

## V.G.11 PEM Fuel Cell Freeze Durability and Cold-Start Project

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### Introduction

In order to meet the DOE cold-start target of starting in 30 s to 50% net power from -20°C, the parameters affecting start time must be understood. Generally speaking, we employ a bootstrap start (BSS), in which the stack is started up under its own power (no active heating of the stack by external means). While this concept has been demonstrated by UTC and others, the procedural variables can have a marked effect on performance. These include the cold-start procedure as well as cell design. Within this project, UTC FC will investigate the effects of only the procedural variables, including the current density profile used during start-up, reactant stoichiometries, and coolant introduction. The objective will be to understand the effect of varying each of the procedural variables in order to be able to specify the optimal start procedure in order to achieve a rapid start time.

DOE's stated goal for survivability is that the cell stack must be able to endure a cold soak at -40°C without damage. Meeting this objective will require understanding what mechanisms cause damage to the cell when it is exposed to this temperature. The third area that UTC FC will investigate is performance loss with repeated cold starts. The DOE automotive targets call for cell stack life of 5,000 hours. Presumably, the automobile will have to start dozens or even hundreds of times from a frozen condition during this period, depending on its geographical area of use. For this reason it is critical that cell performance not be affected by starting from a frozen condition. This means that the cell materials must be able to withstand cold temperatures and that cell's level of hydration must return to the baseline state after a freeze start – a challenge due to the mobility of water under the influence of a thermal gradient, even below 0°C, when certain conditions are met.

### Objectives

UTC Fuel Cells (FC) will investigate the effect of freeze and cold-start procedures on performance decay. Diagnostic experiments will be used to determine the cause of any performance decay. Second, alternative cell materials will be evaluated for their resistance to performance loss with repeated cycles. Data from these experiments will form the basis for future development of advanced materials capable of supporting DOE's cell stack assembly (CSA) lifetime objectives.

### Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section (3.4.4.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability

### Targets

- 90% rated power in 30 sec from -20°C
- Survivability to -40°C

### Approach

UTC FC will approach this problem in two ways. First we will investigate the effect of freeze and cold-start procedures on performance decay as well as procedures after start that may enable performance loss to be "recovered" by redistributing water within the cell. Diagnostic experiments will be used to determine the cause of any performance decay. Second, alternative cell materials will be evaluated for their resistance to performance loss with repeated cycles. Data from these experiments will form the basis for future development of advanced materials capable of supporting DOE's CSA lifetime objectives.

### Results

To date, we have performed cold-start testing of the baseline cell configuration, and evaluated the effect of procedural variables on cold-start decay and start time. We see that the profile of the startup has a marked effect on performance during and after the start, as shown in Figure 1. Investigation of the variation of cell potential from cell to cell indicates that performance varies with position in the stack; typically, end cells adjacent to the large thermal mass of the pressure plates lag behind center cells in performance and recovery (see Figure 2).

We have started to develop an understanding of the key factors related to performance loss after cold-start.

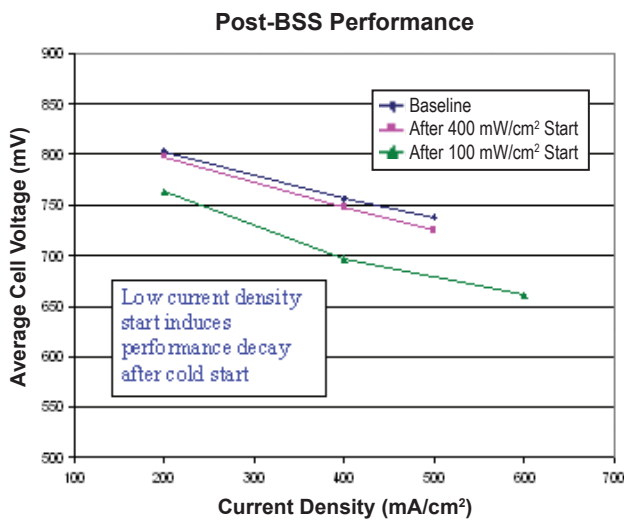


FIGURE 1. Effect of Start-Up Current Density on Performance after Frozen Start

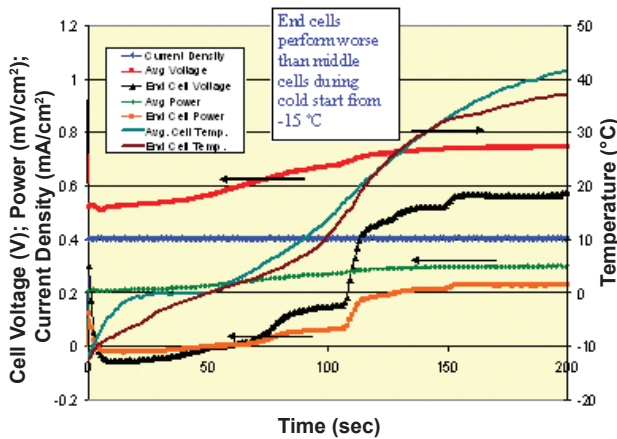


FIGURE 2. Effect of Location in Stack on Freeze Startup Performance

As a result of this understanding, we have developed an alternate cell configuration which reduced cold-start performance losses and improved cold-start capability. The cell performance is improved by altering the gas-diffusion layer (GDL) configuration to interrupt the water movement that occurs in the presence of a large temperature gradient at or near the freezing point. These results are shown in Figure 3.

We have performed freeze-thaw cycling to -40°C on cells of various materials of construction, and have seen no degradation in performance over the cycles performed to date (see Figure 4).

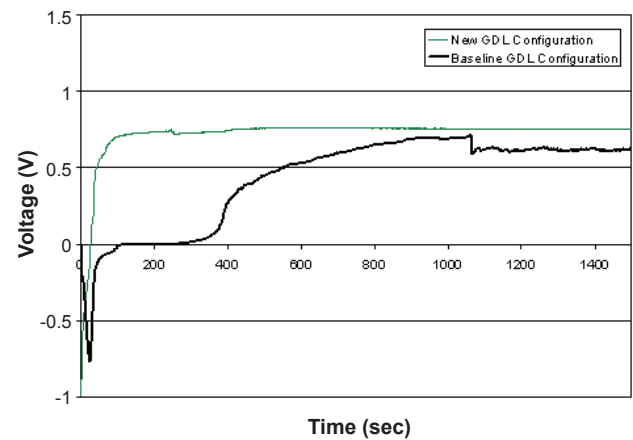


FIGURE 3. Comparison of Frozen Start Performance of Baseline and Improved Gas-Diffusion Layer (GDL), Starting-Up from -15°C

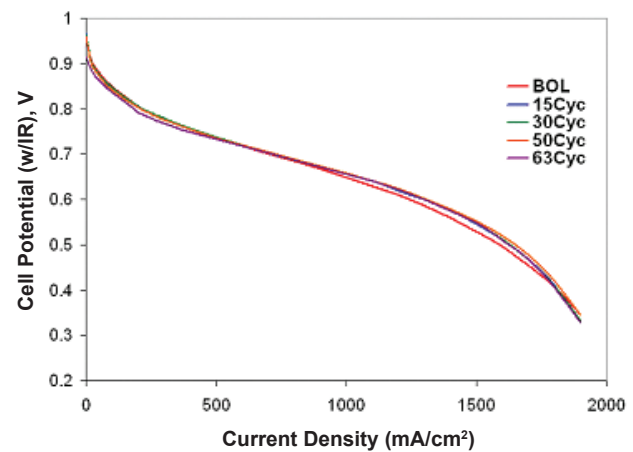


FIGURE 4. Comparison of Cell Performance after Freeze-Thaw Cycling

## Conclusions and Future Directions

Cell construction can be optimized to minimize performance loss and help to optimize start-up from the frozen condition. Our next steps will be to complete the investigation of the effect of material properties and procedural variables on cold-start performance degradation and cold-start capabilities. We will also conduct -40°C freeze/thaw cycling of a short stack and complete teardown analysis.

## FY 2006 Publications/Presentations

1. DOE Annual Merit Review, poster FCP 21.