VI.3 Modular, High-Volume Fuel Cell Leak-Test Suite and Process

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Contract Number: DE-FG36-08GO18054

Subcontractors:
- Pacific Northwest National Laboratory, Richland, WA
- Cincinnati Test Systems, Cleves, OH

Project Start Date: September 1, 2008
Project End Date: June 30, 2012

Objectives

- Design a modular, high-volume fuel cell leak-test suite capable of testing in excess of 100,000 fuel cell stacks per year (i.e., 50 fuel cell stacks per hour).
- Performance leak tests in-line during assembly and break-in steps.
- Demonstrate fuel cell stack yield rate to 95%.
- Reduce labor content to 6 minutes.
- Reduce fuel cell stack manufacturing cost by 80%.

Technical Barriers

This project addresses the following technical barriers from the Manufacturing R&D section (3.5.5) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(F) Low Levels of Quality Control and Inflexible Processes

Contribution to Achievement of DOE Manufacturing Milestones

This project will contribute to achievement of the following DOE milestones from the Fuel Cells sub-section of the Manufacturing R&D section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 9:** Select stack assembly processes to be developed. (4Q, 2010)
- **Milestone 10:** Develop automated pilot scale stack assembly processes. (4Q, 2012)
- **Milestone 12:** Demonstrate pilot scale processed for assembling stacks. (4Q, 2013)

Accomplishments

- Developed a specification for the leak-test suite laboratory prototype.
- Designed leak-test suite prototype.
- Fabricated leak-test suite prototype.
- Installed leak-test suite prototype at UltraCell facility at Vandalia, OH.
- Tested and evaluated leak-test suite prototype.
- Created fuel cell stack quality metrics.
- Developed techniques for analysis of dynamic mechanic analysis data from the leak-test suite prototype.
- Characterized individual fuel cell stack components using leak-test suite prototype.
- Developed a finite element model capable of modeling the dynamic mechanical properties of fuel cell stacks.

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Introduction

There are three fluid circuits in a fuel cell stack. Any fluid leakage between these circuits or to the external atmosphere leads to reduced individual cell or stack performance and results in a failure during stack testing. Fuel cell stacks are typically hand assembled and tested, and it is very time-consuming. Furthermore, the leak-test equipment is often composed of expensive analytical devices, with extensive and excessive capabilities, that are not well suited to rapid testing of stack assemblies in medium- or high-volume manufacturing environments. High labor content and expensive test equipment limit the amount of online leak checks during the assembly process, leading to high scrap rates and low yields.

The development of a Modular, High-Volume Fuel Cell Leak-Test Suite and Process is proposed to address these challenges by reducing labor content; providing more robust, high confidence automated testing; and increasing the speed and throughput at which manufacturing is performed. Each leak-test component will be highly specialized to its specific task and optimized for high throughput, thereby allowing for dramatic cost savings. A variety of methods will be employed to test for leaks between the fuel cell fluidic paths and the environment during the entire process from build to break-in to final test. The test suite will enable manufacturers to select modular test components as needed.

Approach

Six leak-test methods were proposed in the project. These tests include crossover current, current interrupt, voltage decay, pressure decay, flexo-tiltometer test, and fuel cell sensor for coolant leak. These methods will be investigated, and some will be selected to implement in the leak-test suite. These tests will automatically perform in-line during fuel cell stack manufacturing. The leak-test methods not only check the overall leakage, but also identify the location of leak and accelerate the diagnostics and remediation of fuel cell stacks.

Phase I of the project focuses on the analysis of current manufacturing processes, stack failure modes, and leak-test processes. A variety of leak-test methods will be surveyed, and recommendations for the leak-test suite will be made. A leak-test suite prototype will be designed, fabricated, and evaluated. A leak-test suite with 50 stacks per hour capability will be designed. Phase II will focus on pilot production line modification, leak-test suite fabrication, integration, and verification. A limited production test run will be carried out to validate the 50 stacks per hour operation.

Results

A specification for the leak-test suite laboratory prototype was developed. The specification includes required functions, detail procedures to perform these functions, hardware, software, graphical user interface, gas interface, electrical interface, heating system, and compression stand. The design of a leak-test suite lab prototype was completed. A programmable automation controller, CompactRIO, was chosen to control and acquire data for the leak-test suite and prototype. A personal computer LabVIEW application is used for data display, storage, and analysis. CompactRIO is a low-cost reconfigurable control and acquisition system designed for applications that require high performance and reliability. The human machine interface of the leak-test suite prototype includes nine major screens. The main screen will be displayed when the application is started. From this screen the operator can log in, monitor the status of the peripheral devices and change the operating mode. The setup screen is used to enter the parameter files for the tests. The files are entered in Excel spreadsheets. The parameters are divided into eight groups: general parameters, break-in parameters, performance parameters, alarms, temperature controller, report, summary, and notes. When the screen is first accessed, the operator can select and load the desired parameter file. When changes are made to any parameter, the operator can save the file for future use. The prototype can be operated manually and automatically. When in manual mode, the operator can manually control hydraulic press, gas, pneumatic, temperature, crossover current, and stack height. Diagnostic screen displays inputs and outputs. The test screen displays test results. Notes screen is provided to allow the operator to enter notes that can be referred to in the future. The faults screen displays a list of faults as they occur. The calibration screen is used to scale the various input and output functions. The system screen displays human machine interface operation and real-time error, which is used for debug during installation. The user control section is used to perform maintenance on the user database and the user access levels.

The fabrication of the prototype was completed. The leak-test suite lab prototype was installed at the UltraCell manufacturing facility in Vandalia, OH. The whole leak-test suite is shown in Figure 1, and the detail of the fixture is shown in Figure 2. All the functions of the prototype were tested individually. The sequences of multiple functions were then tested to ensure the logic is correct.

The prototype can perform all manufacturing processes which include inline leak-test, compression, bolting, break-in, and performance test (Figure 3). All these processes except bolting are carried out automatically. The prototype monitors all processes, quickly identifies failures, and provides diagnostic information. Safety features were implemented in the

FIGURE 1. Leak-Test Suite Prototype

FIGURE 2. Leak-Test Suite Prototype: Test Fixture

prototype to protect the operator. The prototype can be used for both research and manufacturing with a simple change in the test protocol. A leak-test was repeated five times during the fuel cell stack manufacturing process (Figure 3). The leak-test can be added or removed easily. The average time for each leak-test is 9.3 min. This demonstrated that the leak-test can be performed at a rate greater than 5 stacks/hour. The results obtained from the prototype were compared with existing manual test protocols. It was demonstrated that the new instrument can reliably detect individual cell failures.

Techniques for analysis of dynamic mechanical analysis data from the prototype was developed and used in the leak-test suite prototype to characterize individual components in a fuel cell stack. This provides a necessary database for both the modeling effort and in validation of the new instrument capability. The application of a dynamic force to the fuel cell stack during assembly is expected to reveal how the various components press again each other. However, interpretation of the data requires a theoretical framework that can be used to quantitatively interpret the results. To this goal a finite element model has been developed to explore how the assembled materials respond.

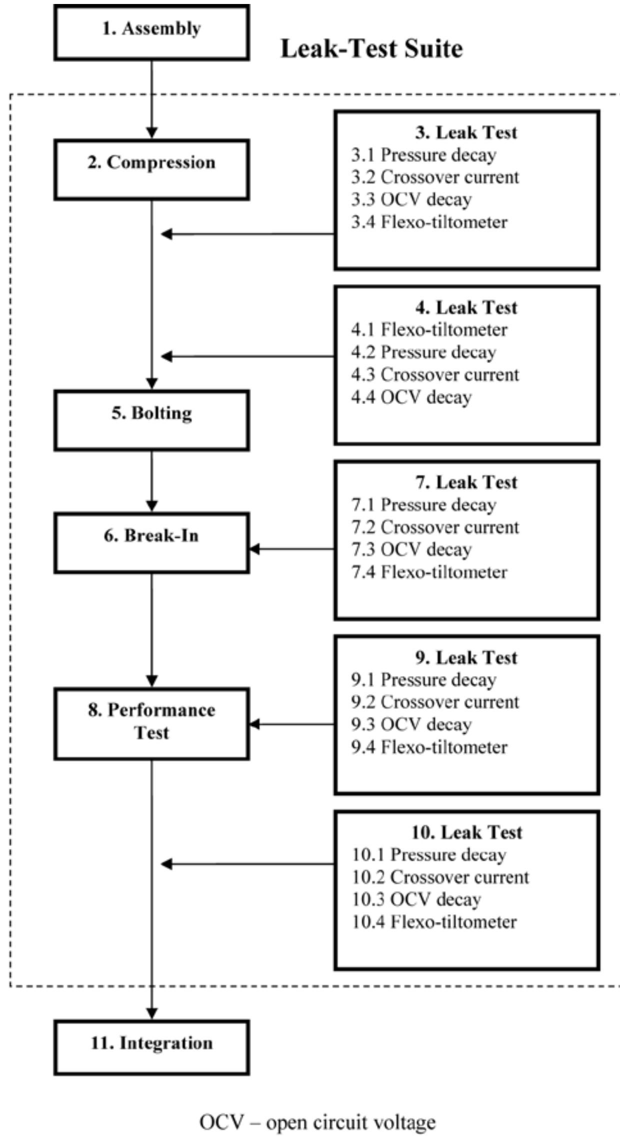

FIGURE 3. Leak-Test Suite and Processes

Conclusions and Future Directions

The conclusions include the following:

- Developed a specification for the leak-test suite laboratory prototype. The specification includes required functions, detail procedures to perform these functions, hardware, software, graphical user interface, gas interface, electrical interface, heating system, and compression stand.
- Designed leak-test suite prototype. The prototype was designed with functions and features for research and development as well as manufacturing uses.
- Fabricated leak-test suite prototype.

- Installed leak-test suite prototype at the UltraCell facility at Vandalia, OH.
- Tested and evaluated leak-test suite prototype. The prototype can perform all manufacturing processes which include inline leak-test, compression, bolting, break-in, and performance test. All these processes except bolting are carried out automatically. The prototype monitors all processes, quickly identifies failures, and provides diagnostic information. Safety features were implemented in the prototype to protect operator.
- Created fuel cell stack quality metrics.
- Developed techniques for analysis of dynamic mechanical analysis data from the prototype.
- Characterized individual fuel cell stack components using the new leak-test suite prototype. This provides a necessary database for both the modeling effort and in validation of the new instrument capability.
- Developed a finite element model capable of modeling the dynamic mechanical properties of fuel cell stacks. This effort is critical in understanding how complex assemblies such as fuel cells actually respond to the applied dynamic forces.

Future directions include the following:

- Fabricate, integrate, test, and evaluate the leak-test suite.
- Modify pilot production line to accommodate the leak-test suite.
- Test run pilot production line with the leak-test suite.
- Validate the leak-test suite.

FY 2010 Publications/Presentations

1. Kaye, I. et al., "Modular, High-Volume Fuel Cell Leak-Test Suite and Process", presentation at the 2010 Hydrogen Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting, Washington, D.C., June 7 – 11, 2010.