Advances in Solid-oxide Fuel Cell Technology: Summary of a Panel Session Presentation

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***Abstract*—Solid-oxide fuel cell (SOFC) systems are based on either a tubular or planar electrode configuration. In each case the operating temperature is in the range of 750 to 1,000 degrees C, which permits internal reforming of hydrocarbon fuels into a hydrogen-rich gas. This presentation will describe the basic design and characteristics of SOFC systems in development for residential, commercial and industrial applications.**

***Index Terms*—fuel cell, cogeneration, solid-oxide, ceramic electrolyte, combined-cycle, topping cycle**

I. Introduction

THIS panel session presentation summary provides an overview of the efforts under way to develop solid-oxide fuel cell (SOFC) systems for a wide range of power ratings (1 – 250 kW) and several configurations (stand-alone, combined-cycle and cogeneration). Examples of tubular and planar electrodes are shown, along with general system configurations for residential and commercial or industrial use. Companies active in the SOFC field as of December, 2003 (date of submission) are listed by type of product. Information is also provided on the U. S. government's Solid-state Energy Conversion Alliance (SECA) program within the Department of Energy.

II RESIDENTIAL SOFC SYSTEMS

Several companies are developing SOFC systems designed for residential combined heat & power (CHP) use. Electrical power output ranges from one to five kW; thermal power ratings begin at 8,500 Btu/hr. Auxiliary heat sources are employed with some products for higher thermal output. Two companies employ planar cells, the third a tubular configuration. In each case, multiple cells are combined into a stack to produce the desired output voltage. Figure 1 shows a planar-cell stack. Manifolds direct the gaseous fuel and air into the stack assembly and hot exhaust components out of the stack into a heat exchanger.

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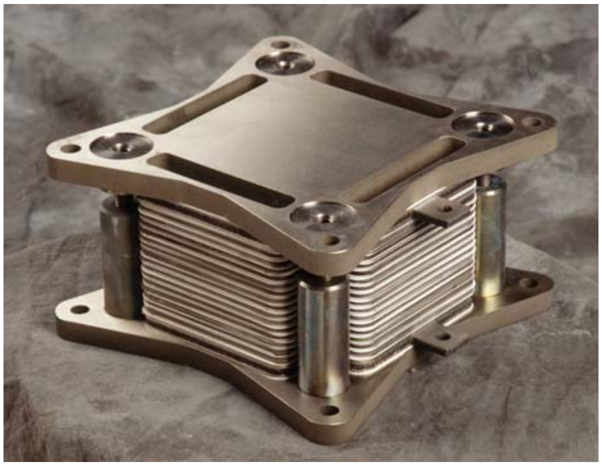
FIGURE 1
PHOTO OF PLANAR SOFC CELL STACK *



* Photo courtesy of Global Thermoelectric, Inc..

II SMALL-SCALE (1-10 kW) SOFC SYSTEMS

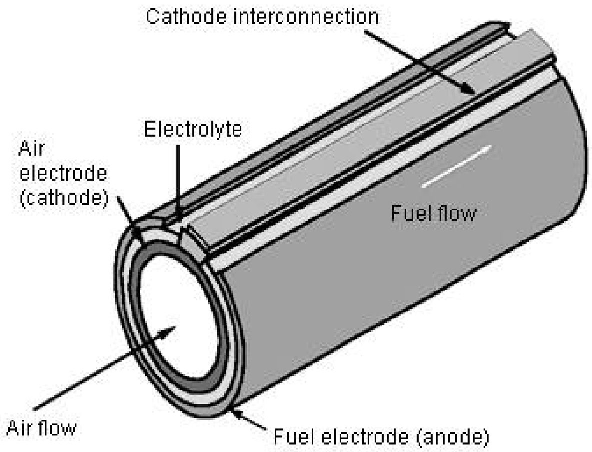
Several other companies are focusing on SOFC systems in this range for commercial or industrial use, as noted below in Table 1. A representation of the tubular fuel cell configuration is shown in Figure 2.

TABLE I
SOFC COMPANIES AND PRODUCT CHARACTERISTICS

Company	**Power ***	**Cell Type**	**Status**
Acumentrics	2-10 kW	Tubular	On market
Ceramic Fuel Cells Ltd	<50 kW	Planar	Concept testing
Delphi Corp.	1-25 kW	Planar	Concepts testing & prototypes
Fuel Cell Technologies	5 kW	Tubular	Prototypes
Global Thermoelectric/ Quantum Fuel Systems	2-5 kW	Planar	Prototypes
Sulzer Hexis	1 kW	Planar	Large-scale test to end in 2003
Siemens/Westinghouse	125 kW	Tubular	Prototypes in test
Rolls-Royce	250 kW	Planar	In development
Ztek	25 kW	Planar	Prototype

* Product on the market, prototype or planned item. Most companies envision products with higher power ratings. NOTE: companies change published ratings as technology advances and plans change.

FIGURE 2
DIAGRAM OF TUBULAR SOFC CELL COMPONENTS *

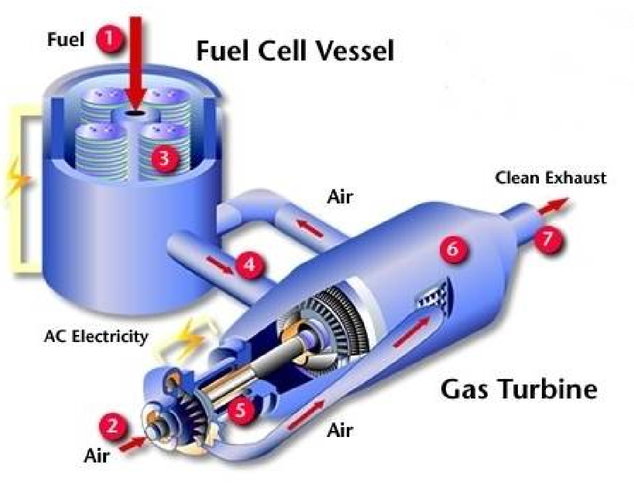


* Drawing shown on Siemens-Westinghouse web site.

III. SOFC SYSTEMS WITH TURBINES

SOFC systems can operate at low or high pressure. For high-pressure systems, several companies have examined the feasibility of using a turbine to capture the energy of hot exit gases and improve overall system efficiency. Both tubular and planar cell stacks have been coupled to gas turbines in experimental or prototype configurations. One company has tested 200-kW and 300-kW (total power) systems. Examples of several configurations will be shown, with the general concept as shown in Figure 3.

FIGURE 3
COMBINED SOFC + TURBINE SYSTEM COMPONENTS *



*Drawing shown on ZTEK Corp. website.

IV GOVERNMENT INCENTIVE PROGRAMS

In the United States, the Department of Energy has set up the Solid-state Energy Conversion Alliance (SECA) to promote the development and advancement of SOFC systems. Primary Participants include three fuel cell companies, GE Power Systems, Cummins and Delphi. Other participants include U.S. national laboratories, universities and specialized fuel cell component companies. The Canadian government has also provided support for SOFC advancement. Additional information on these two programs will be provided.

V CONCLUDING COMMENTS

These remarks will cover the status of major SOFC programs, field tests of products, and general trends in this area of energy conversion.

VI BIOGRAPHY

JOHN J. BZURA (M-1980, SM – 1989) was born in Albany, Georgia on September 14, 1944. He received the B.S., M.E.E. and Ph.D. degrees from Cornell University, Ithaca, NT, in 1966, 1967 and 1971 respectively, all in electrical engineering. In 1974, an M.B.A. degree was granted by Syracuse University, Syracuse, NY.

Dr. Bzura was employed by Arthur D. Little, Inc. from 1974 to 1983, where he performed technical and economic analyses of energy systems. He joined the New England Power Service Company (now National Grid USA Service Company) in 1983, and spent 10 years as Principal Engineer in the Demand Planning R&D Group. The last 10 years have been with the R&D / Technology Transfer group within Engineering. Projects and topics of interest include solar and wind energy systems, distributed generation (DG) technologies, DG interconnection issues, distributed energy storage, electric vehicles and broadband power-line communications.

He is a Senior Member of the IEEE Power Engineering Society, the Energy Development Subcommittee (EDS) and serves as Chairman of the Distributed Generation and Energy Storage Working Group within the EDS.