III.1 Development of a Low Cost 10 kW Tubular SOFC Power System

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Objectives

- Adapting the generator design for integration of the next generation higher power multiple connection chromite cells
- Development of an anode supported tubular cell capable of further doubling the power density presently achieved
- Improving cell and stack design to further reduce the stack cost

Approach

- Increase the current collection points per tube to increase cell power
- Improve material conductivity and stability to allow a higher power, longer lasting fuel cell tube
- Decrease solid oxide fuel cell (SOFC) generator component costs through advanced manufacturing techniques
- Perform preliminary testing on simulated coal gas to determine critical operating parameters

Accomplishments

Key Accomplishments in FY 2007 include:

- **Exceeded 350 mW/cm^2 on multiple interconnection cells:** Multiple interconnection cells have been manufactured achieving >350 mW/cm^2. This increases the average value from 120 mW/cm^2 thereby cutting the required number of cells and cost for a desired power level.
- **Demonstrated a tubular SOFC achieving >60 W/tube:** Further advancements in larger diameter tube technology and multiple take-off connections have been integrated into a single cell design. Previous advancements in isopressing technology have also been incorporated. These advancements take the single cell power from 5 W/tube at the start of the Solid State Energy Conversion Alliance (SECA) program to >60 W at this point.
- **Achieved 1,500 hours operation and completed SECA Phase I testing at Acumentrics:** Acumentrics successfully completed the SECA Phase I testing achieving over 6.1 kW output and greater than 35% efficiency and 97%+ availability with no degradation.
- **Achieved 800 hours validation testing at DOE-NETL:** Acumentrics shipped the unit to the validation site at the National Energy Technology Laboratory (NETL) in Morgantown, West Virginia and operated the unit for an additional 800 plus hours running a scaled down test of the version run in the first test. On this test, the power achieved was higher at 6.4 kW with slightly higher efficiency, near 37%, with similar availability and degradation. This unit has been returned to Acumentrics and has now run for over 3,500 total hours with no noticeable degradation.

Future Directions

- **Demonstrate tubular SOFC performance achieving 100 W/cell for scale up to MW-class coal systems:** Work will commence into scaling the individual tube power to 100 W/cell to show a scaled version of a 600-800 W cell for MW-class coal systems by adjusting tube size as well as current collection points.
- **Demonstrate high power density over a wider temperature range:** Work will focus on opening the cell temperature window while achieving high power density. Under this task, this operating temperature will ideally be opened up to a low range of 700°C from 800°C with no detriment to power density.
- **Perform cost study achieving lower stack cost:** Work will focus on furthering the cost study done during Phase I of the SECA program to verify cost at high volume. Advancements in cell power density and generator component design will be integrated into the model. This cost estimate will focus on the stack itself as the building block for MW-class systems.

Introduction

The Acumentrics SECA program has focused on the design and manufacture of micro-tubular SOFC power systems approaching twice the power density now achieved from state of the art anode supported tubular designs. Based upon DOE funding and a focused research effort, these cells have achieved this goal and the path forward is to again double the power density. These units will be capable of entry into the residential and military markets initially followed by central station power operational on coal gas in the longer term.

Approach

To achieve the reduced stack cost goal, work will focus on increasing cell power thereby decreasing the number of cells per kilowatt or decreasing the cost of each component. With such an aggressive goal, work must focus on both paths. To increase cell power, work is centered on improved materials as well as enhancements in geometry. Cells with increased anode conductivities to decrease electrical bus losses are being investigated. Improved conductivity of cathodes is also being investigated to decrease the potential loss associated with the electrochemical reaction on the airside. Increases in cell tube diameter as well as multiple contact points along the length are also being studied.

Results

Cell and Stack Performance and Power Density

The culmination of three years of cell and stack advancements during Phase I of SECA resulted in the successful completion of the required end of phase test. The Phase I machine achieved practically no voltage degradation over the entire 2,300 hours of testing while achieving a peak power of 6.4 kW on a 5 kW class machine. The machine had an electrical efficiency near 37% while achieving over 97% availability. Figure 1 shows the performance stability of this machine while testing at NETL's site in Morgantown, West Virginia.

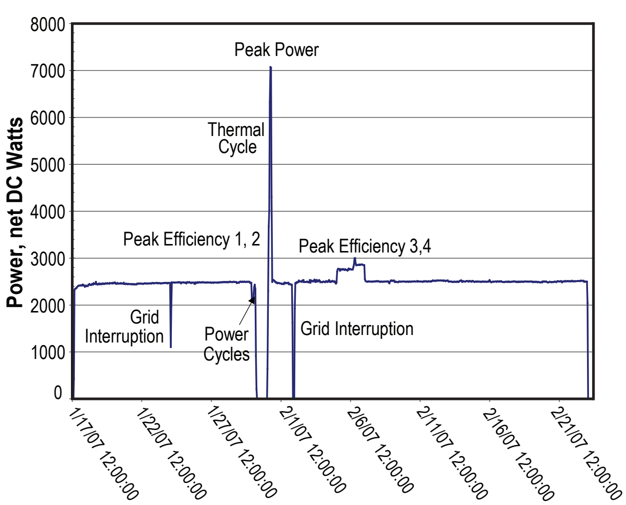

FIGURE 1. Performance Testing at NETL

In addition to major achievements in cell and stack stability, substantial strides in stack power density have been achieved. Figure 2 shows the resulting advancements in stack power density over the entire Phase I SECA program. For a 1.25 kW stack, the cell count has been decreased from 126 cells to 45 cells. Weight has been reduced by 75% from 92 lbs to 23 lbs. Volume has been reduced from 1.55 cubic feet to less than 0.3 cubic feet or by 82%. This results in the desired stack configuration for MW-class systems and now work will focus on cell power density as well as cell size/ power increases.

Generator Design

Work has continued in cost reduction of the generator design as well as scale up for larger MW sub-systems. Progress has been made in advancing both metallic and ceramic recuperators for thermal recovery on the SOFC stack side. Figure 3 shows the resulting reductions in size, weight, and cost of the recuperators used for heat recovery. Figure 4 shows the

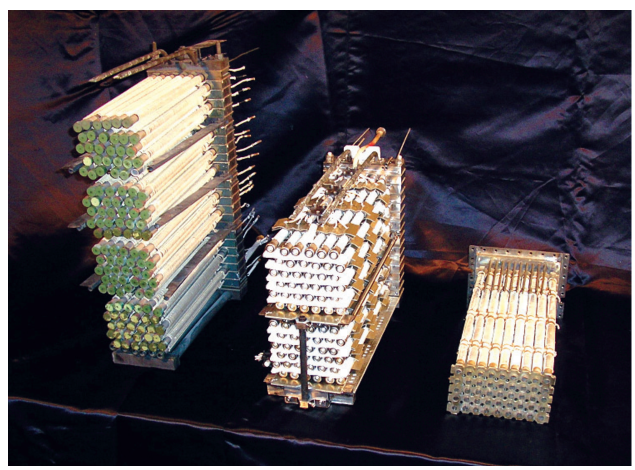

FIGURE 2. Progress in Stack Size and Weight Reduction

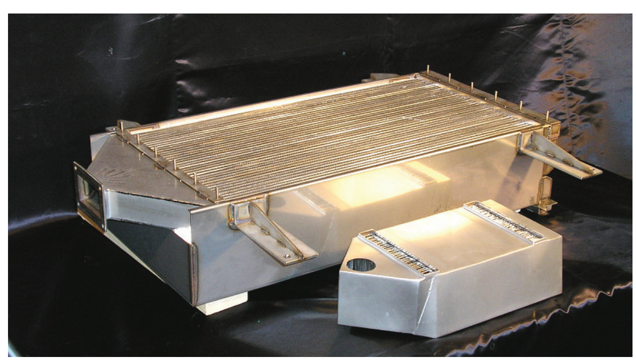

FIGURE 3. Recuperator Advancements

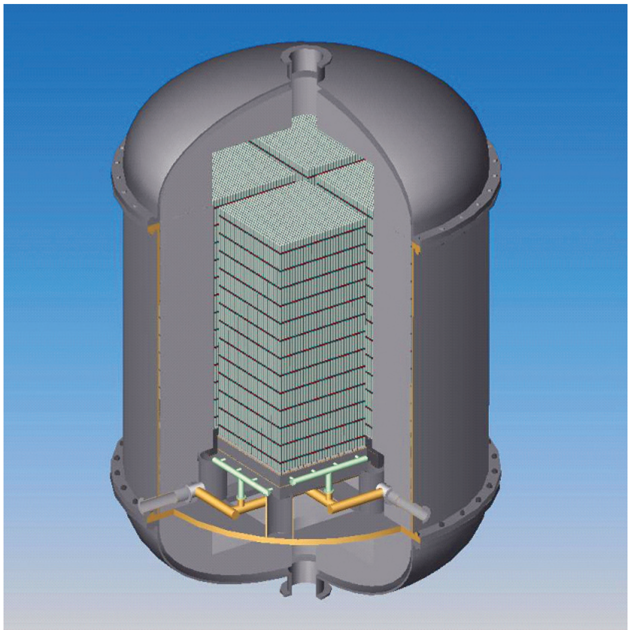

FIGURE 4. 1 MW SOFC Module

resulting preliminary model for a MW-class sub-system incorporating larger tubes with the developed cell power densities previously described.

Conclusions

Continual advancements have been made toward the SECA cost and performance targets in the Acumentrics' SOFC program. These advancements can be summed as:

- Successful completion of all Phase I SECA performance testing and cost analysis
- Cell power densities exceeding 350 mW/cm^2 or 3x greater than previous technology
- Generator design with significant size and weight reductions over pre-SECA designs well suited for mass production

FY 2007 Publications/Presentations

1. "Status of the Acumentrics SOFC Program", N.F. Bessette, Presented at the 2006 SECA Annual Workshop, Philadelphia, PA, September, 2006.

2. "Status of the Acumentrics SOFC Program", N.F. Bessette & D.S. Schmidt, Presented at the 2006 Fuel Cell Seminar, Honolulu, HI, November, 2006.