XII.3 Advanced Direct Methanol Fuel Cell for Mobile Computing

James Fletcher (Primary Contact), Joseph Campbell
University of North Florida (UNF)
1 UNF Drive
Jacksonville, FL 32224
Phone: (904) 620-1844
E-mail: JFletche@unf.edu

DOE Managers
HQ: Ned Stetson
Phone: (202) 586-9995
E-mail: Ned.Stetson@ee.doe.gov
GO: Katie Randolph
Phone: (720) 356-1759
E-mail: Katie.Randolph@go.doe.gov

Contract Number: DE-EE0000476

Subcontractor:
University of Florida, Gainesville, FL

Project Start Date: January 1, 2010
Project End Date: December 31, 2011

Objectives

- The project objective is to develop a direct methanol fuel cell (DMFC) power supply for mobile computing using the novel passive water recycling technology acquired by UNF from PolyFuel, Inc., which enables significant simplification of DMFC systems.
- The objective of the 2011 effort is to build on the objectives completed in 2010 in order to finalize the system design, build and test the packaged 20 W power supply. To date, the system components have been selected and integrated into a brassboard (unpackaged system) for in situ testing. Based on the feedback provided by brassboard and component testing, the final design has undergone minor design revisions. The packaged system is currently in the manufacturing and assembly phase, once the system assembly has been completed, control strategies will be applied and optimized for the packaged system.

Relevance to the American Recovery and Reinvestment Act (ARRA) of 2009 Goals

This project will contribute to the relevance of DOE's objectives for ARRA projects in general and the DMFC projects in particular.

- Create direct and supporting jobs nationwide as the UNF fuel cell technology becomes commercially available.
- Reduce the necessity and use of the power grid as fuel cells power increasing numbers of portable electronic devices, thereby creating more "green" jobs.
- Create more business activity in the fuel cell supply industry.
- Expand the user base of new alternative power technologies.
- Increase the level of competition among producers of alternative energy technologies.

Technical Barriers

This project addresses the following technical barriers for advanced DMFCs outlined by the DOE.

- Specific power
- Energy density
- Operating lifetime
- Manufacturing Cost
- Balance-of-plant components

Technical Targets and Milestones

TABLE 1. UNF Progress toward Meeting Technical Targets for Advanced Direct Methanol Fuel Cell for Mobile Computing

Characteristic	Units	UNF 15 W DP3 2008 Status	DOE 2010 Target	UNF Proposed 20 W System Design
Specific Power[a]	W/kg	35	100	54
Power Density[a]	W/L	48	100	63
Energy Density	W-hr/L	250 (1 x 100 ml)[b] 396 (1 x 200 ml)[b]	1,000	198 (1 x 100 ml) 313 (1 x 200 ml) 507 (3 x 200 ml)
	W-hr/kg	155 (1 x 100 ml)[b] 247 (1 x 200 ml)[b]	N/A	180 (1 x 100 ml) 302 (1 x 200 ml) 532 (3 x 200 ml)
Lifetime[c]	Operating Hours	1,000 hrs in single cell	5,000	2,500 Integrated System
Cost	$/Watt	11 (est. in volume)	<3	<10 (est. in volume)

[a] Beginning of life, 30°C, sea level,50% relative humidity (RH), excluding hybrid battery, power module alone.
[b] Normalized from Design Prototype 3 (DP3) data from 150 ml cartridge to either 100 ml or 200 ml for comparison purposes.
[c] Lifetime measured to 80% of rated power.

Accomplishments

- Submission of revised Hydrogen Safety Plan.
- Baseline testing of components and subsystems complete.

- Integration of subsystems/components into brassboard (unpackaged system).
- Completion of three separate brassboards with hundreds of hours of operation at multiple locations.
- Control strategy optimization from brassboard operation.
- Preliminary design review held for packaged Design Prototype 4 (DP4) system.
- Packaged system components currently in manufacturing and assembly phase.
- Passed Go/No-Go milestone review in January 2011.

✧ ✧ ✧ ✧ ✧

Introduction

The project objective is to develop a DMFC power supply for mobile computing using the UNF novel passive water recycling technology which enables significant simplification of DMFC systems. The objective of the 2011 effort to date is to perform system engineering and extensive brassboard (unpackaged) testing to move towards the 2010 technical targets. The remainder of the project will focus on optimizing the performance of the packaged system.

Approach

This project is focused on balance of plant (pumps, blowers, sensors, etc.) development and overall system integration. These components will be rigorously tested individually, as subsystems, and ultimately at the system level. Initially, existing components will be evaluated for durability and failure modes, and the results will be used to further define component requirements. Once available, the design prototype components will be evaluated for durability and robustness. Subsystems will be integrated for testing, first onto a brassboard enabling detailed instrumentation of the system and verification of sub-system design, and then into an integrated package with auxiliary instrumentation. Control system development will optimize the key operational protocols for start-up, rest/rejuvenation, and shut-down to optimize operating lifetime and minimize both operational and storage degradation rates. In addition, this effort is highly integrated with the UNF-led Topic 5A: New MEA Materials for Improved DMFC Performance, Durability, and Cost project (DOE funded) which focuses on optimizing the passive water recovery membrane electrode assembly (MEA).

UNF submitted a Hydrogen Safety Plan for initial review on June 30, 2010. Based on very helpful comments received on from a DOE reviewer received on December 13, 2010, a revised plan was submitted to DOE on February 28, 2011.

Results

In order to progress towards the DOE 2010 technical targets for advanced DMFCs for mobile computing, it is imperative that each component in the system be tested for both optimal efficiency and robustness. Therefore, an extensive test plan was executed for each component/subsystem with the DP4 system.

The cathode blower subsystem was optimized using two separate methods. First, performance of numerous fans was tested against the component requirements in order to select the optimal cathode fan for the design condition. As shown in Figure 1, the ADDA AD4505HX-K90 offers the lowest parasitic power compared to the other fans that were tested. The ADDA fan has since undergone over 2,000 hours of durability testing while still meeting the design requirements.

The second series of tests that were conducted with the cathode blower subsystem examined flow optimization. This testing revealed the optimal cathode flow channel depth/configuration as well as the sensitivity of spacing between the fan and fuel cell stack inlet.

The recirculation pump used to flow the anode solution through the stack and support components (reservoir tank, gas liquid separator, etc.) was extensively tested. Numerous pumps were selected for testing based on the design requirements. Extensive testing showed that the KNF5 is significantly more efficient than other similar pumps relative

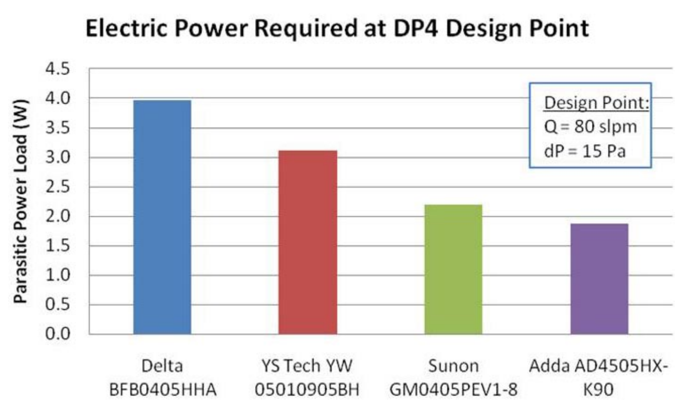

FIGURE 1. Comparison of Candidate Cathode Fan Performance

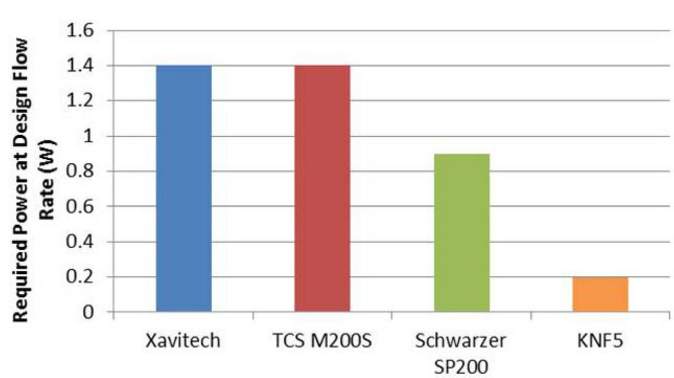

FIGURE 2. Comparison of Candidate Recirculation Pump Performance

to size, weight and hydraulic performance (Figure 2), thus resulting in the best system power and energy density.

The methanol injection pump that was selected for use in the DP4 is one of the few pumps that were able to meet the design requirements. Although the Microbase MBP2115BD has been able to provide hundreds of hours of operation during harsh environmental conditions, testing has revealed inconsistencies in the performance from pump to pump. Currently, testing is underway to determine if there is a significant variation in pump performance due to manufacturing.

The FC-10 methanol sensor was selected as the primary candidate for system integration. Extensive testing was conducted in order to determine any sensitivities to drift or thermal effects. It was determined that the FC-10 has a high sensitivity to temperature fluctuations. In addition, the sensor is not optimized for the application due to size, weight and cost. Therefore other methanol sensing technologies are under active investigation from manufacturers Spreeta and Japan Radio Corporation.

The gas liquid separator has undergone multiple revisions and tests to better understand the behavior of extruded Teflon® and the effect of its performance relative to temperature, pressure and ambient conditions. As a result, a significant reduction in the amount of water loss through the gas liquid separator has been achieved compared to the previous generation gas liquid separator.

The near completion of component and subsystem testing allowed for the design and assembly of the DP4 brassboard (Figure 3). To date, three brassboards have been assembled and tested with over 500 hours of operation on each system at multiple locations. The brassboards have allowed for components and subsystems to be tested in an in situ environment. Hundreds of hours of in situ testing highlighted design revisions and modifications in order to improve overall system reliability and robustness. The brassboard has also enabled accelerated evolution of software code revisions due to its accessibility and ease of use. Furthermore, the control strategies along with the startup and shutdown algorithms have been greatly improved in order to better handle dynamic conditions and different system configurations.

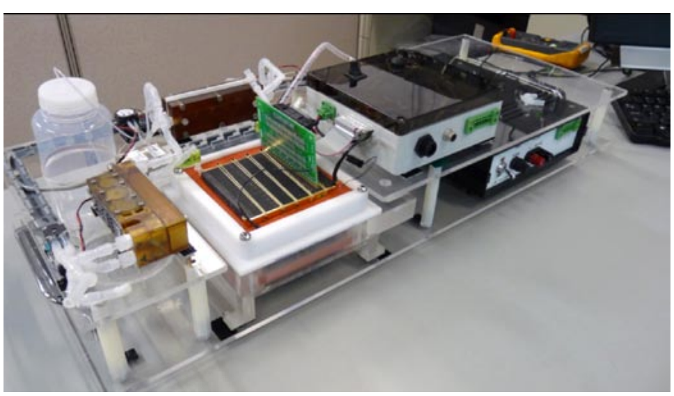

FIGURE 3. DP4 Brassboard (Unpackaged) System

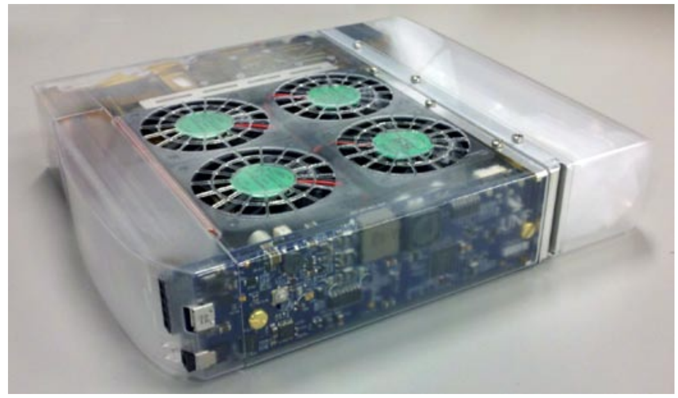

FIGURE 4. Packaged 20 W DP4 Fuel Cell Power Supply

The DP4 packaged system (Figure 4) concept design review was held at the beginning of 2011. Since then, the system has undergone minor design revisions due to the feedback provided from brassboard and component testing. The system is now in the final design stage and integrated prototypes are in the manufacturing and assembly phase. In addition to the completion of the mechanical design, the control board design has been completed and has been sent out for manufacturing. The first packaged system was presented at the Annual Merit Review meeting presentation in May of 2011 and is now in the testing phase.

Conclusions and Future Directions

- System components were tested to establish a benchmark to determine the system requirements.
- The best components were selected to meet the design requirements of the system and were subjected to durability and robustness testing.
- Each component was incorporated into its respective subsystem assembly and integrated into the brassboard system.
- In situ testing provided by brassboard operation allowed for component and control strategy optimization.
- Packaged system design is complete and subassemblies are in the manufacturing and assembly phase.
- Assemble multiple packaged systems for testing.
- Complete development of advanced control strategies with packaged system.
- Test the system extensively to evaluate performance, robustness, and durability.

FY 2011 Publications/Presentations

1. Advanced Direct Methanol Fuel Cell for Mobile Computing (AMR Presentation 05/12/11).