

# MOLTEN CARBONATE FUEL CELLS

## STEADY STATE MODELING OF MOLTEN CARBONATE FUEL CELLS FOR SYSTEM PERFORMANCE ANALYSES

### OVERVIEW

Development of steady state and dynamic simulation capabilities for molten carbonate fuel cell (MCFC) technology is being accomplished in this project. These analyses tools are being developed as part of an effort to advance MCFC and MCFC hybrid technology, and are being validated by comparisons to data from an MCFC test stand and from the world's leading manufacturer of MCFC technology, FuelCell Energy. The simulation tools can be scaled up and combined with the Advanced Power Systems Analysis Tool (APSAT) to model MCFC hybrid systems. To simulate the Direct FuelCell™ approach of FuelCell Energy, the simulation of internal reformation processes are included in the full MCFC stack model.

### OBJECTIVES

The development of this model can help to select the optimal conditions to operate a molten carbonate fuel cell, can be used to garner fundamental insight into the design and operation of MCFCs, and can be used to develop strategies for hybrid MCFC cycles and control systems for the operation of MCFC and MCFC hybrid systems.

### SYSTEM CONFIGURATION

This steady state model is developed with SIMULINK®. The MCFC model is first developed in the scale of a single cell, and then expanded to model a fuel cell stack. In each single cell, heat transfer processes are accounted for in five components: anode and cathode end plates, anode and cathode gases, and electrolyte. Once the types of heat transfer processes are determined in each of the components, conservation of energy can be applied to calculate the temperature. Beside convection, radiation, and conductor, heat is generated by water-gas shift and electrochemical reactions, as well as gas enthalpy from generating reactions.

It is important to evaluate the temperature of electrolyte because it essentially determines the voltage output of the fuel cell. As a result, the temperatures of the other four components are also necessary to be calculated due to their influence on the electrolyte temperature. The electrolyte temperature is then output to calculate the voltage and current generated by the fuel cell.

To accommodate the use of natural gas for fuel cells, a steam reformer model is included. This model involves solving a system of non-linear algebraic equations. The results represent the amount of reaction in the methane reforming and water-gas shift reactions. Due to the use of natural gas, it explains the reason for calculating the amount of heat generation by water-gas shift reaction.

To validate the model, results generated from the MCFC single cell model are compared directly with the results generated by the MCFC test stand. The test stand is capable of simulating any operating conditions, such as pressure and temperature. Therefore, a direct comparison can be achieved. The MCFC test stand and the fuel cell materials for experiment are shown below.



Fig. 1 Front view of the test stand. Its dimension is approximately 8 feet wide, 4 feet deep, and 7 feet tall.



Fig. 2 The necessary components to assembly a single cell. Anode, cathode electrode, matrix, and electrolyte are shown as tapes before loading onto the end plates.

### OPERATING DESIGN

The input variables for this model include the flow rates of anode and cathode gases. The dimensions of a fuel cell and the number of cells can be changed to accommodate fuel cells with different sizes and fuel cell stacks. The outputs are the temperatures of the individual components, voltage and current generated by the fuel cells, and the total power.

### STATUS:

**Late 2000** - Received fuel cell materials for test stand restart

**May 2001** - Started fuel cell operation

**June 2001** - Fuel cell shutdown

**January 2002** - MCFC steady state model complete

**June 2002** - Internal reformer model complete

**TBD** - MCFC model validation

**TBD** - Full MCFC stack model simulations

**TBD** - Full MCFC hybrid system simulations

### PERSONNEL

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