**MOLTEN CARBONATE FUEL CELL
TECHNOLOGY IMPROVEMENT**

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For the Period Ending May 1990**

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**By
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ABSTRACT

This report summarizes the work performed under Department of Energy Contract DE-AC21-87MC23270 during the period March 1, through May 30, 1990. 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.

- The 8-ft² 20-cell, 25-kW stack assembly and installation in the test facility were completed. Testing of the stack was started and 896 hours of test time were reached.
- Manifold seal development focused on a seal to reduce electrolyte transport and test rigs were initiated for shunt current and seal leakage evaluation.
- Development on sheet metal parts was initiated with focus on improved aluminization for separator plate corrosion protection and nickel clad stainless steel for the anode current collector.
- Development of porous parts was initiated with focus on an alternative binder for the electrodes. Design of a laboratory scale continuous debinding oven was completed. Development of an improved material blend for the matrix was also initiated.

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, 1990. This work now consists of seven technical tasks resulting from Modification A010 to the Contract dated March 30, 1990. Task 1, Development of Improved Molten Carbonate Fuel Cell, is a technology effort to increase cell performance and reduce materials cost and which has been completed. Task 2, Stack Technology, incorporating the technology improvements from this program includes the design, fabrication, assembly, and test of a stack. Task 3, Determination of MCFC and Power Plant Subsystem Technology Development Requirements for Competitive CF/MCFC Power Plant, is a systems analysis effort to identify and define competitive power plant cost goals, optimum CG/MCFC and the related MCFC stack and has been completed. Task 4, MCFC Performance and Cost Enhancement, pursues additional increases in cell operation and further cell stack cost reduction.

Subtasks 2.2, 2.3, 2.4, and 4.1 continued during this reporting period and Subtasks 5.1, 6.1, 6.2, 6.3, 6.4 and 7.0 were initiated. A brief description of each task follows.

TASK 1 - DEVELOPMENT OF IMPROVED MOLTEN CARBONATE FUEL CELL

This task has been completed.

TASK 2 - STACK TECHNOLOGY

Subtask 2.1 - Stack Design Risk Analysis and Stack Selection - will define preliminary stack designs

Subtask 2.2 - Stack Repeat Component Fabrication - will fabricate matrices, anodes, cathodes, electrolyte reservoirs, gas field supports, and separator plates to be used in stack testing.

Subtask 2.3 - Stack Non-Repeat Hardware and Assembly - will fabricate the non-repeating hardware, and assemble the stack selected for test. 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 test of the selected stack design. 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

This task has been completed.

TASK 4 - MCFC PERFORMANCE/COST ENHANCEMENT

Subtask 4.1 - Improve Cell Performance - will improve cell operation by defining cell electrolyte tolerance. Cell durability will be improved by reducing electrolyte transport in the manifold seal.

Subtask 4.2 - Reduce Cell Cost - this task has been completed.

TASK 5 - STACK TECHNOLOGY

Subtask 5.1 - Short Stack Evaluation - will verify the improved technology cell design in a short stack test of 8-ft² planform cells for 2000 hours duration by continuing the test initiated under Subtask 2.4.

Subtask 5.2 - Manifold Seal Development - will develop and test a new manifold seal.

TASK 6 - COMPONENT TECHNOLOGY

Subtask 6.1 - Sheet Metal Corrosion - will develop aluminized coating for separator plates and nickel clad stainless steel.

Subtask 6.2 - Cathode Corrosion - will increase the endurance of cells as affected by the dissolution of the cathode.

Subtask 6.3 - Porous Part Improvement - will develop materials and processes for fabricating cell porous parts.

Subtask 6.4 - Single Cell Supporting Testing - will evaluate the cell components being developed individually under subtasks 6.1, 6.2 and 6.3.

TASK 7 - TECHNICAL ASSESSMENT STUDIES - will review key technical issues relating to each component in stack designs.

TASK 2.0 STACK TECHNOLOGY

SUBTASK 2.1 - STACK DESIGN

Objective

Prepare a preliminary design for short stacks of approximately 20-cells of both 1 and 8-ft².

Report of Work Accomplished

Design of the 8-ft² short stack was completed in March, 1990. The cathode manifold seal arrangement was selected. The fuel manifold seals were revised to compensate for the cell edge run out tolerance on the outlet face. Documentation of the final manifold seal arrangements on the stack assembly drawing remains to be completed.

SUBTASK 2.2 - STACK REPEAT COMPONENT FABRICATION

Objective

Fabricate stack matrices, anodes, cathodes, current collectors, separator plates, and end-cell reservoirs meeting the design specifications of Subtask 2.1. Components for an 8-ft², 20-cell stack will be fabricated.

Report of Work Accomplished

The matrix tape which was cast during the last reporting period was assembled to the requirements of the matrix assembly. The matrix assemblies were delivered for use in the 8-ft² short stack.

Fabrication of the anodes and cathodes was completed with final trimming and delivery of parts for use in the 8-ft² short stack.

Matrix Assembly

The Matrix Assemblies for the 8-ft² short stack were fabricated and assembled. Final length, width, thickness, and weight measurements were made on the Matrix Assemblies delivered for use in the short stack. The thickness data, shown graphically in Figure 1 shows that all of the assemblies are very uniform and well within the specification.

Samples adjacent to each matrix tape segment used in the assemblies were retained for testing. The tape samples were evaluated using the standard binder burnout technique to obtain shrinkage data and median pore size.

The shrinkage data values are consistent with requirements for an acceptable level of compaction during stack operation.

The median pore diameters of tape samples are extremely consistent and well within the specification.

Figure 1. Thickness of Matrix Assemblies for 8-ft² Short Stack

Electrode Trimming

Final trimming and deburring of the anodes was completed consistent with requirements for stack assembly. Approximately 70 percent of the anodes are within the required thickness range of nominal ± 1 mil as described in the previous report. Over 90 percent of the parts fabricated were within the anode porosity specifications.

The cathodes were rolled, trimmed and inspected for final characteristics. The thickness distribution for the completed cathodes is shown in Figure 2. All of the parts are on the thin side of the nominal design with approximately 75 percent of the parts meeting the nominal thickness requirement ± 1 mil.

The porosity of the finished cathodes is well within the specification range as shown in Figure 3.

11191-02

Figure 2. Cathode Thickness Distribution

11191-03

Figure 3. Cathode Porosity Distribution

SUBTASK 2.3 - STACK NON-REPEAT HARDWARE AND ASSEMBLY

Objective

Fabricate all required non-repeating hardware and assemble the short stack of 8-ft² planform area cells as specified in Subtask 2.1. Prepare the facilities for assembling the stack and conduct inspections and checkout. Perform assembly checks and inspections and verify that the stack is ready for testing in Subtask 2.4.

Report of Work Accomplished

Stacking of the 20 cell repeat parts was completed. Assembly consisted of placing a separator/current collector subassembly, then the cathode, then the matrix, then an anode and another separator/current collector subassembly. Figure 4 shows the bottom pressure plate, insulation, guard heater, and end plate in the stacking fixture prior to placing the repeat parts. Figure 5 shows the placement of an electrode on the stack. Figure 6 shows the placement of the top separator plate. Figure 7 shows the stack with the upper end plate, insulation, guard heater, and pressure plate installed and axial load being applied to the stack.

After assembly of the repeat parts and loading system, the seals were applied for the fuel and air manifolds as shown in Figures 8 and 9 and the manifold secured to the stack as shown in Figure 10. Thermocouple and voltage lead wire penetrators can be seen on the fuel and air manifolds.

Figure 4. Stacking Fixture and Bottom Non-Repeat Parts PUBS6082

Figure 5. Electrode Placement PUBS6092

Figure 6. Top Separator Plate Placement PUBS6107

Figure 7. Axial Load Application PUBS6511

Figure 8. Fuel Manifold Seal Installation PUBS6117

Figure 9. Oxidant Manifold Seal PUBS6220

Figure 10. Completed Manifold Installation PUBS6223

An electrical check was performed to insure that no thermocouple wires were crossed or shorted to the manifold.

Manifold load bar deflections were measured on all the manifolds to verify that the manifold gaskets were properly loaded. Adjustments were made as required based on the bar deflection measurements.

A final electrical check was performed to insure that no shorting problems were introduced during the final loading of the manifolds. A pressure test of the stack was conducted to verify manifold seal functionality.

The stack was then transported to the test stand and installed in the base of the containment vessel, as shown in Figure 11. Additional steps completed during the installation of the stack in the vessel base included:

1. The installation of the power takeoff system which consists of busbars and flexible cables,
2. The welding of the manifold reactant inlet and exit pipes to the containment vessel dielectric flange assembly pipes, and
3. The thermal insulation of the stack and reactant lines inside the containment vessel.

Upon completion, all remaining instrumentation and electrical wiring was completed and a final check was performed.

The vessel dome was installed, as shown in Figure 12, and the stack was ready for testing.

Work Planned For Next Reporting Period

None. Task completed.

Figure 11. Assembly of 25-kW Cell Stack in Vessel Base PUBS6250

Figure 12. Vessel Dome Installation PUBS6316

SUBTASK 2.4 - STACK TEST AND ANALYSIS**Objective**

Verify the improved technology cell design in a 25-kW short stack test of 8-ft² planform cells for up to 1200 hours duration.

Report of Work Accomplished

Test stand preparation for the stack test was completed. The remaining elements of stand preparation that were completed included the updating of all instrumentation calibrations, electrical checks of all instrumentation and support equipment, and a final pressure test and flow check of the test stand.

The 8-ft², 20-cell, 25-kW stack started during this report period and operated continuously for 896 hours. Heatup followed the start procedure used in the previous 8-ft² stack test and was completed without incident. The stack was loaded to 25 and 50 ASF.

After nine hours the load was removed because of an indication that a single temperature reading exceeded the limit. The single temperature reading which exceeded limits was later determined to be a defective thermocouple.

The stack was operated at 100 psia in order to improve cathode performance in a similar manner to that demonstrated in single cell testing. A significant performance improvement resulted and the stack was then run up to 125 ASF. Additional conditioning at 100 psia was conducted for over 10 hours at 696 hours into the testing. Performance was then obtained on full strength reactants at 100 psia and 60 psia as shown in Figure 13.

Work Planned For Next Reporting Period

Continue testing to 1200 hours under Subtask 2.4. After 1200 hours the testing is to be conducted under a new Subtask 5.1. In Subtask 5.1, it is planned to test the stack to 2000 hours, to operate at current density up to 250 ASF, and to evaluate reactant leakage after 2000 hours operation.

11191-04

Figure 13. 8-Ft² Stack Performance

TASK 4.0 MCFC PERFORMANCE/COST ENHANCEMENT**SUBTASK 4.1 - IMPROVE CELL PERFORMANCE****Objective**

Demonstrate a cell configuration which meets the electrolyte fill tolerance limits consistent with the parts variability representative of low cost manufacturing processes. The combination of the interior cell configuration, the end-cell reservoir configuration, and manifold seal properties will provide the electrolyte management needed to meet life goals.

Report of Work Accomplished

Activity during this reporting period included completion of single cell testing on the cell configuration for the 8-ft², 20-cell stack and prediction of stack performance by correcting single cell data for differences in operating conditions between the single cells and the 8-ft², 20-cell stack.

During this reporting period manifold seals were fabricated for the 8-ft², 20-cell stack using zirconia cloth and caulk developed in the previous reporting period.

Single Cell Testing

One single cell test continued from the previous reporting period. Three cells were run to evaluate stack production components, and one manifold seal test was run. All testing was completed during the first month of this reporting period.

These cells are listed in Table 1, which contains a complete listing of all cells tested in this contract since Cell No. 704. This table contains the test starting date, test termination date, operating conditions of the test, and general results. In addition, the performance levels and internal resistances are listed, both at one atmosphere pressure and at pressurized conditions, if the cell also ran at these conditions.

Beginning with Cell No. 713 the standard pressurized operating conditions were revised to 4 ATM (60 psia) from 6.8 ATM (100 psia) in order to match the stack operating conditions.

Cell No. 716 continued this period, showing greatly improved ambient performance and very good pressurized performance. The crossover was high.

Cell No. 717 had a high anode fill and performance lower than expected, even for the fill level. Crossover was very low.

Cell No. 718 was a stack qualification cell with a low fill level. The performance at 1 ATM was low even when correcting for a low OCV caused by stand problems. The crossover was higher than desired. The cell was not pressurized.

Cell No. 720 evaluated the positive end-cell reservoir configuration. The performance was 50 mV below the best performing center cell configuration at the 160 ASF stack design point. This met the performance requirement for end-cells.

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				6.8 ATM	
							100 ASF (107 ma/cm ²)	Peak Cell Voltage (MV)	Internal Resistance (MV)	Peak Cell Voltage 2 (MV)	160 ASF (172 ma/cm ²)	Internal Resistance (MV) at 100 ASF
704	4.1	10-12-89	12-22-89	A,P	Current collector evaluation	Current collector characteristics	620		104	790		46
705	4.1	10-25-89	11-08-89	A	Stack anode-side components	Performance high	837		35	-		-
706	2.2	11-01-89	12-01-89	A,P	Matrix evaluation	Performance high	831		35	832		28
707	4.1	12-05-89	12-05-89	A,P,S	Pieced matrix	Performance high	806		24	840		26
708	2.2	12-07-89	12-16-89	A	Matrix evaluation	Poor performance	757		32	-		-
709		12-07-89	12-11-89	-	Manifold seal evaluation	High leakage	-		-	-		-
710	2.2	12-13-89	12-14-89	Burn out only	Matrix evaluation	Matrix properties	-		-	-		-
711	2.2	12-13-89	12-17-89	A	Matrix evaluation	Poor performance	0		-	-		-
712	2.2	01-17-90	01-25-90	A	Matrix evaluation	High leakage	814		38	-		-
713	2.2	01-22-90	01-29-90	A,P	Matrix evaluation	Cell improperly compressed	744		34	-		-
714	2.2	02-09-90	02-21-90	A,P	Matrix evaluation	Matrix good	810		34	777		36
715	2.2	02-15-90	02-28-90	A	Cell verification	Performance good	825		36	818		26
716	2.2	02-27-90	Running	A	Cell verification	On load	765		47	-		-
1. Fuel: GF-2, H ₂ + CO utilization 23% (57% at 250 ASF) Oxidant: ROX-1, CO ₂ utilization 9% (25% at 250 ASF) 2. Fuel: GF-2, H ₂ + CO utilization 36% (57% at 250 ASF) Oxidant: ROX-1, CO ₂ utilization 16% (25% at 250 ASF)												

*Revised test condition

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% Cu₂, 47.5% H₂O
 ** ROX-1 Oxidant contains 8.7% O₂, 18.1% CO₂, 65.7% N₂, 7.4% H₂O

Table 1. Cell Test and Performance Summary (Cont'd)

Table 1. Cell Test and Performance Summary (Cont'd)										
Cell No.	Sub-Task No.	Date Started	Date Terminated	Conditions of Test	Purpose of Test	Results	1 ATM		6.8 ATM	
							100 ASF (107 ma/cm ²)	Peak Cell Voltage ¹ (MV)	Internal Resistance (MV)	Peak Cell Voltage ² (MV)
717	2.2	03-01-90	03-14-90	A,P	Verify short stack components	Performance low	755	25	767	33
718	2.2	03-07-90	03-14-90	A	Verify short stack components	Performance low	784	37	---	---
719		03-01-90	03-07-90	A	Manifold seal test	---	---	---	---	---
720	2.2	03-08-90	03-15-90	A,P	Verify short stack components (Pos. and cell)	Performance good	791	32	775	29

A - Ambient Conditions (1 ATM, 1200°F, GF-2*, ROX-1**)

P - Pressurized Conditions (4 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, H ₂ + CO utilization 23% (57% at 250 ASF) Oxidant: ROX-1, CO ₂ utilization 9% (25% at 250 ASF)
2.	Fuel: GF-2, H ₂ + CO utilization 36% (57% at 250 ASF) Oxidant: ROX-1, CO ₂ utilization 16% (25% at 250 ASF)

8-Ft² 20-Cell Stack Manifold Seals

Precast caulk strips were fabricated for the air manifolds of the 8-ft² stack test. Characterization of the mechanical properties, and post-test evaluation of a single cell test support the adequacy of the ceramic caulks for manifold seals.

Mechanical properties of the caulk were characterized by load deflection tests run at room temperature and at 1250°F. Addition of plasticizer to the caulk formulation provided significant room temperature compliance. Load deflection data taken at 1250°F showed the seal had become a rigid ceramic.

Post test evaluation of the seal caulk tested in a single cell was consistent with these results. The caulk was held under a constant load during cell startup. Teardown revealed no cracking, and the caulk was removed as an integral window frame.

Seal caulk for the 8-ft² 20-cell stack test was prepared and caulking strips were cast on nylon sheets using machine shims as a mold.

Work Planned For Next Reporting Period

None. Task Completed.

Manifold seal development is continued under Subtask 5.2.

TASK 5.0 STACK TECHNOLOGY

SUBTASK 5.1 - SHORT FULL-AREA STACK TEST

No activity. Stack still being tested under Task 2.4.

SUBTASK 5.2 - MANIFOLD SEAL DEVELOPMENT

Objective

The objective of this task is to identify a design configuration for the manifold seal which meets the design requirements for gas sealing while reducing the ionic shunt current by a factor of five below the zirconia felt seal currently used.

Approach

The approach is to develop a seal which employs a large particle filler which reduces electrolyte take up, but which possesses enough integrity to resist blow out and erosion during all phases of stack operation. This seal is to be confined between a ceramic rail and the edge seal zone on the face of the stack. The ceramic rail provides electrical isolation of the manifold from the stack and a flange seat for the manifold as well as confinement of the seal.

Report of Work Accomplished

Specifications were established for the filler material and ceramic rails.

Specifications for the rail were established based on preliminary design considerations. The material of choice is alumina based on previous rail experience. The seal side of the rail was found to be generally free of electrolyte in previous stack tear downs.

Three rail vendors were contacted. A vendor capable of producing rails to the design specifications was identified.

Specifications for the fill material are based on previous experience and substantial stability testing conducted in earlier programs. Two filler materials were chosen as the only materials expected to be stable in both fuel and air environments at 650°C exposed to the electrolyte.

Six vendors were surveyed for appropriate filler materials and three candidates were selected. Candidate filler materials were received from the vendors. Preliminary electrolyte transfer measurements on one candidate filler material and the baseline zirconia felt revealed very slow wicking rates for samples which were not pre-loaded with some electrolyte.

The apparatus for electrolyte take up and bulk conductivity measurements is illustrated in Figure 14. This apparatus allows simultaneous measurement of the electrolyte take up of a sample equilibrated with a partially filled oxidized cathode and the volume conductivity.

A "dog bone" shaped thin flat sample is placed on an alumina block. Ni cathodes are set on the wide ends. Sheet metal current collectors with electrolyte are placed on top of the cathodes. The quantity of electrolyte is sufficient to fill the cathodes to the desired level and transfer to the sample. The sample holder is mounted in a retort and heated to 1250°F.

The conductivity of the dog bone length of the sample is separated from electrode polarization effects by ac impedance analysis. Post test weight and dimensional measurements are used to determine the percent fill of all porous components.

Initial attempts to prepare a sample of filler caulk formulation led to samples with insufficient strength. A formulation based on the binder used in the matrix tapes was prepared.

11191-07

Figure 14. Electrolyte Transfer and Volume Conductivity Test Rig

Test Rig Definition

Studies was conducted on test rigs which would properly assess the important characteristics of a seal in non-stack component tests. The important characteristics are:

- Cell to cell and top to bottom shunt currents.
- Seal leakage rates at normal pressure differentials.
- Stability of the seal to erosion at normal leakage rates.
- Blow out tolerance (resistance to transient pressure upsets).

The only single rig which would access these characteristics is an operating stack. Since, this is beyond the scope of the present program, a decision was made to use two test rigs.

The first rig is to measure shunt currents. A conceptual sketch is shown in Figure 15. Up to 20 simulated cells are stacked between alumina dielectric sheets. The alumina rail traps the filler between the simulated stack edge and the rail. The only electrical path between cells is through the electrolyte wetted filler in the seal.

FC29866

Figure 15. Shunt Current Test Rig

The second test rig is to evaluate the gas seal characteristics. This seal leakage test rig is shown in Figure 16. A picture frame alumina plate, simulating the rail, is clamped against a mating stainless plate. The steel plate is machined to simulate the rough stack edge. The seal is applied between the

alumina plate and the stainless steel edge simulator plate. This rig concept was chosen to ensure that the only gas leakage path is through the seal.

FC29865

Figure 16. Seal Leakage Test Rig

Shunt Current Calibration Run

A preliminary background test was performed on a stack of 10 cells to determine if the alumina ceramic dielectric insulators would prevent an ionic shunt current from flowing along the face of the test stack in the absence of a simulated manifold seal. A second reason for the test was to determine how much electrolyte would be lost to creep across the surfaces of the insulators and in the reaction of Al_2O_3 going to LiAlO_2 on the surfaces of the insulators.

The configuration of this test was simpler than that planned for the actual seal shunt current test (Figure 15) since simulation of wicking from the cells to a seal was unnecessary. Pictures of the pretest rig are shown in Figure 17. The stack consisted of nine repeating elements which were composed of alumina plates separated by partially filled cathodes

The cathodes and separator plates were centered along one edge of the alumina plates. Each end of the stack had a gold foil electrical connector. The stack was held together and placed in a retort. The retort was heated to 1200°F under molten carbonate oxidant gas. A voltage of 7.2 volts (0.8 volts per cell) was applied during heat-up, prior to the electrolyte melt. At this point, no current was flowing. A current started to flow just above the melt point and peaked out at 29 microamps. The current then dropped over 16 hours to about 0.08 microamps and remained between 0.05 and 0.08 microamps for the remainder of the test except for a small current spike at about 22 hours.

The stack was cooled and removed from the retort. Visual observation, of the face of the stack where the electrodes were at the edge, showed some dark stains across the alumina plates. Otherwise the electrode face of the stack showed nothing unusual. In the far corner, between alumina plates 2 and 3 was a post of frozen electrolyte which connected the two plates. The post was about $1/8$ inch high and

about as wide. Whiskers of electrolyte were also observed between alumina plates 6 and 7 in the same corner of the stack.

FC30255 ■
900106

Figure 17. Shunt Current Test Rig

Post-test weights were taken on all parts from rig. The results showed that almost all the electrolyte placed into the parts was found still within the stack. Only 2.4 percent was not accounted for and was probably lost to lithiation of the stack parts. Almost all cells in the stack lost electrolyte except for cell #1 which picked up most of the transported electrolyte. This is the direction that would be expected if the electrolyte were migrating under electrical forces. Cell No. 1 is at the top of the stack and is the most negative cell. Figure 18 shows a plot of the electrolyte weight within the electrodes as a function of cell position in the stack. The open circles in Figure 18 indicate the pretest weights and the open triangles indicate the post-test electrolyte weights.

The amount of electrolyte on the alumina insulators was measured by washing the plates in glacial acetic acid to remove the electrolyte without removing any LiAlO_2 that was formed. The amount of free electrolyte on the plates was small and varied between .0013 and .0029 grams per plate. The amount of conversion of Al_2O_3 to LiAlO_2 has not been determined but must be a small value since the total amount of electrolyte lost in the test was 2.4 w percent of the initial electrolyte.

Work Planned For Next Reporting Period

- Design and construct the shunt current test rig and seal leakage test rigs.
- Evaluate candidate filler materials in the electrolyte transfer and volume conductivity test rig.

11191-10

Figure 18. Shunt Current Rig Calibration Run

TASK 6.0 COMPONENT TECHNOLOGY**SUBTASK 6.1 - SHEET METAL CORROSION****Objective**

The objectives of this task are 1) to develop techniques for applying aluminum to the edge seal flanges of the separator plate and to identify more cost efficient processing equipment for heat treating these plates to form a corrosion resistant aluminized coating and 2) to identify vendors that can supply nickel clad stainless steel and to test the current collectors fabricated from these clad materials.

Report of Work Accomplished

Steps in the aluminization processing which results in high production cost were identified and plans outlined for evaluating alternative materials and process conditions to improve process results. A vendor was identified for nickel clad stainless steel and samples obtained for evaluation.

Subtask 6.1.1 Aluminized Separator Plate Flange

The aluminum application method evaluated for aluminizing the flanges of separator plates in the development work for the 8-ft² short stack was reviewed. The surface preparation procedure, the aluminum formulation, and the heat treatment temperature will be investigated in an attempt to minimize the separator plate production cost.

Plans for the evaluation of these material and process changes have been initiated.

Subtask 6.1.2 Cladded Current Collector

A vendor who has demonstrated the ability to clad nickel onto stainless steel has been identified. Samples were requested, received, and will be evaluated in 4 inch by 4 inch single cell tests.

Work Planned For Next Reporting Period

- Conduct aluminization process trials with alternative materials formulations and processing conditions
- Evaluate nickel clad stainless steel in small single cell tests.

SUBTASK 6.2 - CATHODE CORROSION**Objective**

The objective of this subtask is to increase the endurance of cells as affected by the dissolution of the cathode. Electrolyte composition and CO₂ partial pressure will be varied to define the combination that will provide the maximum increase in endurance without adversely affecting performance or cost.

Report of Work Accomplished

One cell, No. 722, was tested to evaluate the effect of increasing the electrolyte lithium carbonate content on the time at which electronic shorting occurs due to nickel oxide cathode dissolution. Experimental solubility data indicate that such an increase should result in a reduced nickel oxide solubility. Loss of a heater controller resulted in the cell temperature decreasing to about 300° F and solidification of the electrolyte shortly after startup. In addition, open circuit voltage, performance, and crossover data indicate that the electrolyte may not have been suitably melted during cell startup. An accelerated shorting test was not performed on the cell because the results would have been considered to be adversely affected by this crossover and the solidification cycle.

Work Planned for Next Reporting Period

- Evaluate the effect of adding an alternative carbonate to the electrolyte to increase time before shorting.

SUBTASK 6.3 - POROUS PART IMPROVEMENT

Objective

The objective of this subtask is to develop improved materials and processes for fabricating porous repeat parts. The specific areas requiring improvements are: (1) slurries for tape cast electrodes; (2) the debinding process for electrode tapes; and (3) the matrix material.

Report of Work Accomplished

Cathodes were successfully fabricated using an alternative formulation in place of the formulation used previously. Their sintered porosity, however, was below the specification. Future trials will attempt to meet the porosity specification by changing the binder content.

The design of a laboratory scale continuous debinding oven was completed. This apparatus will be used to conduct process development trials. The oven, shown schematically in Figure 19, is 8 inch x 46 inch long, and has 3 separately controlled heat zones. A variable speed drive system will transport 6.25 inch x 6.25 inch tapes through the oven. Air will be directed countercurrent to the direction of travel. After debinding, sample tapes will be sintered in a laboratory furnace to reduce any Ni oxidation and permit evaluation of the degree of binder removal. An iterative process will be used to determine the time/temperature and airflow requirements of the process. Parts for the drive and heating systems were ordered. The sheetmetal portion of the oven will be fabricated at IFC.

Matrix tapes were made with an alternate material blend. The material is harder and less porous than the present baseline material.

Work Planned For Next Reporting Period

- Cast cathode tapes with different binder content.
- Begin fabricating the sheet metal portion of the debinding oven.
- Characterize burned out matrix tapes made with alternative materials.

Figure 19. Lab Scale Debinding Oven

SUBTASK 6.4 - SINGLE CELL SUPPORTING TESTING

Objective

The objective of this subtask is to evaluate the cell components being improved individually under Subtasks 6.1, 6.2, and 6.3 in bench-scale cells, and test and analyze these cells in order to compare their data for compliance to the design objectives established for those subtasks. All single cell testing will be conducted under this subtask to facilitate and coordinate the testing activity and provide more efficient use of common resources.

Report of Work Accomplished

Two single cell tests (Nos. 722 and 723) were started during May to support Subtask 6.2, Cathode Corrosion. A test summary of these cells is shown in Table 2. A discussion of Cell No. 722 is presented in Subtask 6.3. Cell No. 723 did not start until the end of this reporting period, therefore, no results are presented.

Table 2 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)		6.8 ATM 160 ASF (172 ma/cm ²)	
							Peak Cell Volts ¹ (MV)	Internal Resistance (MV)	Peak Cell Volts ² (MV)	Internal Resistance (MV) at 100 ASF
722	6.2	5-23-90	Running	A,P	Evaluate increased lithium carbonate electrolyte	Initial performance low	629	39		
723	6.2	5-03-90	Running	A	Evaluate effect of alternative carbonate additive to electrolyte	Test starting				

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)

TASK 7.0 TECHNICAL ASSESSMENT STUDIES**Objective**

The objective of Task 7.0 is to review key technical issues relating to each component in stack designs and to execute specific technical evaluations on a component or stack subassembly basis. The design requirements and specifications for the basis of these studies will be from existing stack designs (or existing power plant systems designs). The purpose of these technical assessments is to determine the merits, in terms of competitive ability to manufacture, of a specific component design or stack subassembly.

Report of Work Accomplished

During the report period, Task 7.0 was initiated with plans for an evaluation of the cell stack materials with emphasis on the repeat parts, based on a bill-of-materials assessment for the commercial stack design.

Work Planned For Next Reporting Period

- Assessment of cell stack repeat parts.

END

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