizing the IMHEX® design. The demonstration project is configured to promote the commercialization of MCFCs by the demonstration of the viability of natural gas-fueled molten carbonate fuel cells to produce electricity in an environmentally benign manner for use in commercial and industrial applications

Project activities have been performed in accordance with the "Statement of Cooperative Agreement Objectives". The major objective of the project is to support the production, development, and testing of full-area, full-height 250 kW MCFC stacks in order to accelerate commercialization of the MCFC technology.

During 1994, the cooperative Agreement was modified to accommodate movement of the demonstration site to Naval Air Station, Miramar located in San Diego. The Department of Defense, through the Advanced Projects Research Agency (ARPA), provided funding for the following tasks:

- Task 7.1, Site Design, Permits, and Manuals
- Task 7.2, Site Preparation and Installation
- Task 7.3, Stack Conditioning and Shipment
- Task 7.4, NEPA Documentation, Update and Approvals
- Task 7.5, Full-Area, 20 kW Stack Verification
- Task 7.6, Advanced Separator Plate Qualifications
- Task 7.7, Pressure Vessel Design Improvement

These tasks were added to the Cooperative Agreement to help maintain project schedules and provide technical verification of components to be used in the Product Development Test Demonstration.

In addition to the U.S. Government's role in the PDT project as defined above, the Gas Research Institute (GRI) is sponsoring balance of plant efforts. SDG&E and EPRI are participating in site related and operational activities. The roles of GRI, EPRI and SDG&E are particularly important as their emphasis is on addressing design issues which will impact acceptance by the utility industry.

III. Technical Results

PROJECT OBJECTIVES

The objective of this project is to design, construct, operate, and evaluate a natural gas-fueled MCFC power plant. The plant is based upon the IMHEX® fuel cell design for converting natural gas fuel to electric power. The PDT project will demonstrate the technical, economic, and environmental viability of the IMHEX® technology. Design objectives include improved performance at reduced cost compared with the Unocal demonstration which also incorporates the IMHEX® technology.

Design goals for the PDT include:

- 1) High electrical and overall efficiency
- 2) Cogeneration acceptability
- 3) Environmental acceptability (noise and emissions)
- 4) Site acceptance (size, aesthetics)
- 5) Ease of operation (start-up, shutdown, unattended operation)
- 6) Reliability/availability/maintainability/safety
- 7) Potential for cost competitiveness

Task 1. Project Management/Permitting

Objective: Development of project management system for planning, budgeting, executing, and controlling the costs and schedules associated with the work. To obtain permits required for stack and BOP fabrication/testing and site related activities.

Subtask 1.1 Management Plan

Discussion: This subtask is complete. The Management Plan was revised to reflect the change in project site from Kaiser Permanente Medical Center to NAS Miramar.

Subtask 1.2 Environmental Information

Discussion: This subtask is complete. An environmental document containing the information necessary to allow DOE to prepare documentation to comply with NEPA requirements has been prepared to reflect the new project site. A categorical exclusion has been received. All local environmental permits/approvals have been obtained and the project is ready for site construction to begin.

Subtask 1.3 Local Permits

Discussion: All local permits/approvals have been obtained. SDG&E is in the last stages of finalizing the site agreement with NAS Miramar. The agreement will be consummated upon completion and submission of site design criteria to the U.S. Navy for approval.

Subtask 1.4 Management and Reporting

The management plan, budget and schedule have been revised to reflect movement to the new project site. There has been an increase in the project budget which was caused by rework of the site design. The scheduled start of operation has been extended by approximately one year to August 1995.

Task 2 Demonstration Design

Objective: Prepare designs for the stack, Balance of Plant, and site which are integrated and consistent with the 250 kW PDT demonstration plant performance objectives.

Subtask 2.1 Stack Design

Discussion: The original stack design concept included having the first 250 kW stack as a duplicate of that used in the Unocal demonstration. Based upon experience gained on the Unocal project, there have been a number of design changes included in the PDT stack. Changes relate to a more simplified clamping device, thinner electrodes, new matrix formulation and an improved separator plate design. A number of trade-off studies have been performed regarding stack sealing, box plenum and the pressure vessel.

The box plenum and pressure vessel designs are in the final stages of analysis. There has been several improvement over the Unocal design:

- Pressure vessel was reduced in weight by 30% and the diameter was reduce by 15%. This was accomplished by employing a reusable cage for stack lifting.
- A change in the specification for the inverter to DC input negative pole grounded results in simplified internal piping.
- Additionally, the fuel cell stack instrumentation has been significantly reduced.

Subtask 2.2 BOP Design

Discussion: The balance of plant (BOP) design represents a significant improvement over the Unocal design. The PDT plant design is more compact. For example, the site is approximately 40% of the Unocal demonstration site area. The layout is presented in Figure 1. Status of the BOP design is presented in Table 1. All major pieces of equipment have been identified.

Figure 1
SDG&E NAS Miramar Fuel Cell Demonstration Compact Plant Layout

Table 1

Current Status of Balance of Plant Design

<u>Activity Description</u>	<u>% Complete</u>
Reformer Design Coordination	100
Process Flow Diagram with Heat & Material Balance	100
Process Description	100
P&IDs (Includes Line Designation Table and Instrument Index)	60
Plant Layout	100
Design Criteria Document	100
General Project Requirement Document	100
Requirements for soils investigation report	100

The Following were revised as a result of the Relocation of the Fuel Cell Demonstration Project to the Naval Air Station Miramar:

- Plant Layout
- Process Flow Diagram complete with heat and material balance analysis (a simplified process flow diagram is shown in Figure 2)
- Piping and Instrumentation Diagrams (P&ID)
- Technical specifications to procure long lead equipment items
- General Terms and Conditions, Special Conditions and Shipping Instructions for inclusion in the equipment procurement packages

Bechtel examined alternate plant arrangements to achieve the following overall objectives:

- To locate the fuel cell and reformer as close as possible to the Balance of Plant skid so that the fuel cell plant will appear as an extension of the Balance of Plant skid and thereby enhance the overall appearance of the plant
- To group all the utilities for the fuel cell plant in an area separate from the Balance of Plant skid, the reformer, and the fuel cell, so that they can be readily identified as a utility area
- To bring the control room/electrical room closer to the fuel cell.

A plant layout has been developed that is much more compact than the Unocal demonstration. The power plant area has been reduced by approximately 55%. The plant layout is shown in Figure 1.

Other Balance of Plant design improvements that have been implemented include:

- Removal of high temperature valves
- Specification of a thermally integrated catalytic plate type natural gas fueled reformer
- Specification of a double connection to the local electric power grid with full back up capability and a shunt trip.

Subtask 2.3 Site Interface Design

Discussion: Site interface design is complete.

Figure 2

Subtask 3. Stack Manufacturing

Objective: Fabricate stack repeat and non-repeat components, assemble and test two 250 kW stacks. One stack shall remain at M-C Power's plant in Burr Ridge, Illinois for testing. The stack shall be made available as a spare for installation at the site, if required.

Subtask 3.1 Component Manufacturing

Discussion: M-C Power has completed the tape casting and sintering of cathodes and is proceeding with the tape casting and sintering of anodes for the first 250 cell stack. 453 cathodes were tape cast; 424 were accepted. 435 cathodes were sintered; 358 were accepted. 270 anodes were tape cast; 268 were accepted. 257 anodes were sintered; 151 were accepted. The tape casting and sintering of anodes will be completed in the last quarter of 1994. All of the active area components for the first 250 cell stack will be completed in the first quarter of 1995. The active area components for the second 250 cell stack will also be completed in 1995.

None of the non-repeat parts for the first 250 cell stack are complete. They are scheduled for completion in the first quarter of 1995.

A new plate design for improved sealing compared to the first 250 cell stack fabricated for the Unocal Demonstration has been developed. Pressing of the improved design separator plates is in progress. They will be used in the first 250 cell stack which will be assembled in the first quarter of 1995.

A new automated aluminization procedure has been developed. The new procedure was developed to reduce the laborious task of manually masking the separator plates before aluminization. The separator plates are expected to be completed by the end of January 1995.

The separator plates and the repeat parts for the second stack will also be completed in 1995. The second stack will use the MOD4 separator plates that are currently under development.

Subtask 3.2 Stack Assembly

Discussion: Stack assembly work is scheduled for the first quarter of 1995. Assembly will begin when the box plenum is received from the manufacturer.

Subtask 3.3 Shop Test and Shipping

Discussion: This work is scheduled for June through August 1995.

Task 4. BOP Fabrication

Objective: Purchase major equipment items, shop test equipment, fabricate skid in accordance with design specifications, and ship the BOP skid to demonstration site.

Subtask 4.1 Equipment Procurement

Discussion: The following bid packages have been issued to the suppliers for quotations: Inverter, Desulfurization Vessels, Hot Gas Blower, Heat Recovery Steam Generator and the Recycle Gas Cooler. The status of equipment purchases is shown in Table 2.

Subtask 4.2 BOP Assembly

Discussion: The BOP assembly is scheduled to begin in the second quarter of 1995 and is dependent upon the delivery of major pieces of equipment.

Subtask 4.3 BOP Shop Test and Ship

Discussion: This subtask will be initiated at the completion of subtask 4.2.

Task 5 Site Work

Objective: Prepare site, installation, and commission 250 kW demonstration plant.

Subtask 5.1 Site Preparation

Discussion: SDG&E is scheduled to begin this subtask during the first quarter of 1995.

Subtask 5.2 Plant Installation

Discussion: The timing of plant installation is dependent upon the receipt of major equipment items. Several long-lead items have a scheduled June 1995 delivery date. Efforts are underway to shorten the delivery schedule. Potential late deliveries may reside with the HRSG and the distributed control system.

Task 6 Testing

Objective: Prepare manuals/test plans and execute test programs which document the PDT demonstration plant's performance.

Discussion: The following subtasks will be executed based upon experience at the Unocal demonstration:

- 6.1 Operating and Maintenance Manuals
- 6.2 Test Plan
- 6.3 Performance Testing
- 6.4 Emission Testing
- 6.5 Test Reports

Table 2

Current Status of Equipment Procurement

<u>Equipment Item</u>	<u>Spec</u>	<u>Procurement Status</u>
Inverter	100	Issued for bids
Reformer	100	Awarded to IHI
Desulfurization Vessels	100	Issued for bids
Hot Gas Recycle Blower	100	Issued for bids
Heat Recovery Steam Generator	100	Issued for bids
Recycle Gas Cooler	100	Issued for bids
Turbocharger	90	
Turbocharger Start-up Blower	90	
Natural Gas Compressors	80	
Instrument Air System	20	
Nitrogen Storage System	0	
Boiler Water Treatment System	0	
Distributed Control System	90	Issued to M-C Power
Data Sheets for Control Valves & Instruments	0	
Motor Control center	100	Issued for bids
Electric Heaters	90	

Task 7. ARPA Enhancements

Objective: Provide support to the PDT demonstration work related to movement of the site and in areas which will improve chances of project success.

Subtask 7.1 Site Design, Permits and Manuals

Discussion: Work has been initialed by SDG&E on the site design and permits as described above. Operating manual activity will commence with Subtask 6.1.

Subtask 7.2 Site Preparation and Installation

Discussion: Work will be initiated by SDG&E during the first quarter of 1995 as described in Subtask 5.1.

Subtask 7.3 Stack Conditioning and Shipping

Discussion: Work will be initiated by M-C Power as described in Subtask 3.3.

Subtask 7.4 NEPA Documentation, Update and Approvals

Discussion: As described in Subtask 1.2, this work has been completed.

Subtask 7.5 Full-Area, 20 kW Stack Verification

Discussion: Anodes, cathodes, current collectors and matrix have been manufactured. The separator plates will be aluminized in January 1995. Work has commenced on making the test stand ready for conducting verification tests.

Subtask 7.6 Advance Separator Plate Qualifications

Discussion: Work has initiated on this subtask. The die has been modified and qualification tests will take place during the first quarter of 1995.

Subtask 7.7 Pressure Vessel Design Improvement

Discussion: Work has initiated on this subtask as discussed in Subtask 2.1.