Solid Oxide Fuel Cell System Development

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Simplified SOFC System & Components

- Microturbine
- SOFC Stack
- SOFC Fuel Cell
- Turbo-Compressor
- Blowers
- Sensors
- CPOX Fuel Processor
- High-T Heat Exchangers
- Controllers
- Valves

- Gas Turbine
- Air Management
- Fuel Processor
- Thermal Management
- Solid Oxide Fuel Cell Stack
- DC Power
- Process Exhaust
- Turbine Inlet
- Cathode Inlet
- Anode Inlet
- Cathode Exit
- Anode Exit
Heat Transfer/Thermal Management

- Extensive experience with thermal management of complex systems
- Broad spectrum of heat exchanger products
- Thermal management systems for a wide range of operating environments
Turbomachinery

- Expert knowledge in positive displacement and dynamic pumps, compressors, and turbines
- Wide range of turbomachinery products
- Development of turbocompressor for PEMFC systems

RAH-66 Fan

50 kW Turbogenerator

Trident Gas Hydraulic Assembly Turbopump

PEMFC Turbocompressor
Controls and Sensors

- Controls
  - Model-base control and optimization algorithms including Fuel Cell Dynamics Component Library
  - Rapid prototyping
  - Load following control system for PEMFC systems

- Sensors
  - Relative humidity
  - Mass air flow
  - Hydrogen
  - Carbon monoxide
System Development Approach

• Low-cost fabrication processes and materials along with compact, lightweight component designs
  – **SOFC**: Tape calendering fabrication process, stack designs incorporating thin-electrolyte cells and thin-foil metallic interconnects
  – **Fuel processor**: Catalytic partial oxidation (CPOX)

• Component designs based on system requirements and other design methodologies (e.g., design-for manufacturing, design-to-cost)

• Focus on lessons learned from small (50 W to several kW) system operation
SOFC Stack Metrics

- Fabrication and operation of multi-cell stack of various sizes (up to kW size)
- 800°C operation at ambient pressure and up to 3 atm
- Thermal cycling
- Start-up and shut-down
- Power density:
  - 0.6 W / cm² with hydrogen
  - 0.4 W / cm² with syngas from JP-8
CPOX Performance Metrics

- Duration: 700 hours to date
- Thermal cycles: 10
- Sulfur tolerance: 1000 ppm dibenzothiophene in JP-8
- Yield: 70-80% of LHV in JP-8
System Design Methodology

System Requirements

- Propose Conceptual Design
- Assume Components
- Model System

Technology Base

- Design Components
- System Analysis
- Trade Studies

Compare to Requirements
- Identify Gaps

Conceptual System Definition

Technology Development

Technology Gaps

System Definition
Solid Oxide Fuel Cell Battery Charger

Requirements

- 7 kg
- 500 W at 28 VDC
- Operation on logistic fuels (JP and diesel)
System Weight Optimization

- 500 W, 28 VDC output
- Hydrogen utilization of 0.8
- Minimum weight at cell voltage of 0.75 V
CPOX/SOFC Integration - Key Parameters

- Start-up and shut-down procedures
- Range of operating parameters
- Pressure drop
- Thermal management
- Transient characteristics
Integrated CPOX-SOFC Operation

**CPOX**

- **Input:**
  - JP-8
  - Air

- **Output:*
  - 17.3% H₂
  - 21.0% CO
  - 0.7% CO₂
  - 11.0% H₂O
  - 50.0% N₂

**SOFC**

**Module Operating on CPOX Product at 800°C**

- Voltage (V)
  - 0.000
  - 0.050
  - 0.100
  - 0.150
  - 0.200

- Power Density [W/cm²]
  - 0.000
  - 0.050
  - 0.100
  - 0.150
  - 0.200

Demonstration of multicell SOFC operation on JP-8 syngas
System Demonstration

• Demonstration of key component integration
  – Integration of system components, especially CPOX fuel processor and SOFC stack

• Operation characteristics
  – Startup
  – Thermal integration
  – Propane and JP-8 fuels
Concluding Remarks

- Low-cost fabrication processes and materials along with compact, lightweight components developed for SOFC systems
- Demonstration of component integration and operation of small systems
- Near-term activities consistent with SECA plan