V.I.4 FC40 International Stationary Fuel Cell Demonstration

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BASF Fuel Cell ETEK, Somerset, NJ

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Objectives

Develop, test and validate a high-temperature proton exchange membrane (PEM), stationary, reformate-based, combined heat and power (CHP), fuel cell system as the first demonstration of a modular, scalable design for a worldwide market.

- Design a system with a total cost of <$750 kW in production volumes.
- Achieve electrical efficiencies of 35% (with line of sight to 40%) and overall system efficiencies of 85%.
- Demonstrate robustness that would lead to a 40,000-hour system life.
- Develop modular and scaleable system and CHP hydraulics concepts.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability
(B) Cost
(C) Performance

Technical Targets

This project is directed at the development of a micro-CHP PEM, stationary fuel cell system. It will advance the state-of-the-art of high-temperature PEM fuel cell technologies, and use this technology to address the following DOE technical targets as outlined in Table 1.

TABLE 1. Progress towards Meeting Technical Targets for Integrated Stationary PEM Fuel Cell Power Systems (5-250 kW) Operating on Reformate

Characteristic	Units	2011 Target	Plug Power 2009 Status
Electrical energy efficiency @ rated power	%	40	30
CHP, energy efficiency @ rated power	%	80	85
Cost	$/kWe	750	2,000
Transient response time (from 10% to 90% power)	seconds	<3	300
Cold start-up time (to rated power @ - 20°C ambient	minutes	<30	not applicable
Continuous use application			(indoor application)
Survivability (min and max ambient temperature)	°C °C	-35 +40	not applicable
Durability @ <10% rated power degradation	hours	40,000	4,000
Noise	dB(A)	<55 @ 10 m	<55 @ 10 m
Emissions (combined NOx, CO, SOx, hydrocarbon, particulates)	g/1,000 kWh	<1.5	not tested

Accomplishments

- Developed an improved membrane electrode assembly (MEA) cathode electrode which is more resistant to corrosion and is robust to load cycling.
- Improved stack design and stack component manufacturing processes that will lead to better performance and life.
- Developed an inverter that is two points higher in efficiency and is half the size and weight of the previous design.

- Integrated advanced technologies into a compact system design ready for commercial development.
- Built and commissioned three systems in the U.S., Germany and the Netherlands.
- Tested systems against real world applications achieving 30% electrical, 85% thermal efficiencies, 30 minute startup and load following capability.
- Achieved over 3,000 hours testing in three installations generating significant learning and opportunity for continued development under the project.

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Introduction

Plug Power Inc. (Plug Power) executed an international development and demonstration project within the framework of the existing European Union (EU)–U.S. Cooperation Agreement on fuel cells. The design, test and validation of a micro-CHP PEM, stationary fuel cell system advanced the state-of-the-art of high-temperature PEM fuel cell technologies and is bringing a domestic fuel cell heating appliance system design one step closer to commercialization.

Approach

Plug Power and BASF have conducted eight years of development work prior to this project, demonstrating the potential of polybenzimidazole membranes to exceed many DOE technical targets. The approach taken to fulfill the requirements of this project was to identify and develop of key enabling technologies and integrate them into a system architecture capable of meeting the needs of a commercial customer. These technologies and this architecture were demonstrated in operational systems in the U.S. and the EU. The major tasks associated with this project are:

- The development of a worldwide system architecture.
- Stack and balance of plant module development.
- Development of an improved, lower cost MEA electrode.
- Receipt of an improved MEA from the EU consortium.
- Integration of modules into a system.
- Delivery of system to EU consortium for additional integration of technologies and testing.

Results

In the past year, the focus of the extended team has been the downselection of key technologies for integration into the final system design, the detailed system design itself and parts procurement, system build and debug. The most significant technology initiatives have been centered on the high-temperature MEA, the stack and system power electronics.

MEA improvement efforts were focused on improving the cathode electrode in order to make it more resistant to oxidation and robust to load cycling. The basis for creating more stable supported catalysts lies in the choice of carbon support. A number of carbon supports were tested for corrosion resistance and the best selected (see Figure 1).

Numerous alloys of Pt were prepared containing Co, Ni, Fe, Vn, and Cr, or ternary combinations thereof. In the course of this task three potential graphitic supports were identified and two were selected for use as catalyst supports. Two supports were developed and the numerous catalysts were downselected to a field of three: Pt alloy(I) on Carbon 1, Pt alloy(I) on Carbon 2, and Pt alloy(II) on Carbon 1. These three candidates were passed to the electrode development team for

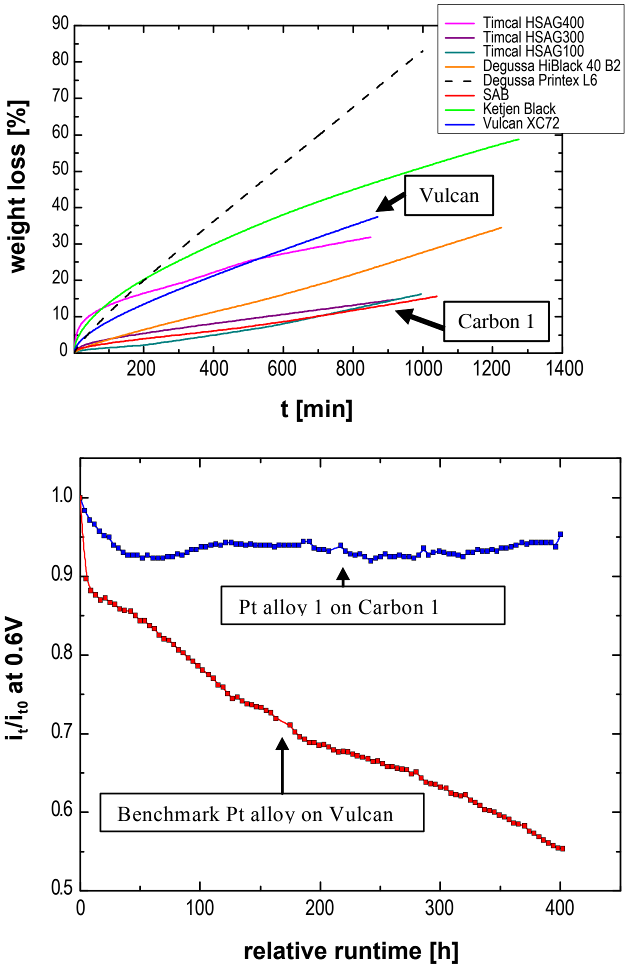

FIGURE 1. Carbon Support Selection and Pt Alloy Performance for MEA Cathode Electrode

optimization. After tradeoff studies, Pt alloy(II) on Carbon 1 was incorporated into the scale up of full-sized MEAs.

Stack initiative efforts were concentrated on analysis and design improvements for increased performance and life. Of particular importance are single-pass versus double-pass anode flow fields and stack compression tolerance stack-up.

Prior to this project, the design team had concluded that a “two-pass” orientation offered the highest anode utilization (1.1 – 1.2 stoichiometry target) and the highest stack efficiency. This has not proven to be the case with the testing of manufactured plates. It is currently believed that while this is thermodynamically correct, the manufacturing tolerances required to maintain a two-pass orientation cannot be held with the current material and design. On reformate, the anode stoichiometry impact begins to be observable when operating below 1.8. At 1.8 anode stoichiometry, the difference between 1-pass and 2-pass was about 13 mV and at 1.4 anode stoichiometry the difference increased to 80 mV (see Figure 2).

It is currently understood that for optimum MEA performance in the high-temperature stack, a nominal cell compression of 20% +/- 5% must be maintained (per BASF’s recommendations). The stack components that determine cell compression are plate pocket depth, MEA thickness, and viton insulator height. The assigned nominal values and associated tolerances of these components must work together to keep the MEA compression within the allowable range (15% - 25%).

Currently, all components have been found to be outside of their tolerance specifications to maintain compression on the MEA to within BASF’s recommendations. The results of this study are being shared with the suppliers in order to leverage work towards improving the nominal and distribution of the insulator height. See Figure 3 as a sample result of a stack component compression analysis.

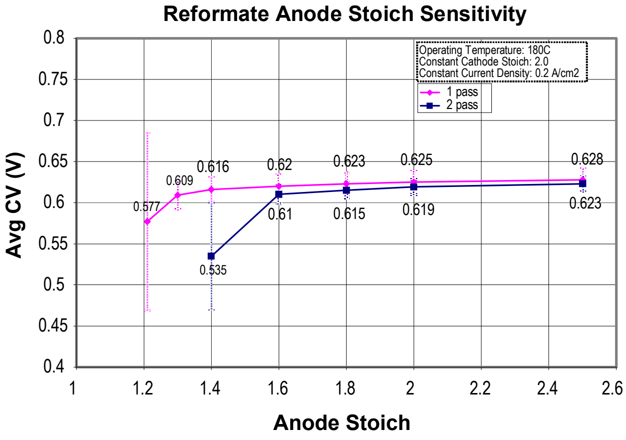

FIGURE 2. Reformate Anode Stoichiometry Sensitivity Comparison Between 1-Pass and 2-Pass

A new transformerless inverter platform was developed and evaluated. The inverter module consists of the inverter card, inductor and heat sink. The stand alone inverter module used for testing is shown below in Figure 4.

Each module was tested for basic functionality and then sub-systems were tested for efficiency with the result that the new design is approximately 2 points higher in efficiency than its predecessor.

The team then built and debugged three systems: “E1”, “E2” and “E3” and installed them in Plug Power, Latham labs, Plug Power, Apeldoorn, Netherlands labs and Vaillant, Remscheid, Germany labs.

On its way to commissioning in the Netherlands, system E2 was displayed at the Hannover Fair in Hannover, Germany in April where it was well received by industry and academia (see Figure 5).

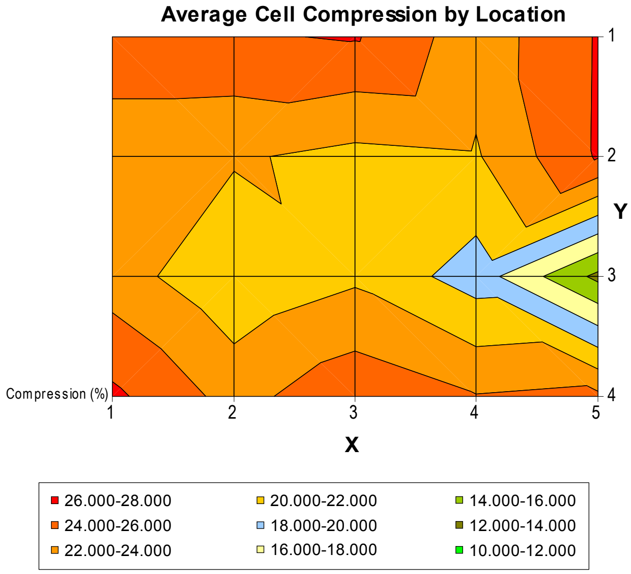

FIGURE 3. Sample Average MEA Compression Distribution

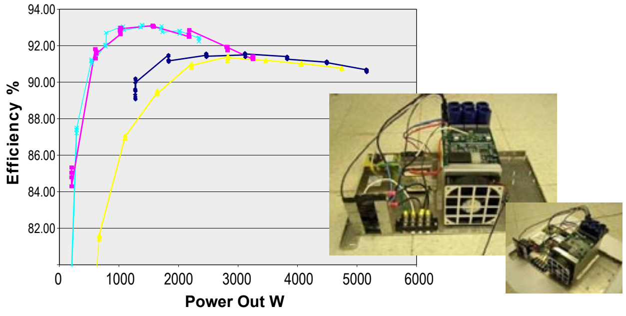

FIGURE 4. Inverter Performance Improvements

After commissioning, the systems were used for controls development and for testing against high level customer requirements. Under test the systems demonstrated 30% electrical efficiency, over 85% thermal efficiency and a 30 minute start-up.

With limited controls development under the project, the team was able to achieve rudimentary load following under simulated operating conditions. The system was able to achieve full-load conditions from zero watts net output in under three minutes. A 1 kilowatt load change could easily be achieved in under 1 minute. Load following is critical to the value proposition of a CHP device and allows the fuel cell appliance to maximize the return on investment by the customer (see Figures 6 and 7).

Finally, the systems were run in continuous power mode to understand life issues and reliability. Under the project, the systems achieved over 3,000 operating hours with 1,500 of them in Vaillant labs (see Figure 8). This testing generated data for additional controls development and reliability improvements. This information is invaluable to the team as it moves forward to commercialize this technology in the United States and Europe.

FIGURE 5. Built, Debugged and Displayed Three Systems

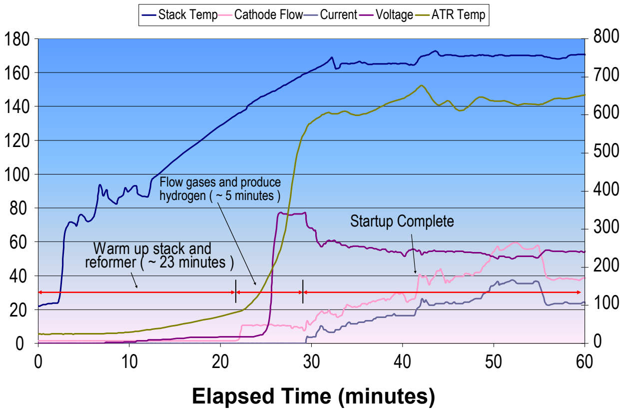

FIGURE 6. Demonstrated 30-Minute Start-up

Conclusions and Future Directions

High-temperature PEM fuel cell systems promise to be a commercially viable technology for micro-CHP, residential and light commercial applications. Much refinement in the areas of manufacturing and supply chain development are required, but the core technology is ready to begin the commercialization process. The following work is planned outside of the project:

- Complete controls development.
- Install systems in employee homes.
- Complete new design with updates from testing.

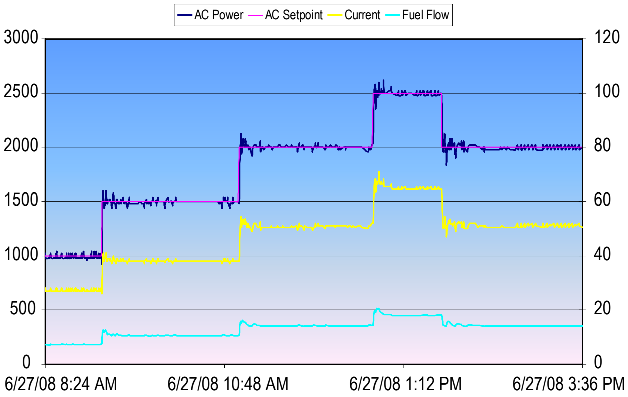

FIGURE 7. Demonstrated Load Following

FIGURE 8. Installation and Commissioning at Vaillant in Remscheid, Germany

- Commission reliability fleet.
- Begin field trials.

FY 2009 Publications/Presentations

1. 2009 DOE Hydrogen Program Review – Washington, D.C. – June, 2009. Presentation FC40.