Non-Flow-Through Fuel Cell System Test Results and Demonstration on the SCARAB Rover

This presentation describes the results of the demonstration of a non-flow-through PEM fuel cell as part of a power system on the SCARAB rover at the NASA Glenn Research Center. A 16-cell non-flow-through fuel cell stack from Infinity Fuel Cell and Hydrogen, Inc. was incorporated into a power system designed to act as a range extender by providing power to the SCARAB rover’s hotel loads. The power system, including the non-flow-through fuel cell technology, successfully demonstrated its goal as a range extender by powering hotel loads on the SCARAB rover, making this demonstration the first to use the non-flow-through fuel cell technology on a mobile platform.
Non-Flow-Through Fuel Cell System Test Results and Demonstration on the SCARAB Rover

Brianne Scheidegger and Kenneth Burke
NASA Glenn Research Center

Ian Jakupca
QinetiQ North America

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Presentation Overview

• AMPS project overview & demonstration goals
• SCARAB rover background
• NASA fuel cell development background
• Non-Flow-Through (NFT) Proton-Exchange-Membrane Fuel Cell (PEMFC) power system
• Demonstration & results
AMPS PROJECT OVERVIEW AND DEMONSTRATION GOALS
AES Modular Power Systems Project

• Project Objectives: AMPS will infuse and demonstrate modular batteries, fuel cells, and other power modules; and, develop modular power design concepts that will guide modular assembly development and ultimately be realized in exploration flight hardware.
Demonstration Requirements and Objectives

Formal Objectives

• Integrate NFT fuel cell power system onto SCARAB rover
• Supply energy to SCARAB to extend mission duration
• Identify integration issues requiring further development to facilitate advancing the technology readiness level (TRL)

Formal Requirements

• Fuel cell power system must provide power to the SCARAB rover
• Cannot damage or modify the rover
SLOPE Test Facility

• Simulated Lunar Operations (SLOPE) Lab at NASA Glenn Research Center
• Used to study traction & power consumption of lunar vehicles operating in soil
• Simulated lunar regolith soil tank for flat surface operations & tilted soil tank for sloped surface operations
SCARAB ROVER
SCARAB Rover

- SCARAB owned and operated by Carnegie-Mellon University (CMU)
- Used in multiple field demonstrations and public relations activities
- Mobile Platform for experiments
  - ISRU
  - Lunar Tire Development
  - 12 Vdc NFT PEMFC
SCARAB Power Requirements

• 28 VDC Power Bus

• Hotel Loads: 175 W (communications, computer, cooling fans, etc.)

• Locomotion –
  
  Stationary (elevation hold): 6 W  (Total = 181 W)
  Driving, level: 85 W  (Total = 255 W)
  Driving, turn: 200 W  (Total = 375 W)
  Elevating body: 225 W  (Total = 400 W)
  Peak Transient: 590 W  (Total = 765 W)
SCARAB Power

• SCARAB has on-board battery bank to provide power during normal operation

• Demonstration of NFT PEMFC power system on rover will act as a range extender by providing power to hotel loads while rover is stationary

• Rover not currently capable of power sharing, so power is provided by either SCARAB battery bank or fuel cell power system, but not both simultaneously
NASA PEMFC BACKGROUND
NASA PEMFC Background

- PEM fuel cells convert hydrogen and oxygen gases into water, waste heat, and electricity.
- A fuel cell can provide power as long as reactants are available.
- NASA NFT technology differs from traditional flow-through technology which operates in terrestrial environments and uses air as a reactant.
- NASA missions operate in reduced and zero-gravity environments, and use pure oxygen as a reactant.
NFT PEMFC Development

Develop “non-flow-through” proton exchange membrane fuel cell technology to improve system-level mass, volume, reliability, and parasitic power

Flow-Through components eliminated in Non-Flow-Through system include:
- Pumps or injectors/ejectors for recirculation
- Motorized or passive external water separators

Non-Flow-Through PEMFC technology characterized by dead-ended reactants and internal product water removal
- Tank pressure drives reactant feed; no recirculation
- Water separation occurs through internal cell wicking
NFT PEMFC POWER SYSTEM
16-Cell NFT PEMFC Stack Overview

- Developed by Infinity Fuel Cell and Hydrogen, Inc.
- **TRL 4/5 technology**
- Active Area: 50 cm$^2$
- Number of cells: 16
- Nominal Stack Voltage: 12Vdc
- Nominal Stack Power: 100 Watts
NFT PEMFC Power System
Demonstration Setup

- Power system mounted on Al plate secured to SCARAB

- Stack & reactants above plate

- Electronics drawer mounted below plate
NFT PEMFC Power System on SCARAB
NFT PEMFC SYSTEM
DEMONSTRATION & RESULTS
SCARAB Power Interface Concept

Legend
- **Power**
- **Instrumentation/Control/Data**
- **Wireless Communication**
- **NFT PEMFC system E-stop**

**SCARAB**

**Fuel Cell and Fluidics**

**Reactant Supply**

**Power Control and Distribution**

**Electronics**

**Battery Bank**

**Ground Support Power**

**NFT PEMFC Power System**

**Ground Support Fuel Cell Computer**
Demonstration

• Tests performed to verify system connectivity, stationary operation, and mobile operation

• Fuel cell power system successfully powered hotel loads during stationary operation

• 16-cell fuel cell stack is undersized for the SCARAB rover
  - An actual mission requiring fuel cells would match the fuel cell power capability with the mission requirements
Mobile Demonstration Power Profiles

![Graph showing power profiles with notes: 1 – Open Stack Contactor & Close Scarab Contactor, 2 – Close Stack Contactor & Close Scarab Contactor.](image-url)
Summary

• Successfully integrated NFT fuel cell technology onto ground demonstration
  • Advances TRL of NFT PEMFC technology
• First demonstration of NFT PEMFC technology for a mobile application
• NASA continues to work to develop advanced NFT PEMFC systems to reduce mass, volume, and parasitic power
Future Activities for NFT PEMFC Power Systems

- Miniaturized electronics
- Advanced thermal & water management systems
- Advanced, custom interface plates with integrated balance-of-plant
Thank you. Questions?

BRIANNE SCHEIDEGER
BRIANNE.T.SCHEIDEGGER@NASA.GOV

KENNETH BURKE
KENNETH.A.BURKE@NASA.GOV

IAN JAKUPCA
IAN.J.JAKUPCA@NASA.GOV