Extended durability testing of an external fuel processor for SOFC

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Overview

Timeline

- Project start: 01/01/2009
- Project end: 10/31/2010
- Percent complete: 5%

Budget

- Project funding total $1,968,000
  - DOE share = $984,000
  - RRFCS (US) Inc. = $984,000
- Funding received in FY08 - $984,000
- Funding for FY09 - $0

Barriers

Fuel Processor

- Durability
- Performance
- Startup and Shutdown time and energy / Transient operation

Partners

- RRFCS (US) Inc. – project lead
- Ohio Department of Development / Stark State College of Technology
  - Funding Outdoor Test Facility

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Stationary power generation with fuel cells

RRFCS believes the Solid-Oxide Fuel Cell (SOFC) is best suited for stationary power generation applications while retaining the capability of being developed subsequently for various transportation, military and marine applications.

With its high electrical efficiency (60 to 70% in non-CHP applications), negligible air emissions, and minimal noise profile, RRFCS's SOFC power plant concept is highly suitable for connection to local distribution networks and in small, secure urban areas. Potential applications include hospitals, universities, shopping malls, factory units, etc.

The system can be configured to use existing hydrocarbon-based fuels, i.e. natural gas and liquid fuels, and alternative fuels such as bio-mass.

Relevance

RRFCS's SOFC power plant concept through its high efficiency, negligible air emissions and fuel flexibility directly supports the DOE Hydrogen Program's mission statement "to reduce petroleum use, greenhouse gas emissions, and air pollution and to contribute to a more diverse and efficient energy infrastructure by enabling the widespread commercialization of hydrogen and fuel cell technologies."

RRFCS's SOFC power plant concept for stationary power directly supports the Hydrogen, Fuel Cells and Infrastructure Technologies Program's goal to "develop and demonstrate fuel cell power systems technologies for transportation, stationary and portable power applications.

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Technical barriers

This project addresses technical barriers A - durability, C - performance, and G - start-up and shut-down time and energy / transient operation from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program (HFCIT) Multi-Year Research, Development and Demonstration (RD&D) Plan.

These barriers will be addressed as they relate to the external fuel processor subsystem in RRFCS' SOFC power plant concept.

The external fuel processor subsystem uses pipeline natural gas and air to generate all gas streams required by the fuel cell power plant for start-up, shut-down, low-load and normal operation. Thus it eliminates the need for on-site bottled gases.

Specific targets and milestones

This project address milestones 59 in the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program (HFCIT) Multi-Year Research, Development and Demonstration (RD&D) Plan.

Milestone 59 is to "evaluate fuel processing subsystem performance for distributed generation against system targets for 2011." These targets will be addressed as they relate to durability, performance (gas quality - sulphur in product stream), and transient response.

External fuel processor

Uses only air and natural gas to prepare all gas streams required by the SOFC power plant during :

- **System heat-up and part-load operation**
- **SOFC start-up & shut-down**
- **SOFC normal operation**

Eliminates the need for storage of bottled hydrogen and nitrogen

Uses no added water as a reactant or for cooling

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Overall Objectives

- **Conduct long-term tests in relevant environment for the external fuel processor for a 1 MWe solid oxide fuel cell generator.**
- **Determine long-term performance of critical components including catalysts, sorbents, heat exchangers, control valves.**
- **Evaluate the impact of ambient temperatures (hot and cold environments) on performance and component reliability.**
- **Determine system response and performance of process controls for transient operation.**
- **Identify any long-term failure mechanisms.**

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Objectives for June 08 – May 09

The objectives from the start of the project (January 2009) through May 2009 include:

- **Issue Hydrogen Safety Plan**
- **Install and commission synthesis-gas subsystem**
- **Begin synthesis-gas subsystem testing**
- **Plan hardware installation in Outdoor Test Facility**

Approach

Use full-scale subsystems and components:

- Synthesis-gas subsystem operates inside the warm SOFC pressure vessel
- Start-gas and desulfurized natural gas generators operate outdoors under extreme weather conditions (summer / winter)

Conduct demonstration tests in relevant environments

- Synthesis-gas subsystem to be tested for multiple startup (at least 10) and 1,200 hours of operation in a heated indoor test enclosure
- Start-gas subsystem to be tested for multiple startups (at least 24) and 200 hours of operation in an outdoor test facility.
- Desulfurizer subsystem to be operated for 8,000 hours in an outdoor test facility.

Perform post-test inspections

- Inspect subsystem components (catalysts, sorbents, piping, reactors, insulation, valves, heaters, heat exchangers, N_2-membrane, etc.) for deposits, signs of wear, damage, corrosion, erosion, and failure. Perform functional checks where possible.

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Planned milestones

No.	Description	Planned
1	Start Preparation of Synthesis-gas Subsystem	January 2009
2	Begin Synthesis-gas Subsystem Durability Testing	April 2009
3	Start Preparation of Desulfurizer Subsystem	July 2009
4	Complete Synthesis-gas Subsystem Durability Test	September 2009
5	Complete 1,000 hours Operation of Desulfurizer	December 2009
6	Start Preparation of Start-gas Subsystem	July 2009
7	Begin Start-gas Subsystem Durability Testing	October 2009
8	Complete Desulfurizer Subsystem Test	October 2010
9	Complete Start-gas Subsystem Test	April 2010
10	Complete Final Report	October 2010

Approach

Start gas for SOFC start-up & shut-down

- Compressed air as a reactant and for cooling
- Polymer membrane (oxygen/ nitrogen separation)
- Natural gas (NG) as a reactant
- Catalytic partial-oxidation reactor - used to generate non-flammable start gas
- Electric heaters (for preheating and hot standby)
- Air cooled heat exchanger
- Automatic control system to meet start-up and shut-down requirements of SOFC

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Approach

Hardware for generating start gas

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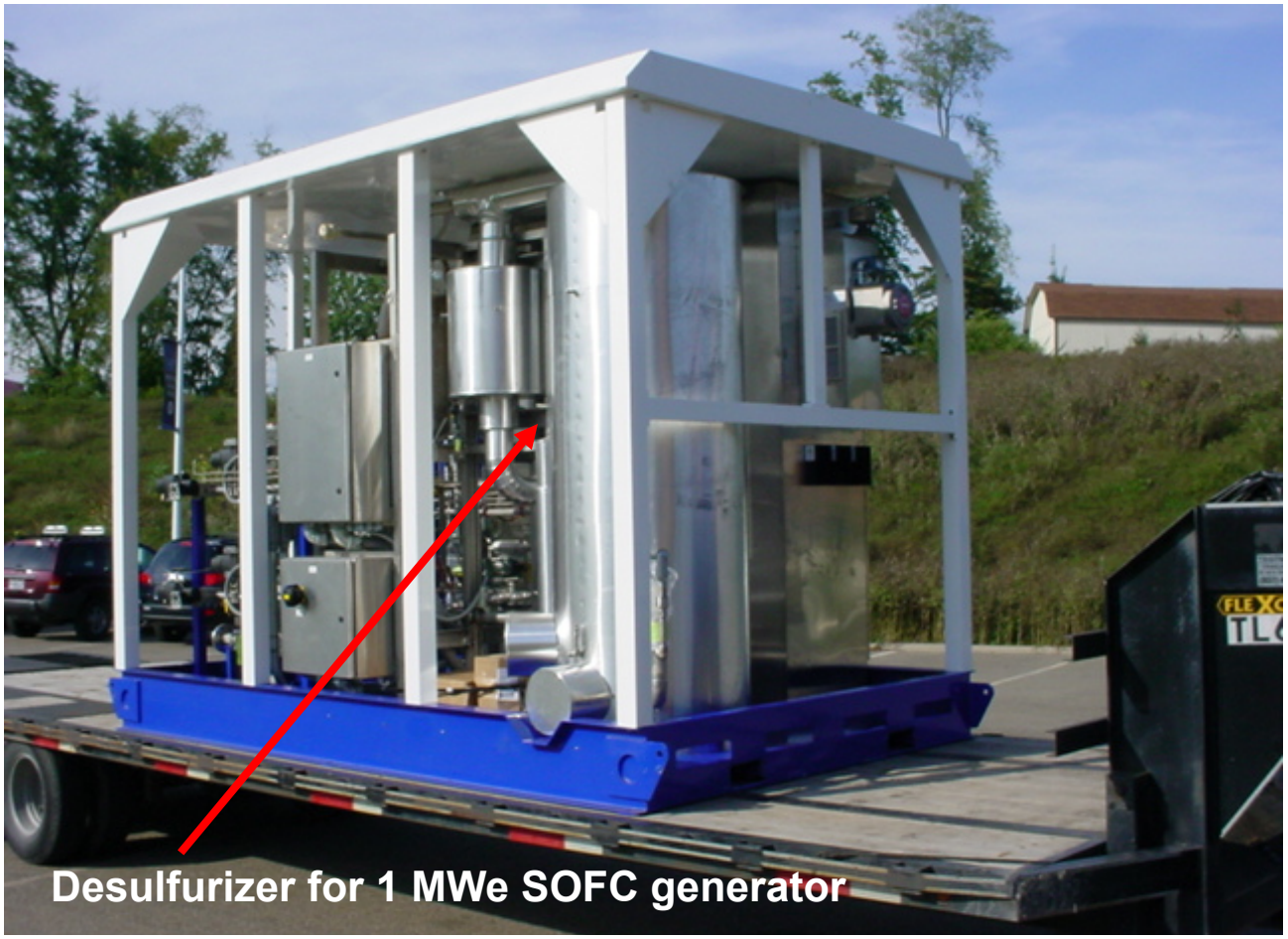
Desulfurized fuel for steady-state operation

- NG as a reactant with 2 to 10 ppmv sulfur
- Compressed air as a reactant
- Catalytic reactor for oxy-desulfurization
- High-capacity sorbent (total sulfur < 100 ppb)
- Electric heaters (for preheating and hot standby)
- Recuperative (gas-to-gas) heat exchanger
- Startup burner (NG) - initial preheating of sorbent bed
- Automatic control system for load following
- Operates 8,000 hrs between maintenance cycles

Approach

Hardware for generating desulfurized NG



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Approach

Synthesis gas for heat-up and low-load operation

- Compressed air as a reactant
- NG as a reactant
- Catalytic partial oxidation reactor - used to generate flammable synthesis gas
- Electric heaters (for preheating and hot standby)
- Automatic control system
- Used during SOFC heat-up and low-load operation

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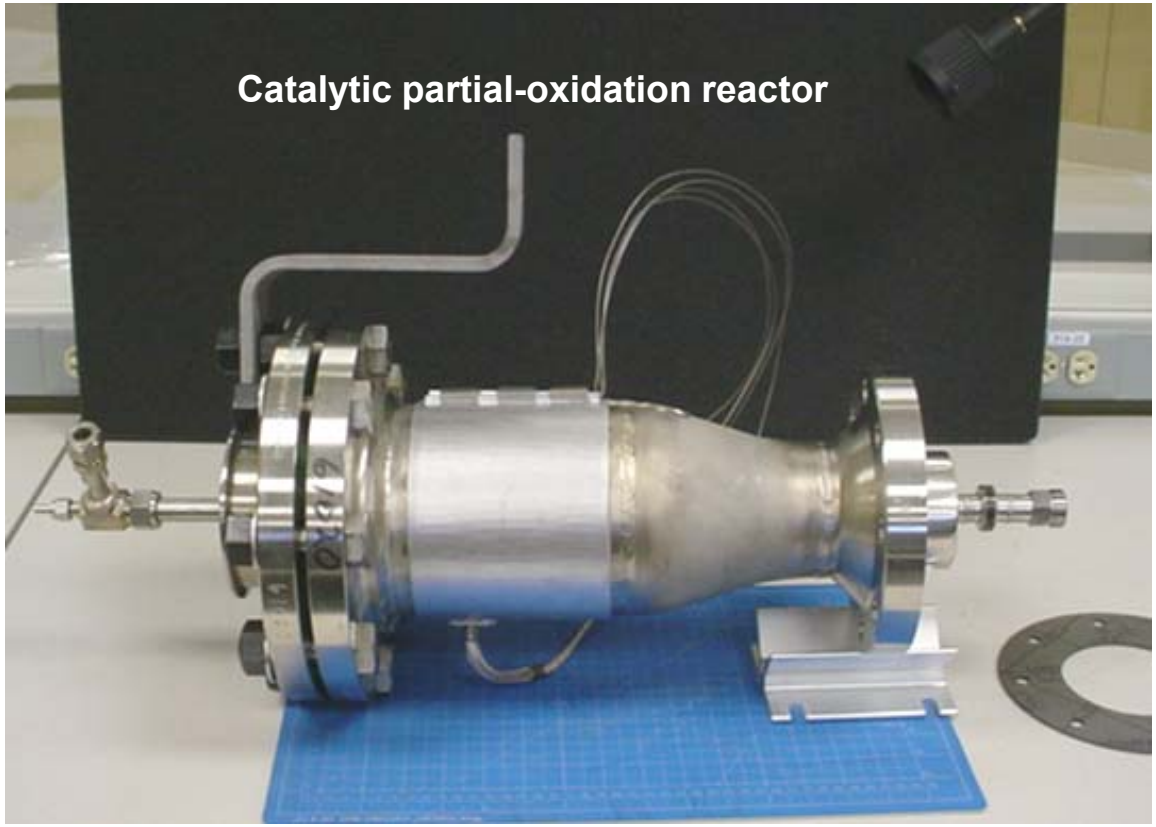
Approach

Hardware for generating synthesis gas



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Technical accomplishments and progress

- **Draft Hydrogen Safety Plan being assembled from internal RRFCS documents**
- **Completed mechanical installation of synthesis-gas subsystem in test enclosure**
- **Confirmed operation of enclosure safety system**
- **Electrical wiring for control system completed**
- **Control Software written and being debugged**
- **Specifications for outdoor test facility issued**

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Synthesis-gas test rig and test enclosure

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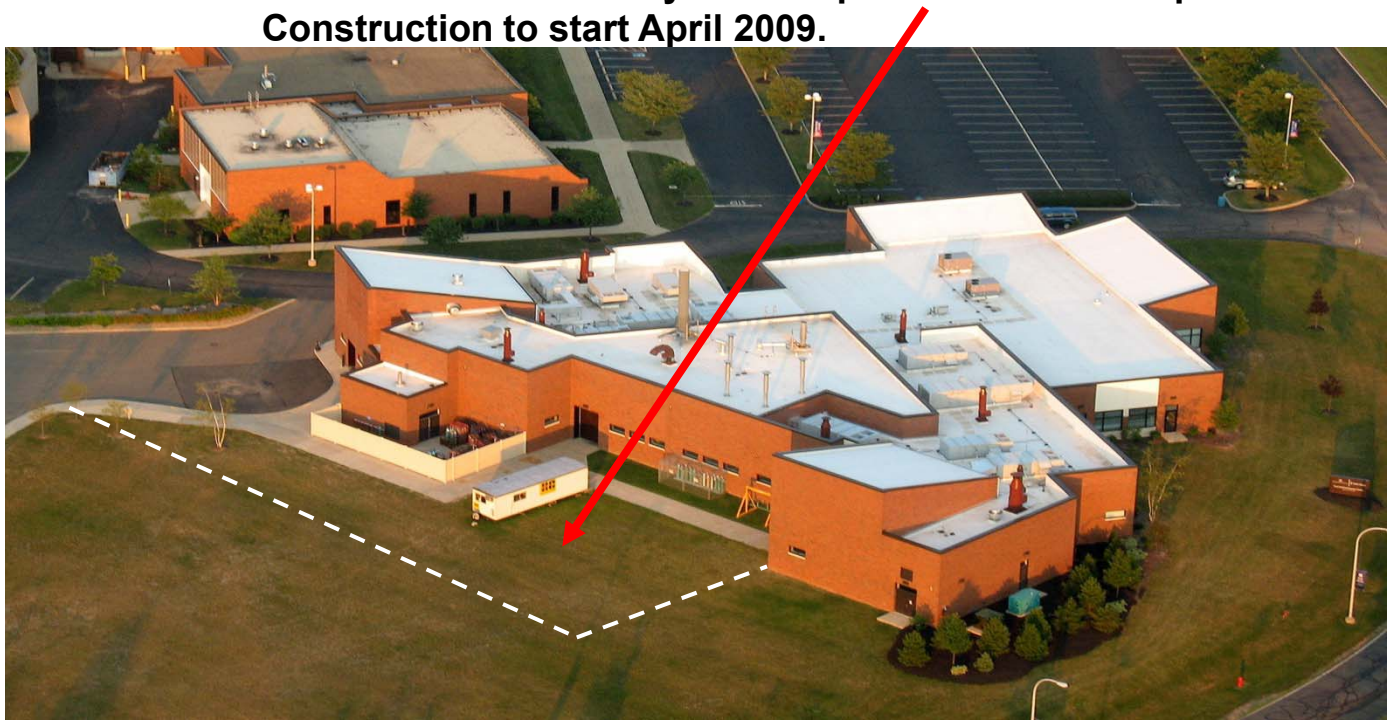
Technical accomplishments and progress

Planned outdoor test facility for testing desulfurizer and start-gas subsystem

Location for Outdoor Test Facility – funding provided through Ohio's Third Frontier by Ohio Department of Development. Construction to start April 2009.



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Milestones

No.	Description	Planned	Actual	Status
1	Start Preparation of Synthesis-gas Subsystem	January 2009	January 2009	Completed
2	Begin Synthesis-gas Subsystem Durability Testing	April 2009		
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Collaborations

- **Rolls-Royce Fuel Cell Systems (US) Inc. is the lead on the project and is the prime recipient of the award. There is significant collaboration required between RRFCS and the Ohio Department of Development (ODOD) to enable the project to go forward.**

- **The Ohio Department of Development is providing funding through Ohio's Third Frontier to build an outdoor testing facility for fuel cell systems. The facility will be added to the Fuel Cell Prototyping Center on the campus of Stark State College of Technology where RRFCS is located. This facility will enable RRFCS to test the fuel processor subsystems in relevant environments.**

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Proposed future work

2009

- Complete synthesis-gas subsystem durability test (FY09 Q3)
- Complete post-test inspections (FY09 Q4)
- Complete installation and commissioning of Start-gas and Desulfurizer subsystems (FY09 Q3)
- Being durability testing of Start-gas and Desulfurizer subsystems (FY09 Q4)

2010

- Complete durability testing of Start-gas and Desulfurizer subsystems (FY10 Q3)
- Complete inspections of Start-gas and Desulfurizer subsystems (FY10 Q4)
- Issue final report for project (FY10 Q4)

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Summary

- An approach was developed for testing durability, performance, and transient operation of an external fuel processor for SOFC application
- Work began to install full-scale fuel processor hardware for testing in relevant environments
- Rolls-Royce Fuel Cell Systems is committed to introducing a megawatt-scale SOFC for stationary power.

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