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OVERVIEW OF COMMERCIALIZATION OF STATIONARY FUEL CELL POWER PLANTS IN THE UNITED STATES

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ABSTRACT

In this paper, the U.S. Department of Energy's (DOE's) efforts to assist private sector organizations to develop and commercialize stationary fuel cell power plants in the United States are discussed. The paper also provides a snapshot of the status of stationary power fuel cell development occurring in the U.S., addressing all fuel cell types. This paper discusses, general characteristics, system configurations, and status of test units and demonstration projects. The U.S. DOE, Morgantown Energy Technology Center is the lead center for implementing DOE's program for fuel cells for stationary power.

INTRODUCTION

The DOE focus is on energy, the environment, and the economy emphasizes the development of high-efficiency, environmentally acceptable, advanced, energy-conversion technologies for generating electricity. Congress has appropriated funding for the development and commercialization of these advanced energy-conversion technologies. The MCFC has been identified as a commercially promising energy-conversion product; overall system efficiencies of 50 to 60 percent are forecast for natural-gas and coal-gasification MCFC power plants. The MCFC, unlike turbines and diesels, offers high efficiency at small size and at part-load. Furthermore, an MCFC power plant can operate on coal or natural, refinery, or process gas.

MCFC stack designs incorporate either internal or external manifolding (fuel and oxidant) and either internal or external reforming. All MCFC designs include flat cell components in the cell package (i.e., anode, matrix to hold carbonate, cathode, current collector, and separator plate).

Figure 1 illustrates the structure of an MCFC stack. Conductive, bipolar separator plates connect the individual cells in a stack both structurally and electrically. The bipolar separator plate is made of stainless steel, and each plate physically separates the fuel-gas stream of one cell from the oxidant-gas stream of the adjacent cell. One side of each separator plate channels a fuel stream so that it flows over a porous anode, while the flip side channels an oxidant stream over a porous cathode. Each bipolar separator plate also collects current, thus electrically connecting adjacent cells of a stack in series. Electrons are conducted from the anode through the bipolar separator plate and into the cathode of the adjacent cell. There they react with the oxidant-gas stream and form carbonate ions. The carbonate ions diffuse through the electrolyte and into the anode, where they react with the fuel-gas stream, releasing electrons into the anode. Electrons are conducted in this manner through all the cells, thus establishing direct current (DC) through the stack. An exter-

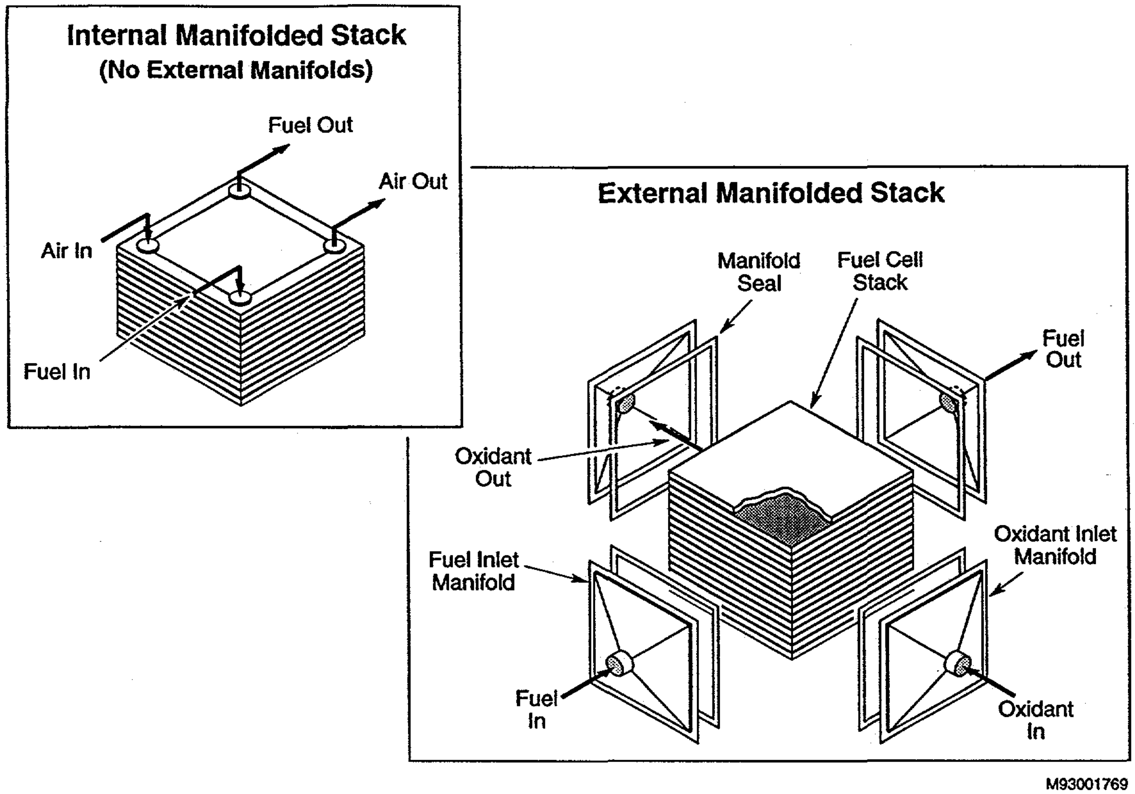

Figure 1. MCFC Stack Structural Designs

nal circuit connects a load between the two end plates of the stack, completing the circuit.

The U.S. DOE is funding two MCFC developers, Energy Research Corporation (ERC) and M-C Power (MCP), that have conceptual designs of efficient integrated MCFC power plants. Operating conditions for these MCFCs are projected to be in the range of 150 to 250 amperes per square foot (ft^2)(160-270 milliamperes per square meter [M^2]), at 0.60 to 0.80 volts, with 50- to 85-percent fuel utilization.[1]

STATUS OF MCFC PROGRAM AND PRODUCT DEVELOPMENT TESTING

The goal of the DOE MCFC program is to develop and commercialize low-cost, packaged, simple, and modular fuel-cell systems. DOE is accelerating the drive for private-sector commercialization of multi-fuel, MCFC power plants. The DOE's Morgantown Energy Technology Center (METC) is in the process of concluding support of MCFC power-plant system development with ERC and MCP under the 1990 Program Research and Development Announcement (PRDA).

The two MCFC developers have collected impressive stack-test performance data under the 1990 PRDA. ERC developed an externally manifolded, externally reformed MCFC, and has constructed a 2 to 10 megawatt (MW) per year MCFC manufacturing plant. ERC is currently expanding their 130-kilowatt (kW) test facility in Danbury, Connecticut, to enable them to test 400-kW stacks. They have also scaled up to a 6-ft^2 (0.56 M^2) area stack. They have tested a 4-ft^2 (0.37 M^2), 75-kW, 234-cell stack for 500 hours at their facility in Danbury and also at the Pacific Gas and Electric, San Ramon, California, facility. ERC has also tested 6-ft^2 (0.56 M^2), 123-kW, 244-cell stacks in Danbury. Under this PRDA, ERC has achieved a combined total of over 50,000 hours of operation including five large area stack endurance tests (10,000, 6000, 8000, and 6500 hours).

MCP is developing an internally manifolded, externally reformed MCFC, and has constructed a >3-MW per year MCFC manufacturing plant. MCP has constructed a 250-kW acceptance test facility in Burr Ridge, Illinois, and has scaled up to an 11.4-ft^2 (1.06 M^2) full area stack. They have tested several subscale-area stacks, including a 1-ft^2 (0.09 M^2), 7-kW, 70-cell stack. MCP has also tested several, 20-kW full-area stacks for over 1,000 hours. The latest stack test is planned to begin in May 1995. Though their research entity (Illinois Institute of Technology, [IGT]), they have also conducted a single cell test for over 11,000 hours.

The 1990 PRDA DOE contracts with these MCFC contractors culminate with tests of full-area, full-height MCFC power-plant systems. Under these agreements, ERC will test a 2-MW system and MCP will test a 250-kW system.

A 250-kW, MCP full-area stack power plant system has been installed at the UNOCAL Science and Technology Center in Brea, California. Start up is planned for spring of 1995. Results of this test will be presented.

ERC has begun installing a 2-MW demonstration test at Santa Clara, California. Start up is planned for late 1995.

DOE funded Product Development Tests (PDTs) are being conducted concurrently with system development at ERC and MCP under the 1990 PRDA to establish a proven track record for emerging MCFC technology in the utility and industrial arenas. A successful demonstration track record will enhance support for MCFC technology from utilities and other end-users in the distributed, repowering, American Public Power Association, industrial, and commercial markets.

The initial MCFC PDTs are in California in 1995/1996. MCP will conduct a 250-kW PDT in San Diego, California, funded by DOE, the Gas Research Institute, and San Diego Gas and Electric and others. This system will be installed at Miramar Naval Air Station, California. Ground breaking for this unit is expected to begin spring 1995 with start up January 1996. This unit is expected to have a reformer utilizing flat plate technology that is about half the size of the unit installed in Brea. They have also demonstrated significant cost savings in the unit through improved processing.

ERC is also participating in a 2-MW Clean Coal Technology V Demonstration project with DOE and Duke Power at a site to be determined. Recently, the New York Power Authority announced a 2-MW (ERC) demonstration at Fresh Kills (Staten Island), New York, in 1998.

STACK TECHNOLOGY, SYSTEM, AND NETWORK ISSUES

DOE assessed the status of MCFC technology and commercialization potential based on recent accomplishments under the 1990 PRDA contracts. DOE found that critical technology, design, and manufacturing issues remain that can hinder commercialization. Technology issues include (1) electrode and separator plate corrosion, (2) power density, (3) thermal cycling, (4) scale-up, and (5) gas leakage and cross-over. These affect endurance and longevity, power density, and cost. The major long-term issue in MCFC operation is cathode corrosion.[2-4] Major network and system issues are cost, heat loss management, footprint, packaging and integration, parasitic power losses, pressurization, and reforming.

Pressurization affects stack and balance-of-plant (BOP) development.[2] A potential advantage of pressurized operation is higher power density (or smaller stack size for a given application). System integration and packaging of MCFC power plants will increase efficiency, power density, reliability, and ease of maintenance and will reduce heat loss, footprint, and capital and field installation costs.

With the initial demonstration of full-area, full-height 250-kW to 2-MW MCFC power plants, the spatial configuration of MCFC stacks into networks in the fuel-cell power plant takes on new importance. Conventional fuel-cell systems have multiple stacks arranged in parallel with the flow of reactant streams. As illustrated in Figure 2, the initial oxidant and fuel feeds are divided into equal streams, which flow in parallel through the fuel-cell stacks. Reactant streams can also be ducted so they flow through a recycle network in series. Figure 2 also shows how reactant streams in a fuel-cell network flow in series from stack to stack.

Internally at the Department of Energy, METC researchers continue to develop computer simulations to evaluate the performance of various internal reforming networks and to compare conventional and networked MCFC power systems.[5] The simulated performance of MCFC networks appear superior to the performance of cells and stacks that were not networked.

PLANNED MCFC PRODUCT DESIGN AND IMPROVEMENT PROGRAM

DOE recently awarded two contracts (ERC and MCP) as a result of a Product Design and Improvement (PDI) PRDA directed at resolving technology, system, and network issues. The objective of this work is to aim current MCFC stack development toward the development of a packaged, commer-

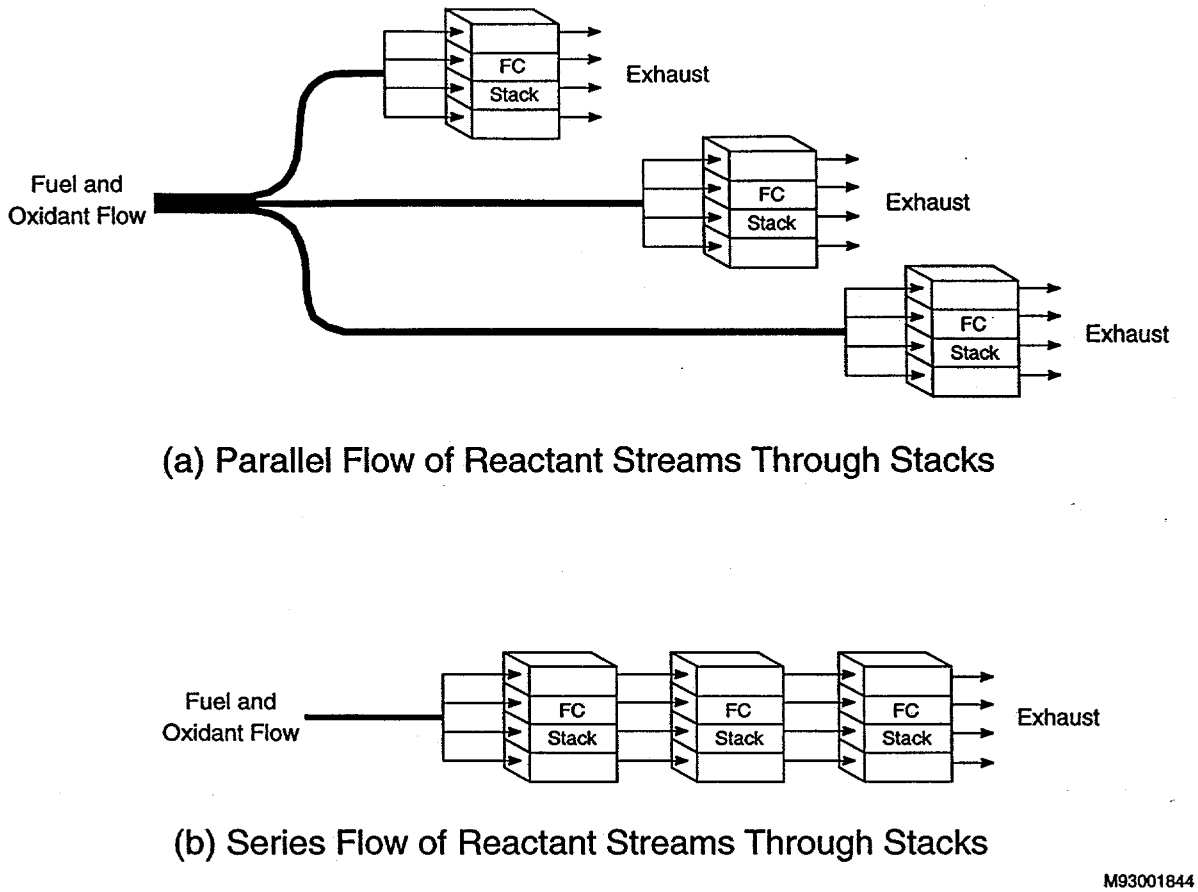

Figure 2. MCFC Networks

cially feasible MCFC product. Contracts under this PRDA will bring a multi-fueled, integrated, simple, low-cost, modular, market-responsive MCFC power plant to the marketplace. The development program is based on a commercialization plan to manufacture and package, demonstrate, and aggressively market MCFC power plants. The PDI PRDA will culminate in the manufacture and construction of high-performance, low-cost, 500- to 2,000-kW MCFC power-plant module(s).

This program encompasses (1) further product definition that reinforces the desired attributes and also follows strong interest of many utility companies in the 1 to 2-MW-size systems, (2) power-plant design that includes stack and BOP modules, (3) manufactur-ing process improvements and commercial facility design, (4) cell area scale-up, (5) development of critical BOP equipment, and (6) verification of power-plant modules.

ERC and its two subsidiaries, Fuel Cell Engineering Corporation and Fuel Cell Manufacturing Corporation, plan a 5-year, private-sector, cost-shared program for product improvement and verification, with an emphasis on multi--fueled, integrated, simple, low-cost, modular, and market-responsive MCFC power-plant development in the 2-MW-size range. ERC will be developing an internal reforming MCFC system that eliminates the external reformer equipment and associated heat exchangers used in other fuel-cell systems. This system is therefore simple and has inherently high efficiency. An efficiency goal of 55 percent (based on a lower heating value of fuel) for a natural-gas plant appears achievable. Based on input from both municipal- and investor-owned utilities, the initial target for market penetration will be 2-MW natural-gas power plants for baseload and dispersed generation applications.

A preliminary design of ERC's market entry 2-MW power plant has been completed. Detailed system design is proceeding as stack design refinements will be verified in a series of tests ranging from 7 by 7 inch (316 cm^2) bench scale to full area/full height commercial stack testing. Stack refinements include eliminating indirect reformer cells and replacing them with about 60 additional direct reforming cells. Another significant refinement will be to increase cell area by 33 percent (from 3.7 M^2 to 6.6 M^2 [6 ft^2 to 8 ft^2]). This is projected to proportionately increase the power output per stack from 130-kW to 250-kW and improve the design of the final product package by reducing the required number of stacks for a 2-MW power plant by 50 percent (from 16 to 8 stacks).

MCP, along with its partners Bechtel Corporation, Stewart & Stevenson, and the Institute of Gas Technology is conducting a 4-year, private-sector, cost-shared program for product improvement. The primary objective of the MCP effort is to establish, by 1998, the commercial readiness of MW-class IMHEX® MCFC power plants for distributed generation and cogeneration applications.

The program focus is cost reduction and verification of product durability, reliability, and performance. Achieving cost reduction goals will require advanced stack technologies that simplify design and fabrication, and BOP designs that are driven by equipment improvements and integration opportunities. Achievement of these goals will be verified through the design, construction, and operation by 1998 of a high-performance, low-emissions, natural-gas-fueled, nominal 1-MW IMHEX® fuel-cell power plant. It is planned that Southern California Edison Company of Rosemead, California, will host the 1-MW IMHEX® MCFC power plant demonstration. This power plant is the initial market-entry product prototype, and utilizes pressurized operation and a reformer/catalytic combustor that is thermally integrated but independent of the stack assembly.

To date, a preliminary commercial specification has been developed. A 20-kW stack test will be tested in May 1995 with many of the technology improvements planned for the commercial unit. A 100 cm^2 cell test has been conducted and has achieved over 11,200 hours of operation. Development of an improved electrolyte is 50 percent complete and other component improvements are ongoing.

CONCLUSIONS

Many challenges for MCFC developers remain. Strategic issues, program objectives, and planned activities in the MCFC product arena have been identified.[6,7] DOE recognizes that funding support is needed in six areas: (1) product definition and planning; (2) system design and analysis; (3) manufacturing process development; (4) assembly and packaging; (5) test facility development; and (6) technology development, improvement, and verification. However, DOE is also concerned with the growing funding requirements for fuel-cell development and commercialization. Various options are being considered to limit Government costs, including reducing the number of designs and concepts being developed, limiting the size and number of demonstrations, increasing the cost share, and combining or limiting development work on the BOP sections.

DOE has identified the MCFC as a promising energy-conversion product for development and commercialization. MCFC technology developers are making significant progress: technological achievements, manufacturing facility development, and extensive testing are occurring. However, several critical issues need to be resolved through research and demonstration under the Product Design and Improvement Program. In addition, MCFC developers need to continue to be responsive to the commercial markets.

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