III.6 Small-Scale Low Cost Solid Oxide Fuel Cell Power Systems

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Objective

To develop a commercially viable 5-10 kWe solid oxide fuel cell (SOFC) power generation system that achieves a factory cost goal of $400 per kWe.

Accomplishments

- Completed testing of Phase 1 prototype meeting or exceeding all objectives.
- Developed the design of next generation cell.
- Fabricated next generation cells.

Introduction

The objective of this project is to develop a standard high performance, low cost SOFC system that can be manufactured in high volume for application in a number of different end uses including residential and as auxiliary power units (APUs) in commercial and military transportation applications. The proposed project is a 10-year, three-phase project with prototype SOFC systems being tested at the end of every phase. Performance and cost improvements made during each phase will be incorporated in each prototype, and products based on each prototype will be made ready for market entry, as they become available.

Approach

We have identified key technical issues that must be resolved to achieve low cost commercial SOFC systems. We will focus on cost reductions and performance improvements to transform today's SOFC technology into one suitable for low cost mass production of small systems for multi-market applications. The key advances identified are:

- Improved cell performance through design and materials innovations to more than double the power and thus reduced cost/kWe.
- On-cell reformation of natural gas fuel to eliminate high cost internal reformer components.
- Use of low cost insulation and containment vessels by lowering the system operating temperature.
- Use of net shape cast components to reduce machining costs.
- Simplification of stack and balance of plant (BOP) designs to lower parts count.
- High efficiency (95%) power conditioning systems to improve overall system electrical efficiency.

In addition to the key advances noted above, adoption of more automated, mass production techniques for cell, module and BOP manufacturing will ensure overall SOFC system cost effectiveness.

Results

Prior to the start of the project, it was recognized that Siemens' seal-less tubular cell design would not be able to meet the cost and performance targets of the project. A need to develop a cell with higher power density and compact design was identified. A new design that combined the seal-less feature and a flattened cathode with integral ribs was chosen. This new design referred to as high power density (HPD) cell has a closed end similar to the tubular design. The ribs reduce the current path length by acting as bridges for current flow. The ribs also form air channels that eliminate the need for air feed tubes. This cell design, due to shorter current path has lower cell resistance and hence higher power output than tubular cells. In addition, a variation of the HPD design, Delta, has a corrugated surface which significantly increases the active area of the cell yielding higher power per cell.

During FY 2007, a prototype system for residential applications was tested. The primary objective of this system was to demonstrate operation of HPD cells in a generator environment. The system ran on internally reformed pipeline natural gas fuel. The test duration was approximately 6,300 hours without any voltage degradation. Table 1 shows system targets versus actual performance. It met or exceeded all DOE targets for a Phase 1 prototype.

TABLE 1. Phase 1 System Performance

Performance Parameter	Requirements	Results
Net DC Efficiency	35%	38%
DC Peak Power (kW)	3-10	5.9
Steady State Degradation	<2% per 500 hrs	0 (2% Power Enhancement)
Thermal Cycle	1	1
Power Cycle	9	9
Availability	80%	100%
Test Duration (hrs)	1,500	6,300

Also during FY 2007, a next generation cell was optimized as the Delta8 design, based on net system power. Several Delta8 cells were fabricated for electrical testing. This cell has an active area of approximately 2,000 cm^2. Figures 1a and 1b show different views of a Delta8 cell.

Computational modeling of thermal and electrical fields to optimize the cell and stack design for maximum power and mechanical stability from thermal stresses during stack operation continued during FY 2007. Efforts were also directed towards the development of cell-to-cell connections to bundle cells.

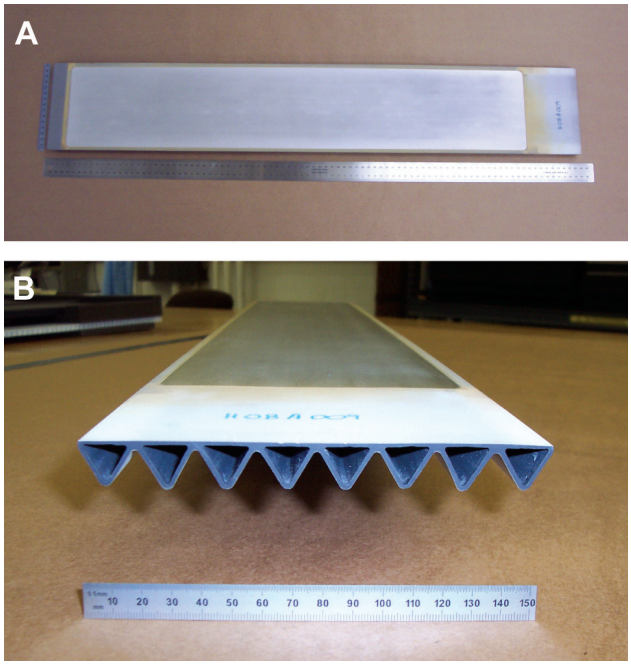

FIGURE 1. (a) Delta8 Cell Top View and (b) Delta8 Open End View

Conclusions and Future Directions

- Completed testing of Phase 1 prototype.
- Fabricated next generation cells.
- Electrically test next generation cells.
- Optimize cell and stack design for maximum power and reliability.
- Evaluate and develop automated mass production processes for cell, module and BOP components.

FY 2007 Publications/Presentations

1. S. D. Vora, "SECA Program at Siemens", Presented at Seventh Annual SECA Meeting, September 12–14, 2006, Philadelphia, PA.

2. S. D. Vora, "Development of High Power Density Seal-less SOFCs", Presented at the 2006 Fuel Cell Seminar, November 13–17, 2006, Honolulu, Hawaii.

3. S. D. Vora, "Development of High Power Density Seal-less SOFCs", to be presented at SOFC-X Symposium, June 3–8, Nara, Japan.