HYBRID FUEL CELL / GAS TURBINE SYSTEMS

REVOLUTIONARY AEROSPACE SCIENCE AND ENGINEERING

OVERVIEW

Support the Honeywell contract with the National Aeronautics and Space Administration (NASA) for Revolutionary Aero-Space Engine Research (RASER) in Fuel Cell APU Study for Aerospace Applications

Compare and contrast PEMFC and SOFC technology

Provide data on the size, weight, and performance characteristics of fuel cells tested at the NFCRC (include site tour and system operation demonstration)

- 25 kW solid oxide fuel cell (SOFC) of Siemens Westinghouse
- 5 kW proton exchange membrane fuel cell (PEMFC) of Plug Power

Simulate revolutionary aerospace systems based upon PEMFC and SOFC technology

Evaluate revolutionary aerospace systems performance based upon current fuel cell technology and expected future fuel cell technology capabilities

GOALS

Assist Honeywell in characterizing the stack AND complete system required to power an unmanned aerial vehicle (UAV) and the APU for a regional jet associated with each of the following:

- Near term SOFC
- Future (10 and 15 years) SOFC
- Near term PEMFC
- Future (10 and 15 years) PEMFC

Provide assistance regarding previous research and published papers/reports on altitude (substandard atmospheric pressure/temperature) performance of fuel cells

Identify key system issues and "balance of plant" features that must be considered in the fuel cell system development

Review and comment on Honeywell SOFC and PEMFC stack models

Review and comment on Honeywell hybrid gas turbine SOFC and PEMFC system models, system architecture and cycle performance data

Review and comment on hybrid gas turbine SOFC system study with jet fuel reformation

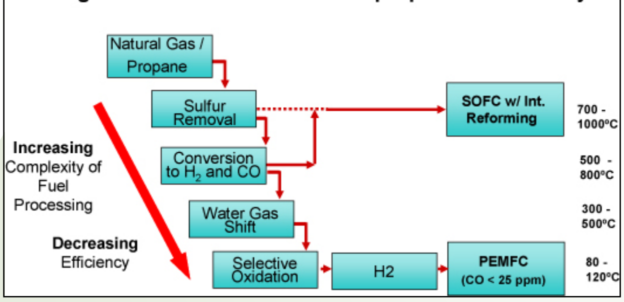
Use an existing NFCRC set of modeling tools to simulate similar configurations for comparison

Determine the approximate size and weight of the SOFC reformation system through iteration with Honeywell's fuel cell and balance-of-plant model.

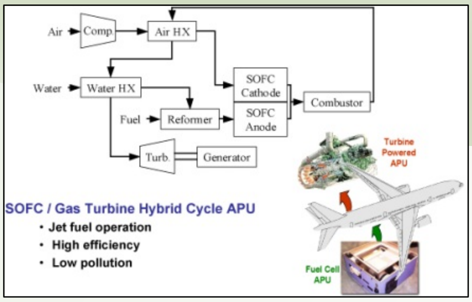
SOFC and PEMFC COMPARISON

	SOFC	PEMFC
Operating Temp	700 – 1000 C	80 – 120 C
Operating Voltage	~0.7V	~0.5V
Electrolyte	Ceramic	Polymer
Catalyst	Ni, Conductive Ceramics	Platinum
Conductive Ion	O=	H+
Fuels	H2, CO, Natural Gas, light hydrocarbons (HC)	H2
Reformation	Internal / External	External
Containments (Poisons)	Sulfur	Sulfur, CO, HC

Requirement for pure H_2 for PEMFC system increases fueling cost and decreases well-to-propulsion efficiency



SOFC AND PEMFC COMPARISON



Efficiency – Higher operating voltages and temperatures and reduced fuel processing requirements give SOFCs an efficiency advantage.

Capital Cost – Use of precious metals are likely to make PEMFCs more expensive.

Startup Times – PEMFC have a rapid startup time providing a major advantage for propulsion and backup power applications.

Maturity – PEMFCs are a more developed and proven technology.

Power Density – PEMFC is historically higher in power density, recent SOFC advancements (slightly lower)

SOFC for Auxiliary Power Unit (APU)

NEED FOR OPTIMIZATION

- **Fuel Cell**
- **Compressor**
- **Combustor**
- **Turbine**
- **Storage Tank**
- **Heat Exchanger•Battery**
- **Motor •Reformer**
- **Solar Array**
- **Electrolyzer**

- Complex systems optimization requires computer simulations, which requires accurate component models.
- Operating pressure has a large impact on the performance and design of the system.
- Operating characteristics of fuel cells at pressures less than 1 atm are largely unknown.
- Optimization of a fuel cell system is impossible without knowledge of low pressure fuel cell operation.

THEORETICAL EFFECTS OF PRESSURE ON FC

Governing Equations – Efficiency, Operating Voltage, and Losses

$$\eta_{electrochemical} = \frac{V_{operating}}{V_{reversible}}$$

← Fuel Cell Efficiency

$$V_{operating} = V_{reversible} - V_{Activation} - V_{Ohmic} - V_{Concentration}$$

← Voltage Equation

$$V_{reversible} = -\frac{\Delta_f G^{\circ}}{nF} + \frac{RT}{nF}\ln\frac{ppH_2 * (ppO_2)^{\frac{1}{2}}}{ppH_2O}$$

Gas partial pressures ← Nernst Equation

$$V_{Activation} = \frac{RT}{n\alpha F}\ln\left[\frac{i+i_n}{i_o}\right]$$

Internal Current; Exchange Current ← Activation Losses (Chemical Kinetics)

$$V_{Ohmic} = r * (i + i_n)$$

← Ohmic Losses (Electronic and Ionic)

$$V_{Concentration} = -\frac{RT}{nF}\ln\left[1 - \frac{i+i_n}{i_L}\right]$$

Internal Current; Limiting Current ← Concentration Loss (Mass Transfer)

LOW PRESSURE PEMFC EXPERIMENT

Variables:

•External Load (20% to 100%)

•Air Temperature (- 60 °C to sea level ambient)

•Air Pressure (10 kPa (~55,000 ft) to sea level ambient)

•Air Flow (1 SLPM to 9 SLPM)*

•Relative Humidity (15% to 60%)Responses:

•Voltage

•Current

•H_2 consumption

National Fuel Cell Research Center

www.nfcrc.uci.edu