

SOLID OXIDE

SIEMENS WESTINGHOUSE: 25 KW TUBULAR SOLID OXIDE FUEL CELL FIRST SOFC PRE-COMMERCIAL PROTOTYPE AND RESEARCH PLATFORM

First SOFC Pre-Commercial Prototype and Research Platform

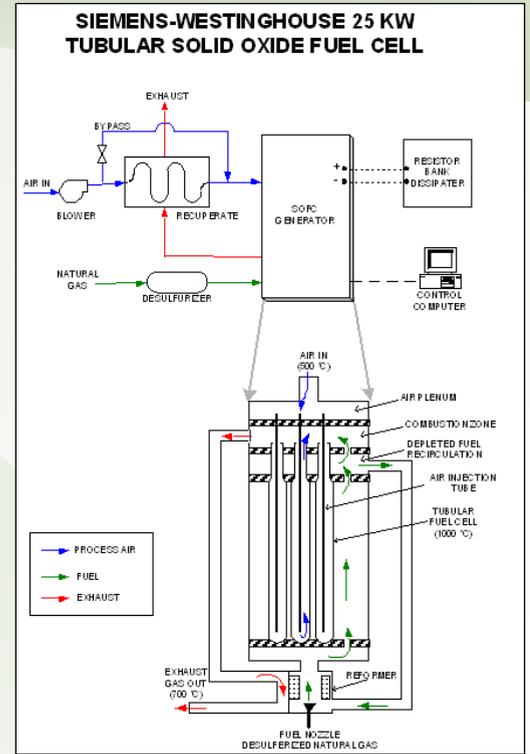
OVERVIEW

Siemens Westinghouse Power Generation has developed tubular SOFC technology as part of the US Department of Energy's (DOE) advanced fuel cell research program, which is managed by DOE's Office of Fossil Energy and overseen by its National Energy Technology Laboratory in Morgantown, West Virginia.



OBJECTIVES

- To provide long-term operating data on the tubular Solid Oxide Fuel Cell (SOFC) design.
- Test component designs including inverters, gas heaters, reformer technology, and controls.
- The NFCRC is using the 25 kW SOFC system to investigate the emissions and dynamic performance of fuel cells and reformer systems in general with detailed measurements of the dynamic performance of each.
- Finally, the NFCRC is examining the fuel flexibility of SOFC systems using this 25 kW SOFC system to test operation on natural gas, diesel, JP-8, and simulated landfill and digester gas.



RESEARCH DATA ACQUISITION: STEADY STATE PERFORMANCE IS EVALUATED FOR VARIATIONS IN:

- fuel utilization
- stoichiometry
- power density
- operating temperature, and
- fuel composition

DYNAMIC PERFORMANCE IS EVALUATED FOR DYNAMIC VARIATIONS IN:

- operating temperature
- load variations
- stoichiometry variations
- fuel composition, and
- fuel and oxidant flow rates

STATUS

The 25 kW tubular SOFC system was initially installed at the Highgrove Generating Station of Southern California Edison in California in the Spring of 1994. It operated approximately 6500 hours on its first stack before being replaced in mid-1995 with a new air electrode supported (AES) tubular SOFC design.

Testing of SOFC operation on logistic fuels began in October 1995 with approximately 750 hours of operation on jet fuel, 1500 hours on diesel fuel, and 650 hours on natural gas during transitions. In February 1996, the system was shut down after 11,500 hours of system testing (5,000 hours on the new stack). The system was then relocated to the National Fuel Cell Research Center and restarted January 1998 where it has operated on natural gas.

As of June 2002, the system has operated for a total of 19,750 hours with 13,250 hours on the current stack.

The system is projected to operate for up to 20,000 hours, after which time the system may be retired to the Smithsonian Museum as the "world's first integrated solid oxide fuel cell system."



CURRENT PROJECTS

Two students (Undergraduate Joan Morrison and Graduate Thomas Smith) are currently conducting research using the 25 kW SOFC system. The students are developing a program that can display and store information from the 25 kW, with user defined variable timing, developing a design of experiments for testing of the unit and acquiring data for model validation

PERSONNEL

Student(s): Tom Smith (Grad), Joan Morrison (Undergrad)

Faculty: Prof. Scott Samuelsen

Staff: Dr. Jacob Brouwer



National Fuel Cell
Research Center
www.nfcrc.uci.edu

Project Sponsors:

- Siemens Westinghouse Power Corporation
- Southern California Edison
- NASA Glenn Research Center
- U.S. Department of Defense
- Electric Power Research Institute (EPRI)
- California Energy Commission

SOLID OXIDE

SIEMENS WESTINGHOUSE: 25 KW TUBULAR SOLID OXIDE FUEL CELL FIRST SOFC PRE-COMMERCIAL PROTOTYPE AND RESEARCH PLATFORM

PAGE 2

HOW IT WORKS

The Siemens Westinghouse SOFC is a tubular design configured as a single cell per tube. The cell is built up in layers on the air electrode (cathode) with an axial interconnection that makes the cathode accessible and allows cells to be connected together in series. A cell cross section is shown in Figure 1.

Currently manufactured as commercial prototypes at a pilot manufacturing facility in Pittsburgh, the cell is nominally 1.59 cm in diameter by 50 cm in active length with one closed end, and with an inside diameter of 1.18 cm. To generate electricity efficiently, the cell must be maintained at an operating temperature of about 1000° C, air must be supplied to the cell interior using an air delivery tube, and fuel is delivered to the cell exterior. At open circuit, a potential of in the range of 900 to 1-volt will be generated per cell, thus cells are connected in series to build voltage. Power produced is proportional to the active surface area of the cells. At atmospheric pressure, a uniform temperature of 1000°C, 85% fuel utilization, and 25% air utilization, a single tubular SOFC will generate power of up to 65 W dc.

To generate commercially meaningful quantities of electricity, many cells must be connected together into a generator module or stack. They are connected into bundles using a nickel felt which makes the electrical connection between cells, as shown in Figure 2. A photograph of a bundle is shown in Figure 3.

Being compliant the nickel felts allow each cell to expand or contract independently of the adjacent cells as the temperature in the stack changes. In a typical stack design, the tubular cells are oriented with the axis vertical and the closed end down. The bundles are arranged into rows connected in series to build up voltage, as shown in Figure 4, the cross section of a typical stack.

Figure 4 - SOFC Stack Cross Section

Between each row is placed an in-stack reformer that is radiantly heated by the adjacent rows of cells. A simplified sketch of a SOFC module is shown in Figure 5.

Figure 5 - SOFC Nodule Arrangement

How it works: Desulfurized natural gas is fed directly into an ejector (also known as a jet pump). The ejector creates a partial vacuum that pulls spent fuel from a recirculation plenum near the [top of page] of the stack. This captures water vapor needed for the reforming of the natural gas. This fuel mixture passes over a catalyst (the pre-reformer) where any higher hydrocarbons are converted to methane, hydrogen, and carbon monoxide. The fuel mixture is then passed through in-stack reformers where the methane is completely converted to hydrogen and carbon monoxide before it reaches the cells. This reformed fuel mixture then enters a fuel manifold at the bottom of the stack where it is distributed to the outside surface of the cells, flowing upwards.

Meanwhile, after preheating in a recuperator, air enters the module and passes through the air manifold into air feed tubes that take it to the bottom of the cells on the inside. Exiting the feed tube the air flows up the inside surface of the cells. With fuel on the outside and oxygen from the air on the inside the electrochemical reaction takes place along the length of the cells, consuming ~85% of the fuel in the process. The temperature inside the module varies somewhat but is generally kept at a maximum of 1000C. Depleted fuel then enters the recirculation plenum where a fraction of it is recirculated and the balance flows into the combustion plenum to mix with the excess air. A small amount of combustion takes place here that helps to preheat the air flowing down the feed tubes. The hot gases now make up the exhaust which leaves the module and passes into the recuperator, and then into another heat exchanger to make use of the valuable heat.

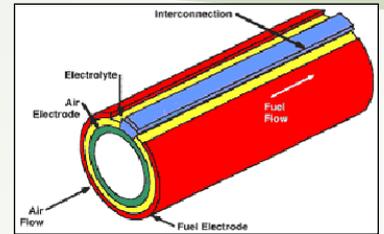


Figure 1

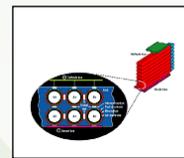


Figure 2



Figure 3

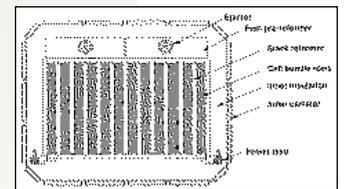


Figure 4 – SOFC Stack Cross Section

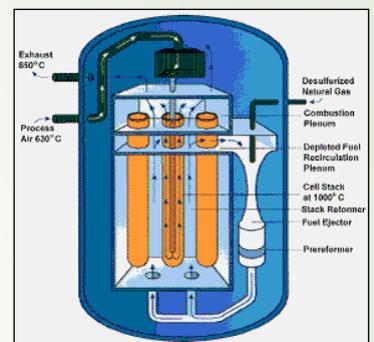


Figure 5