# V.D.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 (HFCIT) Program Multi-Year Research, Development and Demonstration Plan (RD&D):

(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 DOE technical targets as outlined in the HFCIT Multi-Year RD&D Plan (see Table 1).

## 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.

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## Introduction

Plug Power Inc. (Plug Power) is executing an international development and demonstration project within the framework of the existing European Union (EU) – United States (US) Cooperation Agreement on fuel cells. The design, test and validation of a micro-CHP PEM, stationary fuel cell system is advancing 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 is the identification and development of key enabling technologies and the integration of those into a system architecture capable of meeting the needs of a commercial customer. These technologies and this architecture will then be

**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 2008 Status |
|---|---|---|---|
| Electrical energy efficiency @ rated power | % | 40 | 30 |
| Combined Heat and Power (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 | n/a (indoor application) |
| Continuous use application | | | |
| Survivability (min and max ambient temperature) | °C<br>°C | -35<br>+40 | n/a |
| 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/1000 kWh | < 1.5 | not tested |

demonstrated in operational systems in the US 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 down-selection 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

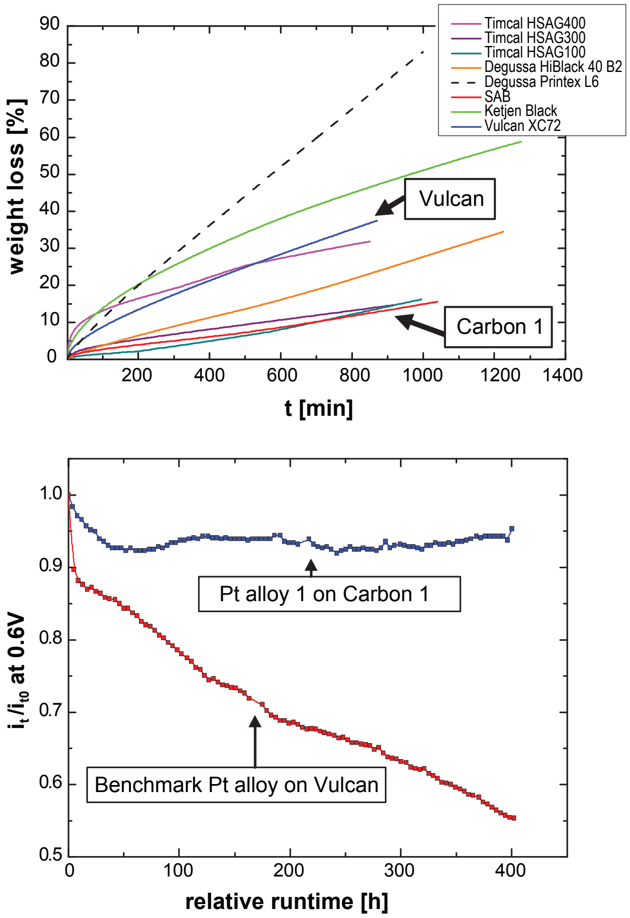

**FIGURE 1.** Carbon Support Selection and Pt Alloy Performance for MEA Cathode Electrode

as catalyst supports. Two supports were developed and the numerous catalysts were down-selected 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 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 stoichiometric 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, anode stoich impact begins to be observable when operating below 1.8 stoichiometric. At 1.8 anode stoichiometric, the difference between 1-pass and 2-pass was about 13 mV and at 1.4 anode stoichiometric 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%).

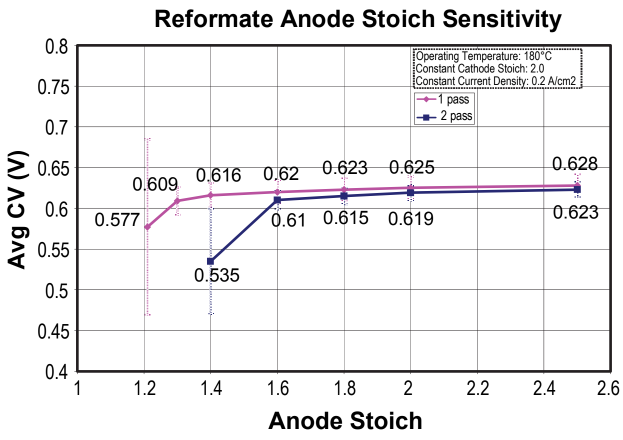

**FIGURE 2.** Reformate Anode Stoichiometric Sensitivity Comparison between 1-Pass and 2-Pass

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.

A new transformerless inverter platform is being developed and evaluated at this time. 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.

## 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 for the final year of the project:

- Complete system build, debug and commissioning.
- Complete design verification testing at Plug Power in Latham, NY.
- Ship systems to Plug Power in Apeldoorn, Netherlands and Vaillant, Germany.
- Complete six month test in Europe.

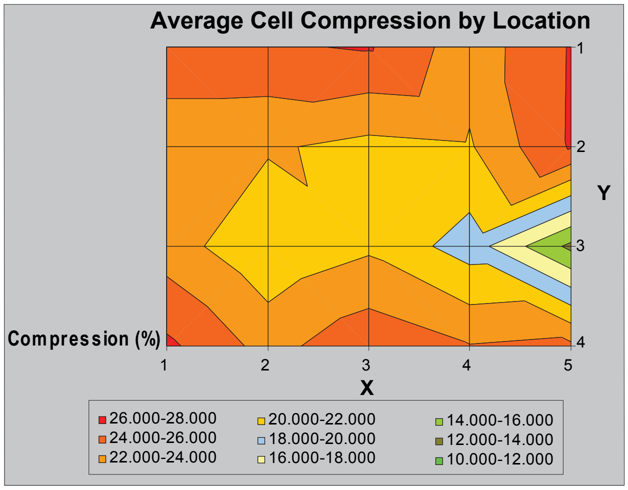

**FIGURE 3.** Sample Average MEA Compression Distribution

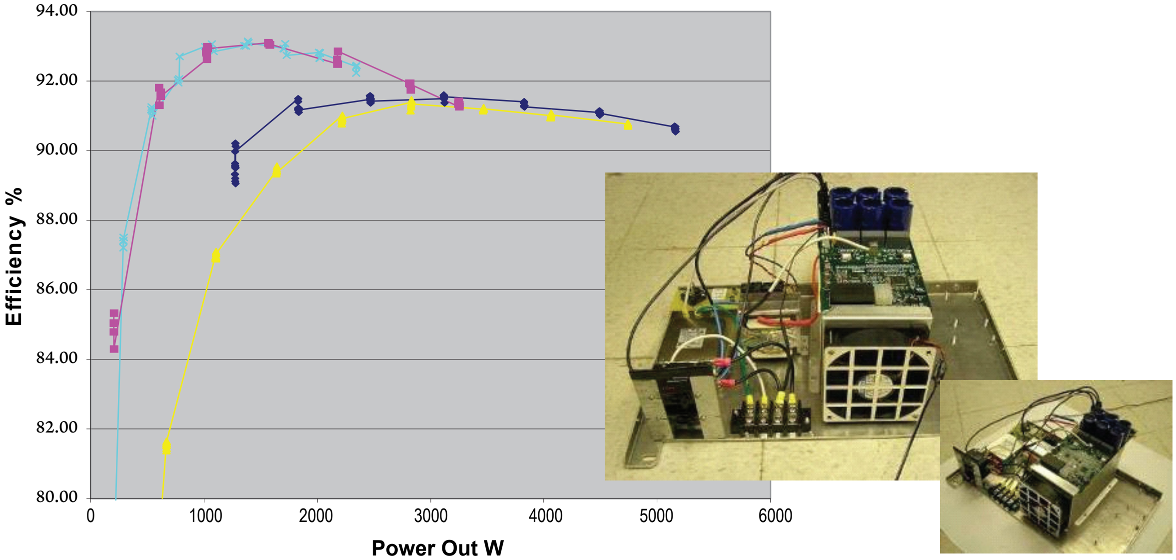

**FIGURE 4.** Inverter Performance Improvements

- Finish stack design up-grade with demonstrated performance in systems.
- Complete controls development.