TITLE:	MODELING AND DESIGN FOR A DIRECT CARBON FUEL CELL WITH ENTRAINED FUEL AND OXIDIZER

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1. ABSTRACT

Objectives

Modern fuel cell development, with its origins in the space program, has concentrated on compact fuel cell designs in which an immobile electrolyte is contained between porous membrane electrodes. Fuel and oxidizer are supplied to the electrodes on the sides opposite the electrolyte, and all reactions take place on the electrolyte-wetted surfaces of the electrode membrane. This type of cell design is effective for a compact cell using gaseous fuel, but it has serious limitations for utility-scale power generation using coal.

An alternate fuel cell concept is proposed. In this concept, the anode and cathode are electrically-connected porous beds. Molten salt electrolyte, with fuel and oxidizer entrained, are pumped through the porous beds.

The purpose of this research program is to initiate development of this concept by:
- Modeling the basic mass transfer processes within the fuel cell electrodes.
- Developing preliminary solutions to design problems such as electrode construction, gas-solid-electrolyte separation, and electrolyte handling and pumping.

This modeling and design activity will bring the concept to a stage where its potential can be better evaluated and the need for further research can be determined.

Accomplishments to Date

During the first six months of the performance period progress has been made on both the design and modeling aspects of the project.

Plant design has gone through several iterations. The current design concept uses entrainment of coal and gases away from the cathode-anode interface to eliminate the need for coal-electrolyte separation while minimizing ohmic losses. The fundamental balance-of-plant concept has been developed, with heat exchangers for air preheating and waste heat recovery. Consideration has been given both to design of eventual utility-scale plants and to laboratory-scale research units.

Modeling to date has covered:

- Developing a basic mass and energy balance for cell and balance-of-plant
- Using the basic mass and energy balance to identify important design issues and identify the design envelope
- Development of a basic porous-bed electrode model, determining cell output as a function of geometric parameters, transport properties, thermodynamic properties, and flow rates.

The last of these three tasks has been the most challenging and is also the most important in determining the feasibility of the fuel cell concept. It is being accomplished by writing differential equations with charge as independent variable and with liquid-, solid-, and gas-phase fluxes as dependent variables. The various dependent variables are related by mass transfer coefficients, mass balances, cell geometry, and electrode kinetics. *Matlab* is being used to numerically solve the equations, with initial conditions those at the cathode-anode interface.

Future Work

Tasks to be accomplished in the remainder of the performance period (April, 2004 – August, 2004) are:

- Finalize, debug, and test porous-bed electrode model.
- Use model to iterate and improve electrode bed design. Full optimization is not justified because of the limited data (thermodynamic properties, transport models, chemical kinetic models) available. The design will be optimized to the degree justified by the input data.
- Incorporate the results of electrode modeling in the overall plant energy balance to determine expected plant performance.
- Develop two preliminary plant designs: one for a utility-scale cell and one for a laboratory-scale cell.

2. LIST OF PAPERS PUBLISHED, U.S. PATENT(S) / PATENT APPLICATION(S), CONFERENCE PRESENTATIONS, STUDENTS SUPPORTED UNDER THIS GRANT

Conference Presentations

- "Energy Balance for a Direct Carbon Molten Carbonate Fuel Cell," R. Agarwal and A. Kornhauser., ASME Heat Transfer / Fluids Engineering Summer Conference, 2004, Paper HT-FED2004-56887, Submitted.

Students Supported under this Grant

- Ritesh Agarwal, doctoral student in the Department of Mechanical Engineering, Virginia Polytechnic Institute and State Unversity