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


Ru Chen (Primary Contact), Hugh McCabe, Ian Kaye
UltraCell Corporation
399 Lindbergh Avenue
Livermore, CA 94551
Phone: (925) 455-9400
E-mail: rchen@ultracellpower.com

DOE Managers
HQ: Nancy Garland
Phone: (202) 586-5673
E-mail: Nancy.Garland@ee.doe.gov
GO: Jesse Adams
Phone: (720) 356-1421
E-mail: Jesse.Adams@go.doe.gov



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## Fiscal Year (FY) 2011 Objectives

- Design a modular, high-volume fuel cell leak-test suite.
- Performance leak tests in-line during assembly and break-in steps.
- Demonstrate improved fuel cell stack yield rate.
- Reduce labor time.
- Reduce fuel cell stack manufacturing cost.

## Technical Barriers

This project addresses the following technical barriers from the Manufacturing 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 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)

## FY 2011 Accomplishments

- Tested and evaluate leak-test suite prototype.
- Achieved five part per hour leak test rate on the prototype.
- Demonstrated that the stack test labor time is reduced dramatically.
- Demonstrated that the stack leak failure is reduced significantly.
- Demonstrated that the prototype can accurately detect leaks in stacks.
- Demonstrated that the prototype does not cause any new failure modes in fuel cell stacks and systems.

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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 verity of leak-test methods will be surveyed, and recommendations for the leak-test suite will be made. 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

Twenty-three fuel cell stacks were built and tested on the leak-test suite prototype. There were 12 cells in each stack. The Celtec-P 1000 high temperature membrane electrode assembly with 18 $cm^2$ active area was used. Pressure decay (PD), crossover current (CC), and open-circuit voltage (OCV) decay were used to detect leak in stacks. The results are shown in Table 1. This demonstrated that 95% of leaks can be detected by the prototype. The leak test times are shown in Table 2. The average leak test time is 590 seconds, and the leak test rate is 6 parts per hour, which exceeds the Phase I milestone: 5 parts per hour.

**TABLE 1.** Leak Test Results

| | YES | NO |
|---|---|---|
| PD correctly confirms CC or OCV results | 19 | 4 |
| CC correctly detects failure on retest | 15 | 0 |
| OCV correctly detects failure on retest | 15 | 0 |
| CC/OCV correctly detects swap or replacement | 24 | 0 |

**TABLE 2.** Leak Test Time

| Leak Test Process | Test Time (sec) |
|---|---|
| Pressure decay | 227 |
| Crossover current | 253 |
| OCV decay | 60 |
| Flexo-tiltometer | 50 |
| **Total** | **590** |

Five stacks were built and tested on the leak-test suite prototype. These stacks passed leak, break-in, and performance tests. Then they were subjected to 30-day life test with one start/stop per day. The stack life test results are shown in Figure 1. All stacks completed life test and meet exit criteria. One cell in stack 084618-02 failed due to the fuel starvation, and was replaced at ~400 hr. However, this type of failure is occasionally observed in production stacks, so the failure should not be attributed to the prototype. Overall, the stack life test demonstrates that leak-test suite prototype does not cause new failure modes in stack.

Three stacks were built and tested on the leak-test suite prototype. These stacks passed leak, break-in, and performance tests. Then they were integrated into fuel cell systems. The system tests include static/dynamic load, cartridge run, -5°C performance, 50°C performance, emission, surface temperature, and polarization curve. System 26 and 50 passed all tests. System 45 passed all tests except emission and polarization curve test (Table 3). During diagnostics, a stainless steel tube on fuel processor broke off. This indicated there was a bad welding in the fuel line. This might cause fuel leak and result in fuel starvation in fuel cell. Later, an air compressor was found to have a manufacturing defect that caused an air leak. The failures

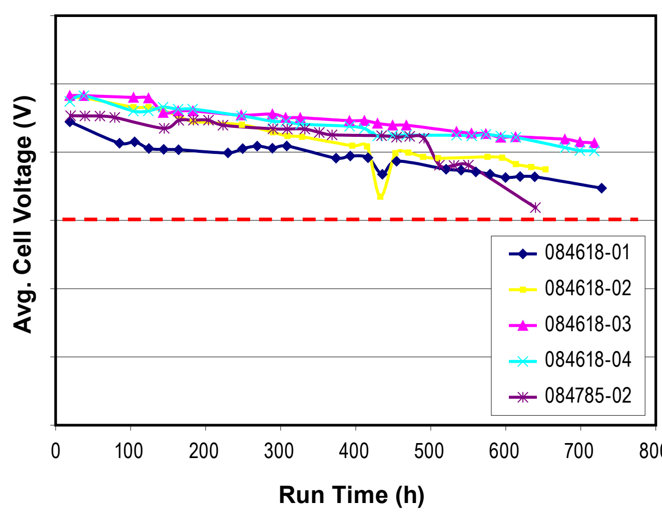


**FIGURE 1.** Fuel Cell Stack 30-Day Life Test

**TABLE 3.** System Test Results

| System Tests | 25E1LC0026 | 25ENDY0050 | 25E1LC0045 |
|---|---|---|---|
| Static/Dynamic Load | Pass | Pass | Pass |
| Cartridge Run | Pass | Pass | Pass |
| -5C Performance | Pass | Pass | Pass |
| 50C Performance | Pass | Pass | Pass |
| Emission | Pass | Pass | Fail |
| Surface Temperature | Pass | Pass | Pass |
| Polarization Curve | Pass | Pass | Fail |

in the system test are due to the balance of plant component failure and not related to the fuel cell stack. The system validation test demonstrates the leak test suite prototype does not cause new failure modes in the fuel cell stack.

## Conclusions and Future Directions

The conclusions include the following:

- The fuel cell stack leak-test suite prototype was tested and evaluated. The prototype achieved five part per hour leak test rate. The prototype is fully automated, significantly reducing the stack test labor time.
- The validation test demonstrated that the prototype can accurately detect leaks in stacks. The leak test processes do not cause any new failure modes in fuel cell stack and system.

## FY 2011 Publications/Presentations

**1.** Chen, R. 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., May 9–13, 2011.