V.L.10 Solid Oxide Fuel Cell Systems Print Verification Line (PVL) Pilot Line*

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Subcontractor:
Rolls-Royce Fuel Cell Systems (US) Inc. (RRFCS)
North Canton, OH

Project Start Date: March 1, 2010
Project End Date: June 30, 2011

*Congressionally directed project

Objectives

- Complete the electrical/mechanical build of the RRFCS fuel cell Stack Block Test System (SBTS)
- Perform mechanical commissioning tests to assure SBTS readiness prior to fuel cell stack block install.

Technical Barriers

This project addresses the following technical barriers for the Fuel Cells section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability
(C) Performance

Technical Targets

This project completes the mechanical and electrical build of a test apparatus (referred to as SBTS) that will allow RRFCS to test at fuel cell stack product size, full operating temperature and pressure, and with fuel cell inlet anode gas pre-processed from pipeline natural gas. Testing will prove the mechanical functionality of the SBTS prior to install of a fuel cell stack for electrical testing.

FY 2011 Accomplishments

- Demonstrated SBTS mechanical performance over the required range of RRFCS fuel cell operating temperature, pressure and anode/cathode gas compositions.
- About 200 hrs of operating time at temperature with long-term operation planned in 2011 as part of the DOE Solid State Energy Conversion Alliance (SECA) program.
- Control and safety system hardware/software demonstrated up to powered stack operation.

Introduction

This project supported the mechanical/electrical build completion and mechanical commissioning of the SBTS located at the Stark State College (SSC) Fuel Cell Prototyping Center in North Canton, OH. As a result, SBTS is ready to support installation and powered operation of a RRFCS solid oxide fuel cell (SOFC) stack block in the second quarter of 2011. The SBTS will be used to evaluate the performance, reliability and durability of developmental fuel cell stacks at powers of about 20 kW. Fuel cell tubes that compose the SOFC stack are manufactured on the RRFCS PVL. The PVL is a fully automated production line for printing anode and cathode electrodes on fuel cell substrates, with the resulting assembly passed to a furnace for material sintering.

Approach

This project leverages earlier investments by the Ohio Department of Development (ODOD Grant TECH 08-053) through Ohio's Third Frontier and the Department of Energy (DOE Award No. DE-FE0000303, SECA), under which the SBTS mechanical build was completed. The subject work completed the mechanical/electrical build and completed the mechanical commissioning that included controls and safety system software checkout.

Results

Task 1 – Controls Software

Control functions were manually exercised to cover stack heat-up from room temperature to 900°C for stack reduction, transition from the stack reduction temperature to a lower temperature for stack electrical loading and stack cool down to ambient temperature. Startup burner control was established. The catalytic partial oxidation (CPOX) reactor light-off was proven with proper anode fuel gas composition provided to the stack. Operator actions were implemented into the automatic control system for SOFC

stack heat-up from ambient to about 750°C following startup burner light-off. Control functions associated with stack electrical operation (e.g., stack reduction and stack electrical loading) will be developed with existing manual control capabilities and then transferred into the automatic controls software as part of electrical commissioning under the 2011 SECA program.

In parallel with controls software development, the independent safety system software was exercised in response to trip signals with the SBTS responding properly during the emergency shutdown control sequence.

The user interface (HMI) to the control system was proven and enhanced as the various mechanical commissioning tests were completed under this contract. The HMI provides a satisfactory interface for SBTS operation and support for the future electrical commissioning tests.

Task 2 – Facility Electrical and Controls Wiring

All wiring tasks were completed in January 2011 with the installation of the high voltage (~1,100 V direct current) SOFC stack bus bar wires to the load controllers. Operational checks of the eight load controllers and calibration of associated current and voltage transducers were completed including communications to the control system and HMI. All instrumentation associated with SBTS was operated during mechanical commissioning except those associated with the electrical stack operation. The two items associated with cleaning of the oxygen supply tubing and cooling water connection to the load controllers were completed.

Task 3 – Commissioning

Stage 1 commissioning scope included the following:

- Hardware and Configuration. Verification of electrical continuity, component operation and instrument continuity through the control programmable logic controller and HMI. Verification of data storage to disk for each instrument.
- Instrument Calibration. Operation and calibration check of each flow meter.
- Facility and Safety System. Verify operability of natural gas; compressed air; and steam boiler delivery systems, system flare, exhaust pressure control system, and facility safety system/alarms. Exercise the CPOX reactor to demonstrate its functional performance and operating procedure.

System operation. Operation of the entire SBTS as a system from ambient temperature startup to hot stack operation at a condition ready for electrical power loading (Stage 2 commissioning performed in 2011 under the DOE SECA program). Demonstrate normal control system shutdown and safety system emergency shutdown. Perform control loop tuning to achieve acceptable response and stability during normal operation and expected transients.

All of the planned Stage 1 commissioning tasks described by the previous bulleted items were completed by the middle of November, 2010. Progress was interrupted at the end of June due to damage of the high temperature insulation. Following its replacement, Stage 1 commissioning resumed and demonstrated the capability of SBTS to achieve the highest stack operating temperature of 900°C. During the interim period while the insulation was being replaced, the SBTS was able to operate for CPOX reactor control setup as well as establish the stack back pressure automatic control. Operation and automatic control of the startup burner was demonstrated. Functional performance and operation of the CPOX reactor was demonstrated with fuel delivered to the stack, albeit not electrically active for the Stage 1 program testing. All operations of the SBTS were demonstrated as needed to heat the stack from room temperature to 900°C for stack reduction and subsequent return to a lower stack temperature as required for stack electrical loading. Electrical stack tests will be accomplished outside of this project and part of the 2011 DOE SECA program.

Normal shutdown and safety/emergency shutdown response of the SBTS was demonstrated.

Controls operation was discussed in Task 1. During Task 3 commissioning, control loops were tuned to achieve acceptable response during SBTS operation.

For reference, Figures 1 and 2 show the completed SBTS test vessel and its installation for the Stage 1 project test.

Task 4 – Post-Operation Inspection

Following Task 3 test completion, inspection of the stack and hot zone components was made. In general, the internals were found to be in good condition and suitable

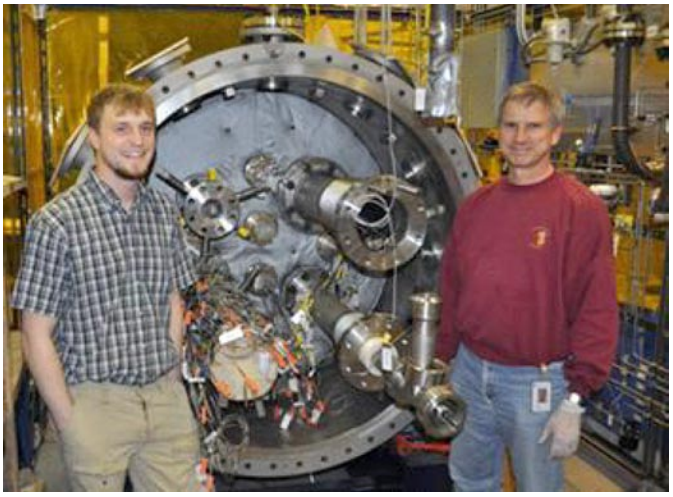

FIGURE 1. SBTS Vessel Assembly Prior to Install of the Outer Vessel Head

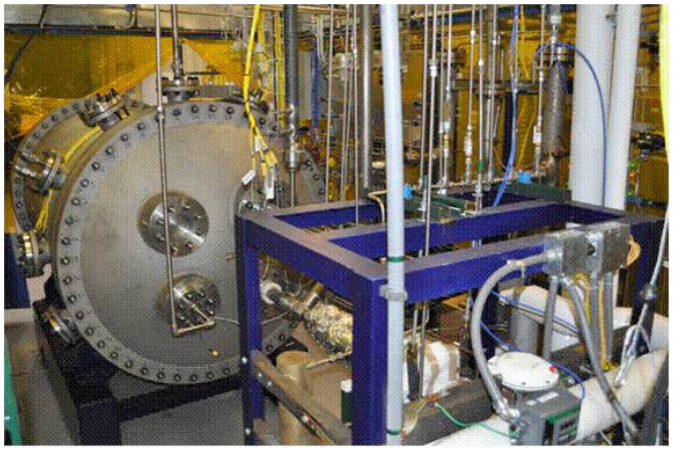

FIGURE 2. SBTS Ready for Commissioning Test

for use in the next test series subsequent to this contract. Carbon was observed in the burner inlet fuel line from CO use and will not be used in subsequent tests.

Conclusions and Future Directions

- Completion of the mechanical commissioning test proved the readiness of SBTS for install of a fuel cell stack and electrical commissioning test. Such testing is planned to begin in April of 2011.
- Control of the major SBTS subsystems was exercised and proven.
- The control and safety system software were exercised and shown ready for electrical commissioning test.
- The SBTS will be used in 2011 by RRFCS to obtain further performance and durability data for the RRFCS solid oxide fuel cell stack block which is the repeat unit for power generation at 1-MW scale.

FY 2011 Publications/Presentations

1. 2011 DOE Hydrogen and Fuel Cells Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting, Poster, May, 2011.