DOE/MC/24221-3244

DOE/MC/24221--3244

DE93 008645

ADVANCED WATER-COOLED PHOSPHORIC ACID

FUEL CELL DEVELOPMENT

TECHNICAL PROGRESS REPORT NO. 5

A QUARTERLY REPORT
for
JULY - SEPTEMBER 1988

Contract DE-AC21-88MC24221

FCR-9919

Prepared for

U.S. Department of Energy
Morgantown Energy Technology Center
P.O. Box 880, 3610 Collins Ferry Road
Morgantown, WV 26505-0880

International Fuel Cells®

P.O. Box 739
195 Governors Highway
South Windsor, Connecticut 06074

MASTER

TABLE OF CONTENTS

PROGRAM HIGHLIGHTS

- Completed the initial conceptual design configuration.
- Baseline on-site electrodes were tested at electric utility conditions in 2 x 2 inch cells.
- GSB-18P cathodes were fabricated in preparation for testing in 2 x 2 inch cells.
- Design of the small area development stack was initiated and long lead time items ordered.
- Molded cooler thermal cycling tests were initiated.
- Equipment to evaluate alternative manifold coating processes and materials was procured.

I. INTRODUCTION

The Advanced Water Cooled Phosphoric Acid Fuel Cell Development program is being conducted by International Fuel Cells Corporation (IFC) to improve the performance and minimize the cost of water cooled, electric utility phosphoric acid fuel cell stacks.

The program adapts the existing on-site Configuration B cell design to electric utility operating conditions and introduces additional new design features. Task 1 consists of the conceptual design of a full-scale electric utility cell stack that meets program objectives. Tasks 2 and 3 develop the materials and processes required to fabricate the components that meet the program objective. The design of the small area and three 10 ft^2 short stacks is conducted in Task 4. The conceptual design also is updated to incorporate the results of material and process developments, as well as results of stack tests conducted in Task 6. Fabrication and assembly of the short stacks is conducted in Task 5 and subsequent tests are conducted in Task 6. The Contractor expects to enter into a contract with The Electric Power Research Institute (EPRI) to assemble and endurance test the third 10-ft^2 short stack. The management and reporting functions of Task 7 provide DOE/METC with program visibility through required documentation and program reviews.

This report describes the cell design and development effort that is being conducted to demonstrate by subscale stack test, the technical achievements made toward the above program objectives.

II. STATUS

TASK I - CONCEPTUAL DESIGN

Objectives

The objective of this task is to define the conceptual design for a cell stack having a performance level of at least 175-W/ft^2 and a manufactured cost of less than $400/kW. The stack must be capable of operating for a minimum of 40,000 hours at electric utility conditions.

Activity

Parametric studies to select the initial conceptual design operating point and the cell stack configuration were completed. The design selected is as follows:

Stack Configuration

- 366 cells
- 6 cells/cooler

Output

- 300 watts/ft^2
- 1125 kW DC

Cell Configuration

- 10 ft^2 nominal active area
- 41.7" x 41.9" planform

Performance

- 0.75 volts/cell at 400 ASF
- 405°F average cell temperature

Operating Conditions

- 120 psia reactant pressure
- 85% fuel utilization
- 70% air utilization

Life

- 40,000 hours

The conceptual design layout was updated to incorporate the repeating cell configuration.

TASK 2 - COMPONENT DEVELOPMENT

Objectives

The objectives of this subtask are to provide an improved substrate, verify the stability of low cost substrate and electrolyte reservoir materials at pressurized cell operating conditions, and increase the thermal conductivity of the electrolyte reservoir.

Activity

Electrode substrates and electrolyte reservoir plates (ERP's) formed by commercial processes were sampled for corrosion testing at electric utility conditions. These tests will serve as a baseline for comparison with materials and processes developed under this program. The lab test set-up and personnel training required to perform these tests are in progress.

Subscale electrode substrate precursors, formed in supplier trials, were characterized. Handsheets were formed in these trials to evaluate forming and curing operations. Forming alternatives are being evaluated to improve uniformity of thickness, finish, and appearance. Additional handsheets are being evaluated to select parameters for a combined resin impregnating and cure process.

Handsheets were formed to assess substrate precursor ingredient mixing that occurs prior to forming. Tests were conducted using the baseline and an alternative pitch based carbon fiber. The results are shown in Table 1-1 below:

Table 1-1

Effect of Mixing Time on Precursor Uniformity

**Basis: Subscale Handsheets
Fiber Content Constant
No Forming Additives
Basis Weight Constant**

Normalized Mixing Time	Uniformity: Baseline Fiber	Uniformity: Alternate Fiber
1	Good	Fair
2	Good	Good

Subtask 2.2 - Single Cell Testing

Objectives

The objectives of this subtask are to test subscale cells to evaluate improvements in cell components consisting of substrates, electrolyte reservoir plates, catalyst and matrix; verify performance and endurance of components fabricated for short stacks; optimize the hydrophobicity of catalyst layers made from the GSB-18P catalyst for operation at power densities of 200 WSF or greater; evaluate a higher performing laboratory catalyst for this application, and define the permissible range of operating conditions.

Activity

Two subscale configuration B cells were built and tested during this report period. Cells #6490 and 6491, containing baseline on-site cell components were tested to evaluate the impact of processing variables selected for ambient operation at electric utility conditions. Performance at ambient and electric utility conditions is shown in Table 2-1.

Initial performance was 0.737 ± 0.002 V at 300 ASF, which is about 15 mV below prediction. Diagnostic tests showed that both cells had high O_2 gains.

Table 2-1

Performance Histories of Cells 6490 and 6491

Time (hr)	Temperature (°F)	Pressure (psia)	Current Density (ASF)	Utilization RM-1 (U_{H_2})	Utilization Air (U_{O_2})	Cell Voltages 6490	Cell Voltages 6491
154	415	14.7	300	80	50	0.595	0.597
155	415	120	300	85	70	0.737	0.740
238	400	14.7	200	80	50	0.639	--
350	400	14.7	200	80	50	--	0.644
561	400	14.7	200	80	50	0.621	0.626

During this reporting period GSB–18P catalyst, was made into electrodes using shop production methods. Cathode catalyst layers with two different Teflon contents were deposited on graphitized carbon paper substrates. The electrodes were then halved. One half was processed through completion – the remaining halves are available for future alternative process trials. The completed electrodes were coated with SiC matrix.

TASK 3 - PROCESS DEVELOPMENT

Subtask 3.1 - Substrate

Objectives

The objectives of this subtask are to develop the process technologies required to produce low cost thin substrates, to continuously resin-impregnate, densify and thermoset thin substrates, and to demonstrate that 10-ft^2 thin substrates can be handled and formed at low cost.

Activity

Electrode substrate precursor handsheets formed with pitch based carbon fibers are being evaluated in the Materials Development Subtask. The subscale handsheets were formed using several front end forming modifications. The baseline precursor and other promising candidate precursors were additionally processed to evaluate alternative methods of combining the resin impregnating and cure operations. The handsheets are being evaluated on a basis of tensile strength and uniformity.

Subtask 3.2 - Integral Separator

Objectives

The objective of this subtask is to develop the process technology to fabricate integral separators, up to 10-ft^2 in size, that meet the technical requirements and cost objectives established in the conceptual design.

Activity

Samples of the bill of material on-site integral separator plate have been submitted for corrosion testing at electric utility conditions. The test set-up and operator training required to perform these and cross-pressure tests is in progress. Cross pressure tolerance will be assessed in gas permeability and diffusion tests of the separator at temperatures from 400-500°F and at pressure differentials up to 20 psi.

Subtask 3.3 - Seals and Matrix

Objectives

The objective of this subtask is to develop the technology to fabricate higher integrity seals and matrices that meet the technical requirements and cost objectives established in the conceptual design.

Activity

Finer particle size silicon carbide materials were procured for processing trials and evaluation at 120 psia electric utility conditions. Matrix inks were formulated and a bubble pressure test fixture was fabricated.

Matrix inks were formulated with 100, 50, 30 and 10% finer particle size silicon carbide mixed with the baseline particle size material. The on-site baseline ink was also formulated for comparison with the new inks.

The bubble pressure test fixture was fabricated and assembled. Check-out was completed using on-site baseline cell packages. The test fixture features a variable loading system to simulate a range of axial loads. Testing will begin during the next report period.

Subtask 3.4 - Molded Cooler

Objectives

The objective of this subtask is to develop material and process technology to fabricate molded coolers 10-ft^2 in size that meet the technical requirements and cost objectives established in the conceptual design.

Activity

Resins, graphites, and sub-scale cooler arrays were procured to resume the materials development activity conducted in the prior DOE Task Order Program. Sub-scale moldings of the baseline resin/graphite system were formed to measure structural properties as a function of time at operating temperature. Testing will begin during the next reporting period.

Full-scale molded cooler assemblies are being thermal cycled to measure structural integrity. Blisters and cracks have developed in cooler assemblies after only a few thermal cycles. The defects appear randomly and do not appear to be associated with array location. The resin system supplier and molder judge that the defects can be reduced or eliminated by post-curing the composite after molding. Post-cure cycles are being developed.

The cooler array design for small area stack scale heat transfer testing is in progress. These arrays will be used in trial molded coolers to measure the overall cooler thermal resistance.

TASK 4 - STACK DESIGN

Objectives

The objective of this task is to update the full-scale conceptual design and to define designs for one small area development stack and three 10-ft^2 subscale stacks.

Activity

Design of the small area development stack was started. The design layout locates the small area stack assembly in the rig pressure vessel to establish fluid, electrical and instrumentation interfaces and clearances. The bill of material lists quantities and part numbers for rig hardware items and tooling required to assemble the rig.

A reactant manifold shell assembly was designed incorporating those features common to both fuel and air manifolds. Common features include manifold size, retention brackets to provide loading for manifold seals, drain bosses, and instrumentation bosses. Procurement of the long lead time shell assembly can now take place concurrent with the design of reactant inlet and outlet configurations which will be bolted onto the shell assembly. Design of the stack pressure plate was also completed. This design utilizes an existing ambient pressure stack plate with added lifting holes and power take-offs, and an alternative arrangement for manifold retention. The next item scheduled for design is the mount plate used to adapt the pressure vessel mount points to the stack mount points.

TASK 5 - FABRICATION

Subtask 5.1 - Repeat Components

Objectives

The objective of this effort is to fabricate the repeat components for one small area development stack and three 10-ft2 subscale stacks each consisting of approximately 30 cells. These stacks will be of the Configuration B cell design. The repeat components consist of the substrates, electrodes, electrolyte reservoir plates, and cooler assemblies.

Activity

No activity scheduled during this report period.

Subtask 5.2 - Non-Repeat Components

Objectives

The objective of this effort is to fabricate the non-repeat components for the small area development stack and three 10-ft^2 subscale stacks of approximately 30 cells each. These stacks will be of the Configuration B cell design. The non-repeat components consist of reactant manifolds, coolant manifolds, axial load system, power take-off hardware and pressure containment vessel.

Activity

Design of the small area stack has defined several long lead time items. The purchase of these items has been initiated, and includes the reactant manifold shells and the axial load hardware.

A program to evaluate alternative, lower cost reactant manifold coating systems was initiated. Coating coupons fabricated from the manifold shell material are being procured. Equipment and coating materials to evaluate an alternative coating process have been procured with IFC funding. Set-up and check out of this equipment is scheduled to occur during the next report period.

Subtask 5.3 - Stack Assembly

Objectives

The objective of this effort is to assemble the small area development stack and two 10-ft^2 subscale stacks of Configuration B cells for testing at 120 psia. The third 10-ft^2 subscale stack will be assembled and tested under an anticipated EPRI program.

Activity

No activity scheduled during this report period.

TASK 7 - MANAGEMENT AND DOCUMENTATION

Objectives

The objective in this task is to provide the program management necessary to maintain technical and budget control of the program activities, and to provide adequate documentation of its progress per contract requirements.

Activity

The work plan, FCR-9641 was approved by the DOE COTR in July and the conceptual design was reviewed and approved in August. A proposal for contract modification C001 was submitted in August and finalized in September. In the new work, International Fuel Cells (IFC) will evaluate an alternative electrode substrate material, fabricate and evaluate alternative electrolyte reservoir plate (ERP) and integral separator plate (ISP) components, fabricate and evaluate an alternative electrode, and identify and select advanced technology improvements (for development in other programs outside the contract) for incorporation and verification testing in the 200-kW Verification Test Article (VTA) built under contract DE-AC21-88MC24222.

The following reports were submitted during the quarter:

- Technical Progress Report No. 1 for April/May (FCR-9726) was submitted on July 24, 1988.
- Quarterly Technical Progress Report for April-May-June (FCR-9779) was submitted on August 12, 1988.
- Technical Progress Report No. 3 for July (FCR-9785) was submitted on August 24, 1988.
- Cost Management Report No. 1 for April/May (FCR-9703) was submitted on July 15, 1988.
- Cost Management Report No. 2 for June (FCR-9748) was submitted on July 25, 1988.
- Cost Management Report No. 3 for July (FCR-9784) was submitted on August 25, 1988.
- Cost Management Report No. 4 for August (FCR-9827) was submitted on September 27, 1988.

END

DATE FILMED

3 /29/ 93