Small-Scale Low Cost Solid Oxide Fuel Cell Power Systems

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ABSTRACT

Tasks carried out during the first six months of the program are summarized. Development of seal-less cells with increased power density at lower operating temperature (800°C) was started. This required a new cell design and investigation of new cell materials. Conceptual design of the generator and balance of plant (BOP) for a residential system was initiated.

Attachment 1 describes the progress in cell development and Attachments 2 and 3 deal with status of the generator and BOP design. Overall progress during the first six months and plans for future work are summarized in Attachment 4.

EXECUTIVE SUMMARY

This report summarizes tasks carried out during the first six months of the contract period. Progress was made in several key areas through development of concepts, selection of materials and fabrication of test samples and cells.

Prior to the start of the program, it was recognized that Siemens Westinghouse's seal-less tubular cell design would not be able to meet the cost and performance targets of the SECA program. 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) SOFC has 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.

Analytical modeling was initiated to optimize the number of ribs (channels) for maximum power and mechanical stability from thermal stresses during operation. Based on initial results, HPD cell design with five channels (HPD5) was selected for cell preparation in the initial stage.

Cell preparation was intended to identify critical issues in fabrication and testing. Over 50 HPD5 tubes were extruded and sintered. Poor attachment of closed end cap was identified as a major issue to solve in the early stage of the program. A plan has been prepared to address the closed end attachment problem. In the long term, a seam-less closed end is envisaged. Despite the closed end attachment problem, several HPD5 cells were fabricated to develop plasma spray technology and electrical performance testing.

Analytical modeling to further improve the cell design continued. Improved design with 10 channels referred to as HPD10 is being considered. Tubes of HPD10 geometry were also extruded and sintered.

State-of–the art Siemens Westinghouse tubular SOFCs nominally operate at 1000°C utilizing yttria stabilized zirconia (YSZ) as the electrolyte. The focus in the SECA program is to lower the operating temperature to nominally 800°C. Lowering the operating temperature allows use of lower purity materials (and hence lower cost). Sr and Mg doped lanthanum gallate (LSGM) was selected as the electrolyte for low temperature operation. Compositions for cathode and interconnection compatible with LSGM were investigated. The investigation involved determination of thermal expansion, thermal cyclic shrinkage, electrical conductivity and chemical compositions of candidate materials. Based on the results, a cathode composition was selected for powder preparation. Selection of interconnection composition is in progress.

Parallel with the development of LSGM and compatible materials, ways to improve low temperature performance of YSZ electrolyte cells were investigated. This involved development of new cathode composition and cathode interlayers. Composite interlayers consisting of mixed ionic and electronic conducting phases were developed. A slurry based process was used to deposit the interlayers. Several tubular cells with composite interlayers (YSZ electrolyte) were electrically tested. These cells showed increased power at lower temperatures. The cathode compositions investigated have higher conductivity at lower temperatures. Cell fabrication with new cathode composition will be carried out in the next reporting period.

Design of cell-to cell electrical connections was initiated. Drawings of a new Ni foam electrical connector and bundle configuration have been completed. This design allows for optimal current distribution while allowing adequate fuel flow.

Siemens Westinghouse's partner Blasch Precision Ceramics is developing a low cost, impermeable ceramic housing for the stack. Blasch has considered and investigated eight external coating/surface treatment technologies in attempt to impart gas impermeability of their mullite bonded alumina refractory ceramic. Four of these were terminated for various reasons and four are still active and under further investigation/effort. A gas permeability test

apparatus for ceramic disk specimens was designed and assembled, and has been used. Adhesion of metal foil to the ceramic has been tried, but without success to date. Blasch has also internally devised a coating method (in attempt to impart gas impermeability), and has set-up and just begun working with this equipment. Additionally, application of chemicals and powders has been tried by different methods with some success. Some of the chemicals applied effectively reduced gas permeability by 30%. Further effort is planned on this approach.

Conceptual design for the residential system was started. Siemens Westinghouse worked closely with Fuel Cell Technologies (FCT), partner in generator and BOP development, on this task. The overall thrust of the task is to start from the existing residential prototype system design and develop concepts to simplify the system.

FCT initiated the design of BOP components/systems. Design of hot gas recirculator was completed and a prototype was assembled for testing. Similarly, design of gas fired start-up heater was completed and a prototype was tested. Inverter development was carried out for both grid-connected and stand alone operation. Considerable work was carried out on load sharing between battery and stack to enable a degree of load following capability. A simple desulfurizing cartridge was tested and several deodorants were characterized.

EXPERIMENTAL

Experimental methods used are detailed within each specific section in Attachment 1 (please see pages 1-2, 1-9, 1-13, 1-17, 1-19, 1-22, and 1-23), Attachment 2 (please see pages 2-1, 2-10 and 2-13) and Attachment 3 (please see page 3-3).

RESULTS AND DISCUSSION

Relevant data, including statistical data, and an explanation of how such data was interpreted is detailed within each specific section in Attachment 1 (please see pages 1-3, 1-10, 1-13, 1-17, 1-21, 1-22 and 1-24), Attachment 2 (please see pages 2-9, 2-11, and 2-14) and Attachment 3 (please see page 3-4).

CONCLUSION

Conclusions, including logical implications of how the successes are relevant to future technology development, are detailed within each specific section in Attachment 1 (please see pages 1-9, 1-10, 1-19, 1-21, 1-23, and 1-24), Attachment 2 (please see pages 2-13 and 2-15) and Attachment 3 (please see page 3-5).

REFERENCES

None.