FOSSIL ENERGY

MOLTEN CARBONATE FUEL CELL TECHNOLOGY IMPROVEMENT

Quarterly Technical Progress Report No. 17
For Period Ending May 1989

FCR-10541

Program Manager: W. H. Johnson

September, 1989

Work Performed Under Contract No.
DE-AC21-87MC23270

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

By
International Fuel Cells Corporation
South Windsor, Connecticut

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INTRODUCTION

This report summarizes the technical work performed under Department of Energy Contract DE-AC21-87MC23270, "Molten Carbonate Fuel Cell Technology Improvement," during the period March 1, through May 31, 1989. This work now consists of four technical tasks resulting from Modification A001 to the Contract dated February 24, 1988. The original contract was comprised of Task 1, Development of Improved Molten Carbonate Fuel Cell, which is a technology effort to increase cell performance and reduce materials cost. The modification A001 adds three technical Tasks. Task 2, Stack Technology, will include the design, fabrication, assembly, and test of a 200 cell, 1-ft^2 stack. Task 3, Determination of MCFC and Power Plant Subsystem Technology Development Requirements for Competitive CF/MCFC Power Plant, will conduct systems analysis work to identify and define competitive power plant cost goals, optimum CG/MCFC and the related MCFC stack. Task 4, MCFC Performance and Cost Enhancement, will pursue additional increases in cell performance and further cell stack cost reduction.

Task 1.0 and Subtasks 2.1, 2.2, ,3.2,, 4.1, and 4.2 continued during this reporting period and Subtasks 2.3 and 2.4, were started. A brief description of each task follows.

TASK 1 - DEVELOPMENT OF IMPROVED MOLTEN CARBONATE FUEL CELL

Subtask 1.3 - Design of Improved MCFC Cells - will define improved cell designs directed toward meeting the performance, life, and cost goals of this contract. Two cell designs, one for the interior cells of a stack, and one for the cells at both ends of a stack, will be conducted. Cell design requirements will be established and used for generating the improved cell component designs. Preliminary designs for the anodes, cathodes, matrices, electrolyte reservoirs, and reactant flow field distribution components will be generated to guide the process development efforts in Subtasks 1.4 through 1.7. Feedback from these subtasks will be assessed and integrated to modify the designs as required. Data from integrated single cell testing (Subtask 1.8) shall be used to establish the final design specifications for each cell component.

Subtasks 1.4 Through 1.7 - Development of Improved Matrices, Anode-Side Components, Cathode-Side Components, and End-Cell Reservoirs - will develop improved components for interior cells and end-cells using new materials and configurations defined in the design subtask. These subtasks provide input to the design subtask in terms of component fabricability and scale-up, physical property measurements, and out-of-cell and single cell test results. The output of these subtasks will be definition of scalable processes for fabricating components meeting design requirements and specifications.

Subtask 1.8 - Single Cell Testing of Improved Anode and Cathode Components Integrated into One Cell - evaluates the anodes, cathodes, and matrices developed in Subtasks 1.4 through 1.6 in integrated single cell tests. These tests will determine cell component interactions and provide data for assessment in Subtask 1.3. Post-test analyses will be conducted to verify design requirements are met.

TASK 2 - STACK TECHNOLOGY

Subtask 2.1 - Stack Design - will define stack component and hardware specifications and prepare construction drawings for a 5-20 cell short stack and a 200 cell tall stack of 1-ft^2 cell plan area. The stack test data from Subtask 2.4 will be assessed relative to the design objectives.

Subtask 2.2 - Stack Repeat Component Fabrication - will fabricate matrices, anodes, cathodes, electrolyte reservoirs, gas field supports, and separator plates of 1-ft^2 planform for the 5-20 cell short stack and 200 cell tall stack.

Subtask 2.3 - Stack Non-Repeat Hardware and Assembly - will fabricate the non-repeating hardware, and assemble the 5-20 cell short stack and 200 cell tall stack. Assembly checks and inspections will be conducted to verify the stack is ready for testing.

Subtask 2.4 - Stack Test and Analysis - will conduct a short stack test for up to 500 hours and a tall stack test for up to 2000 hours duration. Testing and post test analyses will confirm design requirements of the improved cell design were met.

TASK 3 - DETERMINATION OF COMPETITIVE CG/MCFC POWER PLANT AND TECHNOLOGY DEVELOPMENT REQUIREMENTS

Subtask 3.1 - Define Competitive non-fuel Cell Power Plant Characteristics - evaluates competing, coal-fueled, non-fuel cell electric generating systems using a developed and approved set of evaluation criteria which addresses electric utility requirements. The criteria is used to select the most competitive non-fuel cell power plant system which in turn establishes goals for a CG/MCFC power plant.

Subtask 3.2 - Identify Optimum CG/MCFC Power Plant and Determine MCFC and Power Plant Subsystems Technology Requirements - identifies an optimum CG/MCFC power plant that meets or exceeds goals established from the non-fuel cell studies in Task 3.1. The optimum CG/MCFC is analyzed for adaptation to allow use of alternative fuel. Technology development requirements required for the optimum CG/MCFC will be determined.

Subtask 3.3 - Systems Analysis Topical Report - provides a comprehensive report of all the competitive, non-fuel cell systems studies and the optimum CG/MCFC Power Plant System Studies.

Subtask 3.4 - System Review - provides input and guidance to the program from several electric utility companies, particularly those who would have specific interest in coal fueled power plants.

TASK 4 - MCFC PERFORMANCE/COST ENHANCEMENT

Subtask 4.1 - Improve Cell Performance - will improve cell performance by reducing cell internal resistance and cathode polarization, and increasing open circuit voltage. Cell durability will be improved by reducing electrolyte transport in the manifold seal.

Subtask 4.2 - Reduce Cell Cost - will reduce the cost of sheet metal repeat parts. Lower cost stainless steel will be substituted for the INCO 825 presently used. Cost effective processes for applying protective coatings to sheet metal components will be developed.

Subtask 4.3 - Integrated Cell Test - will evaluate the cell components developed in Subtasks 4.1 and 4.2 in integrated single cell tests. Post test analyses will be conducted to verify design objectives are met.

ABSTRACT

This report summarizes the work performed under Department of Energy Contract DE-AC21-87MC23270 during the period March 1, through May 31, 1989. The overall objective of this program is to define a competitive CG/MCFC power plant and the associated technology development requirements and to develop an improved cell configuration for molten carbonate fuel cells which has improved performance, has reduced cell creep and electrolyte management consistent with 40,000 hour projected life, reduces existing cell cost, and is adaptable to a range of power plant applications.

Component design specifications for the end-cells of the alternative cell configuration were completed.

Testing to evaluate new components was performed on 14 cells during this reporting period with eight tests started and terminated, and six tests continuing into the next reporting period. A test and performance summary of all the single cell tests conducted to date on this program is presented in Table 1.

A single cell test to qualify new matrix materials and matrix reinforcement was successfully completed.

Integrated cell testing of new anode- and cathode-side components was completed.

Single cell tests were conducted to identify the electrolyte fill procedure for the new cell configuration.

Methods of fabricating manifold seals from the new candidate materials are being developed.

Preparation of construction drawings for the 1-ft^2 short stack was continued.

Fabrication of repeating cell components for the 1-ft^2 short stack was initiated. Trials to tape cast electrodes and matrices were initiated, tooling to form current collectors is being fabricated, and existing tooling to form separator plates is being modified.

Non-repeat components from the previous 1-ft^2 short stack that are acceptable for re-use were identified. New non-repeat components that are required have been ordered.

Preparation of the test stand for the 1-ft^2 short stack test was initiated.

Table 1. Cell Test and Performance Summary

Cell No.	Sub-Task No.	Date Started	Date Terminated	Conditions of Test	Purpose of Test	Results	1 ATM 100 ASF (107 ma/cm²) Peak[1] Cell Volts (MV)	1 ATM 100 ASF (107 ma/cm²) Internal Resistance (MV)	6.8 ATM 160 ASF (172 ma/cm²) Peak[2] Cell Volts (MV)	6.8 ATM 160 ASF (172 ma/cm²) Internal Resistance (MV) at 100 ASF
624		12–18–87	1–11–88	A	Stand Checkout		790	56	–	–
625	1.4	1–7–88	3–11–88	A,P, S	Control cell for shorting test	Cell used for stand checkout	804	29	806	34
626		1–14–88	2–26–88	A	Determine electrode polarizations with ref. electrode	Ref. electrode data not valid	770	68	–	–
627	1.4	1–26–88	3–21–88	A, P, S	Control cell for shorting test	Shorted in 369 hours	806	39	827	39
628	1.4	2–2–88	3–31–88	A, P	Matrix Evaluation	Good	804	42	805	42
629	1.6	2–12–88	2–23–88	A	Measure performance of Config. A cathode	Performance poor.	781	47	–	–
630		2–22–88	4–4–88	A	Determine electrode polarizations with ref. electrode	Polarizations defined	800	43	–	–
632	1.5	2–25–88	7–22–88	A	Measure performance of Config. B anode	Performance good	800	46	–	–
633	1.4	3–4–88	4–7–88	A,P,S	Evaluate Config. A matrix in shorting test	Time to short reduced	831	29	821	30
634	1.6	3–9–88	4–14–88	A	Measure performance of Config. A cathode	Diffusional resistance present	800	52	–	–
635	1.6	3–15–88	4–19–88	A	Measure performance of Config. C cathode	Performance good	807	35–65	–	–

Table 1. Cell Test and Performance Summary

							1 ATM 100 ASF (107 ma/cm²)		6.8 ATM 160 ASF (172 ma/cm²)	
Cell No.	Sub-Task No.	Date Started	Date Terminated	Conditions of Test	Purpose of Test	Results	Peak[1] Cell Volts (MV)	Internal Resistance (MV)	Peak[2] Cell Volts (MV)	Internal Resistance (MV) at 100 ASF
636	1.4	3–21–88	5–4–88	A, P, S	Evaluate effect of Config. B matrix on shorting	No effect on shorting time	815	43	829	29
637	1.4	3–31–88	4–29–88	A, P, S	Evaluate effect of $SrCO_3$ electrolyte on shorting	Time to short reduced	811	49	790	33
638	1.5	4–15–88	5–24–88	A	Measure performance of Config. C anode	Performance good	802	35	–	–
639	1.8	4–15–88	5–27–88	A	Integrated cell	Long time to reach peak performance	744	51	–	–
640	1.4	4–22–88	5–12–88	A, P	Evaluation effect of Li_2CO_3/Na_2CO_3 electrolyte on shorting	Test terminated	< 821	25	< 840	24
641	1.6	5–3–88	6–7–88	A, P, S	Measure performance of Config. C cathode and shorting	Performance good	815	40	809	41
642	1.5	5–20–88	6–20–88	A	Measure performance of Config. D anode	Performance good	804	37	–	–
643	1.6	5–18–88	6–2–88	A	Measure performance of Config. C cathode with broader pore spectrum	Performance low	737	59	–	–

Table 1. Cell Test and Performance Summary

Cell No.	Sub-Task No.	Date Started	Date Terminated	Conditions of Test	Purpose of Test	Results	1 ATM 100 ASF (107 ma/cm^2) Peak[1] Cell Volts (MV)	1 ATM 100 ASF (107 ma/cm^2) Internal Resistance (MV)	6.8 ATM 160 ASF (172 ma/cm^2) Peak[2] Cell Volts (MV)	6.8 ATM 160 ASF (172 ma/cm^2) Internal Resistance (MV) at 100 ASF
644	1.4	6-1-88	7-18-88	A, P, S	Evaluate effect of $SrCO_3$ electrolyte on shorting time	Time to short reduced	829	36	813	35
645	1.4	6-3-88	7-7-88	A, P, S	Evaluate effect of Li_2CO_3/Na_2CO_3 electrolyte and Config. C cathode on shorting	Time to short reduced	790	35	808	30
646	1.4	6-6-88	7-22-88	A, P, S	Evaluate effect of Li_2CO_3/Na_2CO_3 electrolyte on shorting	Shorted in expected time	827	25	826	24
647	1.8	6-14-88	7-13-88	A, P	Integrated cell	Performance good	814	37	807	34
648	1.6	6-22-88	7-12-88	A	Measure performance of Config. C cathode	Performance fair	794	61	-	-
649	1.5	7-6-88	10-4-88	A	Measure performance of Config. D anode (repeat of 642)	Anode performance good	795	52	-	-
650	1.4	7-12-88	8-17-88	A	Evaluate reinforced matrix	Performance good	835	34	-	-
651	1.6	7-24-88	10-26-88	A	Measure performance of Config. C cathode (repeat of cell 648)	Performance good	812	50	-	-
652	1.6	8-3-88	10-7-88	A	Measure performance of modified Config. B cathode	Performance high	824	50	-	-

Table 1. Cell Test and Performance Summary

Cell No.	Sub-Task No.	Date Started	Date Terminated	Conditions of Test	Purpose of Test	Results	1 ATM 100 ASF (107 ma/cm^2) Peak[1] Cell Volts (MV)	1 ATM 100 ASF (107 ma/cm^2) Internal Resistance (MV)	6.8 ATM 160 ASF (172 ma/cm^2) Peak[2] Cell Volts (MV)	6.8 ATM Internal Resistance (MV) at 100 ASF
653	1.5	8–9–88	11-9-88	A	Measure performance of Config. D anode with broad pore spectrum and reference electrode	Anode performance good Polarizations defined	800	53	–	–
654	1.6	8–12–88	9-27-88	A	Measure performance of alternative cathode structure	Performance low	678	78	-	-
655	1.8	8–24–88	9-30-88	A	Integrated cell	Performance fair	782	49	-	-
656	1.4	8–22–88	9-21-88	A,P,S	Evaluate effect of 250 ASF on shorting	Shorted in expected time	824	39	-	-
657	1.4	8–31–88	11-30-88	A,P,S	Evaluate effect of 0 ASF on shorting	Time to short extended	817	44	811	35
658	1.4	9-2-88	10-6-88	A,P,S	Evaluate effect of increased matrix thickness on shorting time	Time to short reduced	806	63	785	60
659	1.4	9-15-88	11-2-88	A,P,S	Evaluate effect of Li_2CO_3/Na_2CO_3 electrolyte on shorting	Time to short increased	807	32	770	57
660	1.6	10-5-88	11-2-88	A	Measure compaction of Config. C cathode	Low compaction	750	82	-	-
661	1.4	10-3-88	11-11-88	A,P,S	Effect of reinforced matrix on shorting time	Time to short not affected	817	46	821	46

Table 1. Cell Test and Performance Summary

Cell No.	Sub-Task No.	Date Started	Date Terminated	Conditions of Test	Purpose of Test	Results	1 ATM 100 ASF (107 ma/cm²) Peak[1] Cell Volts (MV)	1 ATM 100 ASF (107 ma/cm²) Internal Resistance (MV)	6.8 ATM 160 ASF (172 ma/cm²) Peak[2] Cell Volts (MV)	6.8 ATM 160 ASF (172 ma/cm²) Internal Resistance (MV) at 100 ASF
662	1.4	10-11-88	4-13-89	A,P	Shorting time at less accelerated conditions	Shorted near expected time	836	44	842	33
663	1.8	10-19-88	11-23-88	A, P	Integrated cell	Performance good	803	80	770	76
664	1.5	10-24-88	1-18-89	A	Measure performance of modified Configuration D anode	Performance high	828	33	-	-
665	1.4	11-10-88	12-8-88	A	Evaluate alternative matrix strain distributor material	Build problem	790	33	-	-
666		12-1-88	12-8-88	A	Integrated cell	Build problem	622	185		
667		12-2-88	12-13-88	A	Effect of Config. B cathode on shorting time	Build problem	802	38		
668	1.4	12-6-88	1-12-89	A	Evaluate alternative $LiAlO_2$ matrix material	Performance high	827	36	-	-
669	1.4	12-7-88	3-10-89	A	Evaluate alternative matrix strain distributor material	Performance high	831	39	-	-
670	1.4	12-14-88	1-10-89	A,P,S	Effect of Cs_2CO_3 electrolyte additive on shorting time	Time to short reduced	828	36		
671	1.8	12-20-88	1-10-89	A	Integrated Cell	Initial performance fair, sudden performance loss	796	52		

Table 1. Cell Test and Performance Summary

Cell No.	Sub-Task No.	Date Started	Date Terminated	Conditions of Test	Purpose of Test	Results	1 ATM 100 ASF (107 ma/cm²) Peak[1] Cell Volts (MV)	1 ATM 100 ASF (107 ma/cm²) Internal Resistance (MV)	6.8 ATM 160 ASF (172 ma/cm²) Peak[2] Cell Volts (MV)	6.8 ATM 160 ASF (172 ma/cm²) Internal Resistance (MV) at 100 ASF
672	1.4	1–13–88	4-17-89	A	Evaluate alternative matrix material, strain distributor	Performance high	847	25		
673	1.8	1–18–89	2–24–89	A,P	Integrated Cell	Performance good	818	48	826	40
674	1.8	1–25–89	2–16–89	A	Integrated Cell	Performance low	698	63		
675	1.4	1–25–89	3-7-89	A	Evaluate alternative matrix material, strain distributor, matrix reinforcement.	Performance high	845	25		
676	1.8	2–2–89	4-28-89	A,P	Integrated cell	Performance low	796	59	804	38
677	1.7	2–8–89	5-9-89	A,P	End cell reservoir	Performance low	700	66	682	45
678	4.1	2–10–89	3-22-89	A,P,S	Effect of Conf. B cathode on shorting time	Time to short not changed	807	32	850	44
679	4.1	4–4–89	5-15-89	A,P,S	Effect of Rb_2CO_3 electrolyte additive on shorting time	Time to short not changed	844	25	860	22
680	1.8	2–22–89	2-28-89	A	Integrated cell	Shut down due to low performance	640	62		
681	2.2	3–7–89	3–23–89	A	Evaluate matrix	Performance low	764	80		
682	4.2	3–9–89	3–22–89	A	Evaluate matrix	Performance fair	792	67		

Table 1. Cell Test and Performance Summary

Cell No.	Sub-Task No.	Date Started	Date Terminated	Conditions of Test	Purpose of Test	Results	1 ATM 100 ASF (107 ma/cm²) Peak[1] Cell Volts (MV)	1 ATM 100 ASF (107 ma/cm²) Internal Resistance (MV)	6.8 ATM 160 ASF (172 ma/cm²) Peak[2] Cell Volts (MV)	6.8 ATM 160 ASF (172 ma/cm²) Internal Resistance (MV) at 100 ASF
683	4.2	3–15–89	4–11–89	A,P	Evaluate 310 S.S. anode-side components	Performance good	800	49	806	31
684	4.2	3–28–89	5–25–89	A	Evaluate lower cost aluminizing process	Performance high	844	25		
685	4.1	4–5–89	4–7–89	A	Fill and start procedure	No performance taken	-	-		
686	4.1	4–10–89	4–27–89	A	Fill and start procedure	Performance good	804	46		
688	4.1	4–19–89	4–26–89	A	Fill and start procedure	Would not hold load				
689	1.8	5–3–89	5–8–89	A	Fill and start procedure	Performance low	729	60		
690	1.8	5–4–89	5–9–89	A	Fill and start procedure	Low open circuit voltage	758	106		

A – Ambient Conditions (1 ATM, 1200_F, GF-2, ROX-1**)*
P – Pressurized Conditions (6.8 ATM, 1200_F, GF-2, ROX-1)
S – Accelerated Testing Conditions (10 ATM, 1200_F, GF-2, 90% CO2/10% O2)

* *GF-2 Fuel contains 29.4% H2, 5.5% CO, 17.5% CO2, 47.5% H2O*

** *ROX-1 Oxidant contains 8.7% O2, 18.1% CO2, 65.7% N2, 7.4% H2O*

1. Fuel: GF-2, H2 + CO utilization 23% (57% at 250 ASF)
   Oxidant: ROX-1, CO2 utilization 9% (25% at 250 ASF)

2. Fuel: GF-2, H2 + CO utilization 36% (57% at 250 ASF)
   Oxidant: ROX-1, CO2 utilization 16% (25% at 250 ASF)

3. Based on corrected active area

TASK 1.0 DEVELOPMENT OF IMPROVED MOLTEN CARBONATE FUEL CELL

SUBTASK 1.3 - DESIGN OF IMPROVED MCFC CELLS

Objective

The objective is to design a cell configuration that meets the specific performance and life goals outlined below. The design activities include defining cell component requirements and specifications, supported by analytical studies and assessment of data generated in integrated cell tests, component cell tests, and out-of-cell tests.

- $\geq$ 0.717 volts at 250 amps-per-square foot performance using an oxygen-blown Texaco coal gasifier fuel at 85 percent utilization, operating at 100 psia.
- $\leq$ 4 mils of cell creep in 40,000 hours of projected stack life.
- Electrolyte management consistent with a 40,000-hour projected life for 8-ft^2 cells.
- Maintain existing cost associated with materials fabrication and assembly of cells and stack.
- Reactant flow distribution components that are readily adaptable to a broad range of power plant applications.

Report of Work Accomplished

The design specifications for the selected end-cell reservoir configuration were completed. This design utilizes a conductive reservoir material and is configured to have improved performance relative to the end-cell reservoir tested in Cell No. 677. This cell test is discussed in Subtask 1.7.

Work Planned For Next Reporting Period

- Work in this subtask is completed.

SUBTASK 1.4 - DEVELOPMENT OF IMPROVED MATRICES

Objective

Develop matrices that incorporate alternative materials and define low cost, scalable fabrication processes.

Report of Work Accomplished

Process development work was completed previously. The final single cell tests to evaluate alternative matrix materials were completed during this quarter.

Process Development

Process development activity in the subtask was completed in the previous quarter. Activity to tape cast large area matrices is reported in Subtask 2.2, Stack Repeat Component Fabrication.

Single Cell Testing

Single cell testing was completed to evaluate matrices fabricated with alternative materials. The alternative materials include a new supply of lithium aluminate and a new strain distributor material. The final single cell test was conducted to evaluate the new matrix materials combined with the matrix reinforcement that was qualified previously.

Cell No. 669 (a repeat of Cell No. 655) was started during the previous quarter to evaluate a matrix containing an alternative strain distributor material. The performance of Cell No. 669 was very good (831 mV at 100 ASF, 1 ATM). After 2000 hours of testing, which included three shutdown cycles, there was no significant change in open circuit voltage or cell cross leakage (Table 1.4-1).

Cell No. 672 was started during the previous quarter to evaluate a matrix fabricated from a combination of the new lithium aluminate and strain distributor materials. Testing was completed this quarter after 2180 hours of load time. This cell had the highest performance to date (847 mV at 100 ASF and 1 ATM) and a low internal resistance (25 mV at 100 ASF). The cell diagnostics in Table 1.4-1 indicate good matrix integrity.

Cell No. 675 was started during the previous quarter to evaluate the new matrix materials (lithium aluminate and strain distributor) in combination with matrix reinforcement. The performance of this cell was essentially the same as Cell No. 672. Peak performance measured 845 mV at 100 ASF, 1 ATM with an internal resistance of 25 mV at 100 ASF. The cell was subjected to two shutdown cycles. The low gas crossover leakage (Table 1.4-1) verifies the acceptability of this matrix configuration.

Work Planned For Next Reporting Period

- Work in this subtask is completed.

Table 1.4-1. Cell Diagnostics

Cell	Load Time (Hrs.)	Cell Cross Leakage (CCM at 5 in. H_2O Cross Pressure)	Open Circuit Relative to Theoretical (mV)
669	155	—	0
		Cool Cell to 800°F and Reheat	
	189	0	0
	275		0
		Cool Cell to 150°F and Reheat	
	292	0	0
	604		0
		Cool Cell to 150°F and Reheat	
	645	8.0	0
	1228		0
	1820		0
	2095	0	
	2132		0
	2137	Shutdown	
672	136	—	0
	291	3.2	0
	760	—	0
	928	—	0
	1264		0
	1600		0
	1936		0
	2135	5.6	0
	2181	Shutdown	
675	301	0	-6
		Cool Cell to 150°F and Reheat	
	316	5	-7
	580		-6
		Cool Cell to 150°F and Reheat	
	597	4	-10
	717		-11
	860		-10
	864	Shutdown	

SUBTASK 1.5 - DEVELOPMENT OF ANODE-SIDE COMPONENTS

Work in this subtask is completed.

SUBTASK 1.6 - DEVELOPMENT OF CATHODE-SIDE COMPONENTS

Work in this subtask is completed.

SUBTASK 1.7 - DEVELOPMENT OF END-CELL RESERVOIRS

Objective

Develop an electrolyte reservoir for end-cells which extends the projected life of stacks to 40,000 hours by providing additional reservoir capacity in those cells that experience a considerable change in electrolyte inventory due to migration from the positive to the negative end of the stack. The performance penalty of a cell operating with this increased reservoir capacity should not exceed 50 mV/250 ASF throughout its projected life.

Report of Work Accomplished

Three end-cell reservoir designs were defined previously. One of the designs utilizes a non-conductive electrolyte reservoir material and two designs utilize a conductive material. Previous single cell tests (Cell Nos. 666 and 674) showed the design with a non-conductive reservoir material to be unacceptable.

Cell No. 677 was started during the previous quarter to evaluate the second end-cell reservoir design. This was the first of the two end-cell reservoir designs with a conductive reservoir material. The peak performance of this cell was very low at 700 mV at 100 ASF, 1 ATM with an iR of 66 mV. The end-cell reservoir in this cell caused a high anode polarization and the design is not considered acceptable.

Fabrication of components for the second design with a conductive reservoir material is in progress.

Work Planned For Next Reporting Period

- Complete components for the third end-cell reservoir design.
- Evaluate in single cell test.

SUBTASK 1.8 - SINGLE CELL TESTING OF IMPROVED ANODE AND CATHODE COMPONENTS INTEGRATED INTO ONE CELL

Objective

The objective is to combine the cell components being improved individually under Subtasks 1.4 through 1.6 into integrated bench-scale cells, and test and analyze these cells in order to compare their data for compliance to the design objectives established for interior cells in Subtask 1.3.

Report of Work Accomplished

Testing of three integrated cells was conducted during this reporting period.

The ninth integrated cell (Cell no. 676) was continued from the previous quarter. This cell contained Configuration D anode-side components and Configuration D cathode-side components, and a matrix fabricated with the alternative materials. This cell was similar to the seventh integrated cell (No. 673) except for the electrolyte content and alternative matrix materials. The performance of this cell was initially low, but continued to increase throughout most of the 1900 hour test. Peak performance was 796 mV at 100 ASF, 1 ATM with an iR of 59 mV. The improving electrode performance confirmed the electrode flooding that was suspected in the previous quarterly report. The performance history of cell No. 676 is shown in Figure 1.8-1.

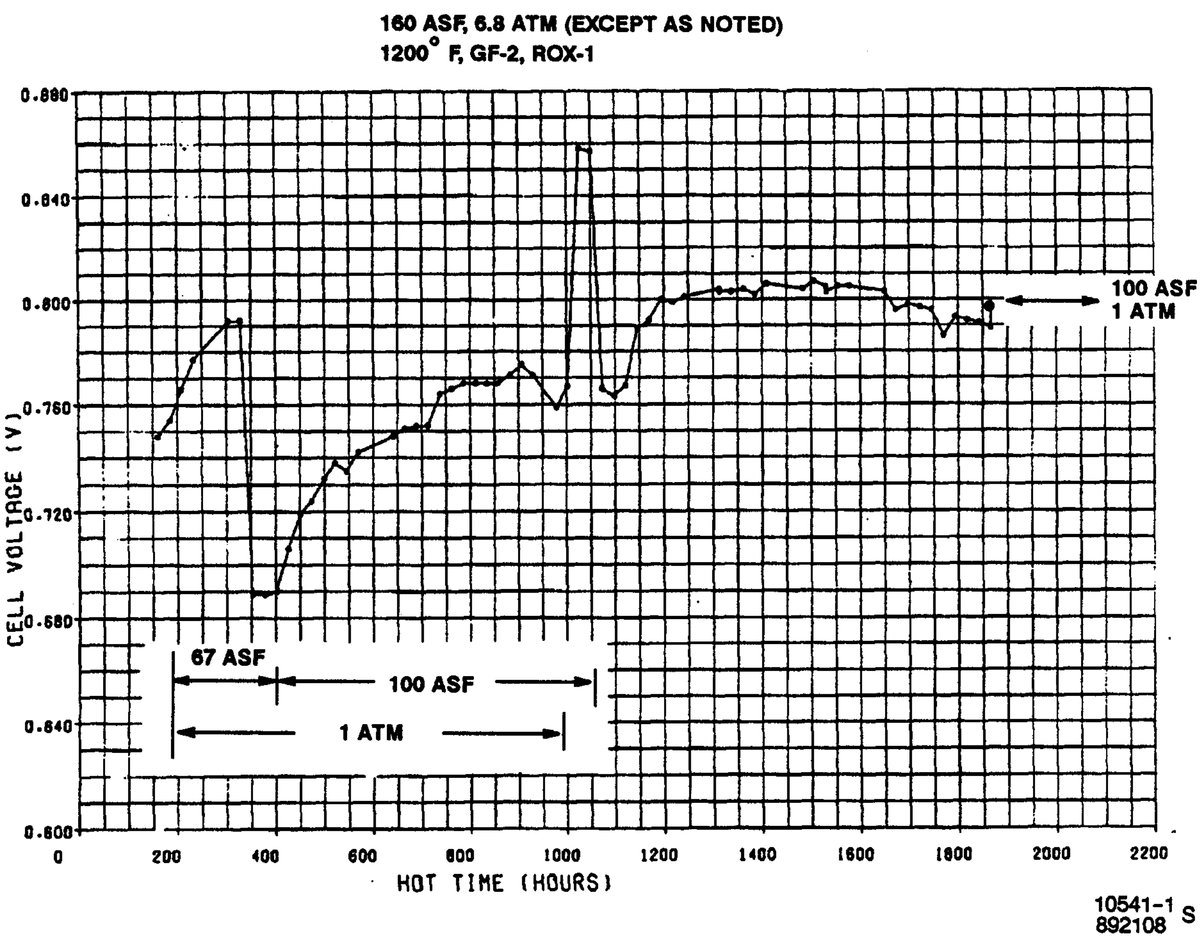

Figure 1.8-1. Performance History of Cell No. 676 (Ninth Integrated Cell)

The tenth integrated cell (No. 680) completed testing in February and results were included in the previous quarterly report.

The eleventh and twelfth integrated cells (Nos. 689 and 690) were conducted to define the electrolyte fill and start-up procedures for the new cell configuration. These cells are reported in Subtask 4.1 along with additional cells tested to define the electrolyte fill and start-up procedures.

Work Planned For Next Reporting Period

- Cell testing in this Subtask is completed.

TASK 2.0 - STACK TECHNOLOGY

SUBTASK 2.1 - STACK DESIGN

Objective

Prepare a set of construction drawings for a 5-20 cell short stack and a 200 cell tall stack of subscale cells that will incorporate the interior cell and end-cell designs completed in Subtasks 1.3 through 1.7. The tall stack design will address the issues associated with height by testing a subscale stack of 200 cells with each cell being approximately 1-ft^2 in plan area. The stack component and hardware specifications will be defined and the stack test data from Subtask 2.4 will be assessed relative to the design objectives.

Report of Work Accomplished

Work was continued to prepare construction drawings for the 1-ft^2 short stack. The design of the last 1-ft^2 short stack in the previous program was reviewed last quarter to identify non-repeat stack hardware that could be re-used or duplicated from existing drawings. New drawings were found to be required for the following non-repeat stack hardware.

- Manifold seal
- Manifold load bars
- Thermal Insulation

The new drawings for the manifold load bars were completed first, since these are long lead time parts. The drawings for the thermal insulation and manifold seal will be completed next.

The following construction drawings for the cell repeat components of the new cell configuration were completed.

- Current collectors
- Separator plates
  - -Interior reservoir cell
  - -Cathode end-cell
  - -Anode end-cell

Construction drawings are nearly completed for the following cell repeat components.

- Anode
- Cathode
- Matrix
- End-cell reservoirs

Work Planned for Next Reporting Period

- Complete construction drawings for 1-ft^2 short stack.
- Initiate construction drawings for 1-ft^2 200 cell tall stack.

SUBTASK 2.2 - STACK REPEAT COMPONENT FABRICATION

Objective

Fabricate stack matrices, anodes, cathodes, current collectors, separator plates and end-cell reservoirs of 1-ft^2 planform area meeting the design specifications of Subtask 1.3. Conduct out-of-cell tests, single-cell tests, and an interim short stack test of 5-20, 1-ft^2 cells for up to 500 hours and confirm compliance with the design requirements for these components.

Report of Work Accomplished

Activity during this reporting period included processing trials to tape cast electrodes and matrices and fabrication of tooling for forming current collectors..

Anode, Cathode, and Matrix

Trials were initiated to cast anode, cathode, and matrix tapes using an automated tape casting machine capable of producing parts for a 1-ft^2 short stack. The objective of the initial trials was to establish parameters such as casting speed and drying conditions.

A matrix casting trial produced tape that met specifications for thickness, porosity, and pore size distribution. Matrices from this trial are being used in single cell tests.

The initial trials cast anodes and cathodes resulted in tapes which contained some cracking after drying. The slurry formulations for the anodes and cathodes are being modified to improve the quality of the dried tapes

Sheet Metal Components

The design of the tooling for forming large area current collectors was completed and tooling fabrication is underway. The tooling is scheduled to be ready for trials by early July.

Fabrication of separator plates for the 1-ft^2 short stack was started. The separators will be made using tooling from the previous program. The tooling is being modified to meet the flange heights for the new cell configuration.

Work Planned for Next Reporting Period

- Conduct fabrication of repeat cell components for 1-ft^2 short stack.

SUBTASK 2.3 - STACK NON-REPEAT HARDWARE AND ASSEMBLY

Objective

Fabricate all required non-repeating hardware and assemble the interim short stack and the tall stack of 1-ft^2 planform area cells as specified in Subtask 2.1. Prepare the facilities for assembling the stack and conduct inspections and checkout.

Report of Work Accomplished

Inspection of the major non-repeat hardware previously used in the test of last 1-ft^2 short stack in the previous program (DOE no.4) was completed. The four reactant manifolds, both end-plates and the heater plates were cleaned prior to inspection. All components were acceptable for re-use in the 1-ft^2 short stack. The aluminized surfaces on the end-plates and the manifolds were also judged to be acceptable for use without any additional processing. Machining to remove broken manifold load bar bolts (broken during the disassembly of DOE No.4) from the edge of the heater plates was completed and those parts are now acceptable for use.

The balance of the required non-repeat stack parts have been ordered. These include alumina insulator components, manifold load bars, and other minor parts.

Work Planned for Next Reporting Period

- Continue non-repeat hardware preparation.
- Prepare fixtures and tooling for stack assembly.

SUBTASK 2.4 - STACK TEST AND ANALYSIS

Objective

Confirm design requirement compliance in an interim short stack test for up to 500 hours and verify the improved technology cell design in a 200 cell stack test of up to 2000 hours duration.

Report of Work Accomplished

Activity was initiated to prepare the test stand for testing the 1-ft^2 short stack. An assessment of the start-up and operating requirements for the stack showed that the test stand would be essentially unchanged from previous testing. The stand preparation will consist of normal calibration, maintenance and pre-test checkout of all systems. Prior to starting these activities, new electronic pressure and flow controllers will be installed to provide improved control stability relative to the previously used pneumatic controllers.

Work Planned for Next Reporting Period

- Complete preparation of test stand for short stack test.
- Prepare Test Plan.
- Initiate test of short stack.

TASK 3.0 - DETERMINATION OF MCFC AND POWER PLANT SUBSYSTEM TECHNOLOGY DEVELOPMENT REQUIREMENTS FOR COMPETITIVE COAL FUELED/MOLTEN CARBONATE FUEL CELL (CF/MCPC) POWER PLANT

Progress for this Task has been reported in the Topical Report Draft (FCR- 9822).

TASK 4.0 - CELL DEVELOPMENT AND DEMONSTRATION

SUBTASK 4.1 - IMPROVE CELL PERFORMANCE

The objective of this subtask is to develop a cell configuration that meets the specific performance and durability level defined in Task 3 and be competitive with alternative power generation systems. To increase the performance, the cell internal resistance and cathode polarization will be reduced and the open circuit voltage increased. To increase durability, electrolyte transport will be decreased.

Report of Work Accomplished

Activity during this reporting period included single cell testing to evaluate the effect of new cell components and electrolyte changes on shorting due to NiO dissolution, and continued development of an improved manifold seal to reduce electrolyte transport. These activities were previously reported in Subtask 1.4.

Single Cell Testing to Measure Shorting Time

Two single cell accelerated shorting tests were conducted to evaluate a Configuration D cathode and an electrolyte change on the time at which shorting occurs due to nickel oxide dissolution. These were Cell Nos. 678 and 679. The results of these cell tests and tests conducted previously to study matrix, electrolyte, and cathode changes are shown in Table 4.1-1.

Cell No.678 was tested to measure the time before shorting for a Configuration D cathode. A loss of fuel mixture control occurred at about the same time as shorting occurred. The best estimate of shorting time is 215 hours. The estimated shorting time is 226 hours which is in good agreement with the measured value.

Cell No. 679 was tested to evaluate an electrolyte with rubidium carbonate added to the lithium carbonate-potassium carbonate electrolyte. This cell shorted at a time about 20 percent longer than a standard cell without the electrolyte addition.

Table 4.1-1. Summary of Cell Accelerated Shorting Data

Cell No.	Description	Estimated Time-to-Short for Standard Cell (Hours)	Measured Time-to-Short (Hours)	Ratio Measured Estimated
627	Control Cell	297	369	1.24
633	Config. A Matrix	287	147	0.51
636	Config. B Matrix	255	310	1.22
637	$SrCO_3$ Added to Electro-lyte	264	198	0.75
641	Li/K Electrolyte Config. C Cathode	299	181	0.61
644	$SrCO_3$ Added to Electro-lyte	424	304	0.72
645	Li/Na Electrolyte Config. C Cathode	308	177	0.58
646	Li/Na Electrolyte	308	276	0.90
656	Effect of 250 ASF Operation	225	198	0.88
657	Effect of Open Circuit Op-eration	546	1558	2.85
658	Effect of Thicker Matrix	595	384	0.65
659	Li/Na Electrolyte	252	445	1.77
661	Li/Na Electrolyte (Higher Li content)	300	395	1.32
670	$Cs_2 CO_3$ Added to Electrolyte	304	148	0.49
678	Effect of Configuration D cathode on shorting time	226	215	0.95
679	$Rb_2 CO_3$ added to Electrolyte	322	390	1.21

Cell Electrolyte Fill and Start-up Procedure

A series of single cell tests was conducted to identify the most effective electrolyte fill and start-up procedure for the new cell configuration in terms of cost and cell performance. These cells were Nos. 685, 686, 688, 689, and 690. An electrolyte fill and start-up procedure was selected based on the results of these cell tests. Additional cells will be tested to confirm the selected electrolyte fill and start-up procedure and determine the electrolyte fill tolerance for the new cell configuration

Development of Improved Manifold Seal

Work was continued to develop a manifold seal that would provide increased resistance to the migration of electrolyte from the positive to negative end of the stack.

Methods of fabricating the bonded ceramic manifold seal materials being developed in this subtask were evaluated. One method consists of making a aqueous caulk, applying the caulk to the cell stack assembly, and allowing the binder in the caulk to flow during stack heat-up. Another method being considered is to flame spray the seal material.

Manifold seal samples fabricated by the two methods were evaluated. Pore spectra analysis showed reduced microporosity in the flame sprayed seal. The amount of large pores was the same for both seal fabrication methods.

The electrolyte transport characteristics of seals fabricated by the two methods were measured under an imposed voltage gradient in the electrolyte transfer rig. The electrolyte transfer (shunt current density) as a function of electrolyte fill level of the seals is shown in Figure 4.1-1. The flame sprayed seal and caulk seal have essentially the same electrolyte transport behavior. Both seals have lower electrolyte transport than a zirconia felt control sample.

Work Planned for Next Reporting Period

- Conduct single tests to define electrolyte fill tolerance for new cell configuration.
- Continue development of improved manifold seal.

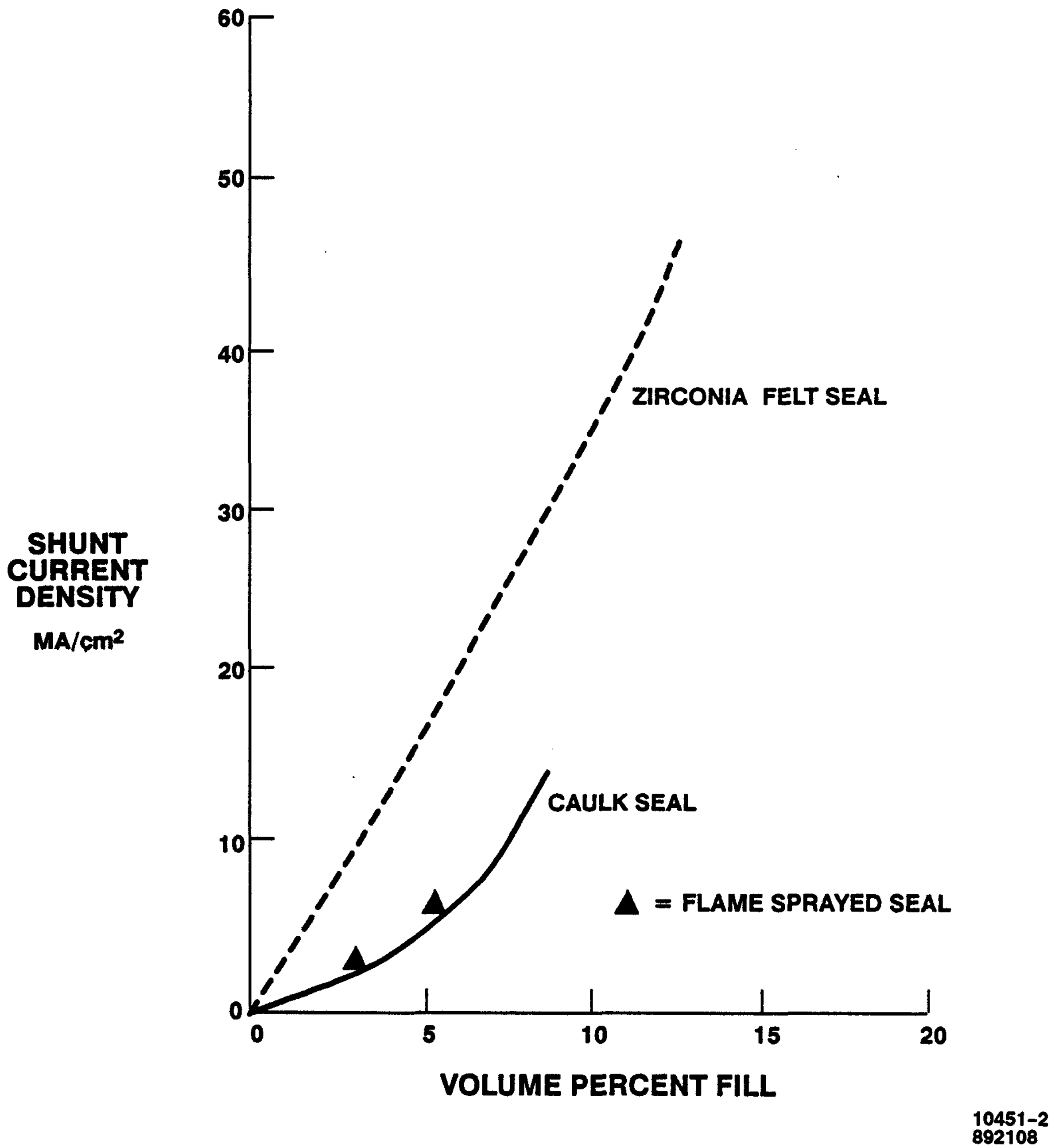

Figure 4.1-1. Electrolyte Transport of Manifold Seal Materials vs. Volume Percent Fill

SUBTASK 4.2 - REDUCED CELL COST

Objective

The objective of this subtask is to reduce the projected high-volume production costs of the stack components. The two areas targeted for cost reduction involve the sheet metal repeat parts. The first is to substitute lower cost stainless steel for the presently used INCO 825 in both the separator plate and current collector. The second is to develop cost effective processes for providing protective coatings on the anode-side sheet metal components.

Report of Work Accomplished

Activity during this reporting period included cell testing to evaluate an aluminized stainless steel flange and stainless steel separator.

Current Collectors

A method of forming stainless steel current collectors with the required flow field depth was defined previously from subscale forming trials. The activity to form full-scale current collectors is now reported in Subtask 2.2, Stack Repeat Component Fabrication.

Separator Plates

Stainless steel separator plate flanges were fabricated to a configuration that could be tested in single cells and were aluminized by the lower cost aluminizing process identified previously. One of these flanges was tested in Cell No. 684 for 1372 hours. The visual condition of the flange appeared satisfactory after test. Cross-section metallography will be conducted.

Cell No. 683 was tested with a stainless steel sheet placed between the cell and anode housing to simulate anode-side separator plate conditions. After 616 hours of testing, only mild surface oxidation was observed on the stainless steel sheet. Additional cells of this type will be tested in other subtasks.

Work Planned For Next Reporting Period

- Complete post-test analyses of stainless steel cell components. Work in this Subtask will then be completed.

SUBTASK 4.3 - INTEGRATED CELL TEST

No activity scheduled.