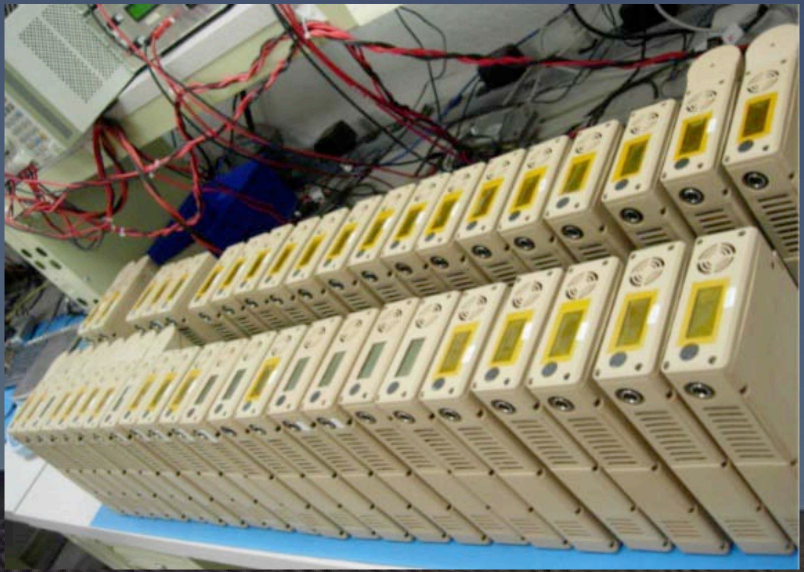
D.O.E. Program Review

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



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Pacific Northwest National Laboratory

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Cincinnati Test Systems

June 11, 2010

Project ID # MN003

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Start: 09/01/2008
- End: 08/31/2011
- 50% complete

Barriers

F: Low levels of Quality Control and inflexible processes

Budget

- Total project funding
  - DOE $2,411,888
  - Contractor $2,281,603
- Funding received in FY09
  - $1,041,805
- Funding for FY10
  - $253,013

The funding shown for FY09 and FY10 are actual expenditures rather than DOE obligations

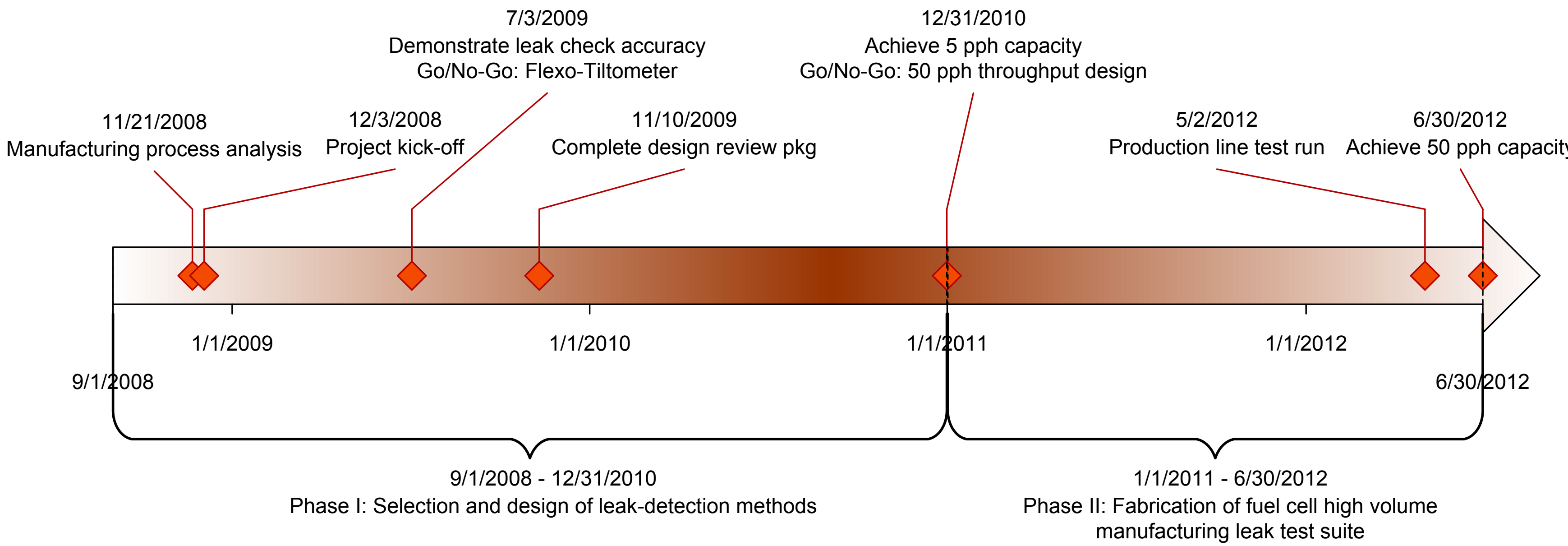
Partners

- UltraCell – Project lead
- PNNL – Fuel cell stack properties, method selection, quality metrics
- CTS – Leak-test suite design, fabrication, and installation

Objectives - Relevance

- **A fuel cell is an excellent leak-sensor: we use the manufactured part as part of the sensor network**
- **Project Objectives**
  - Design a modular, high-volume fuel cell leak-test suite capable of testing in excess of 100,000 fuel cell stack per year (i.e., 50 fuel cell stacks per hour).
  - Perform leak tests inline during assembly and break-in steps
  - Demonstrate fuel cell stack yield rate to 95%.
  - Reduce labor content to 6 min.
  - Reduce fuel cell stack manufacturing cost by 80%.
- **Objectives for past year**
  - Develop leak-test methods
  - Design and fabricate leak-test suite prototype

Milestones - Relevance



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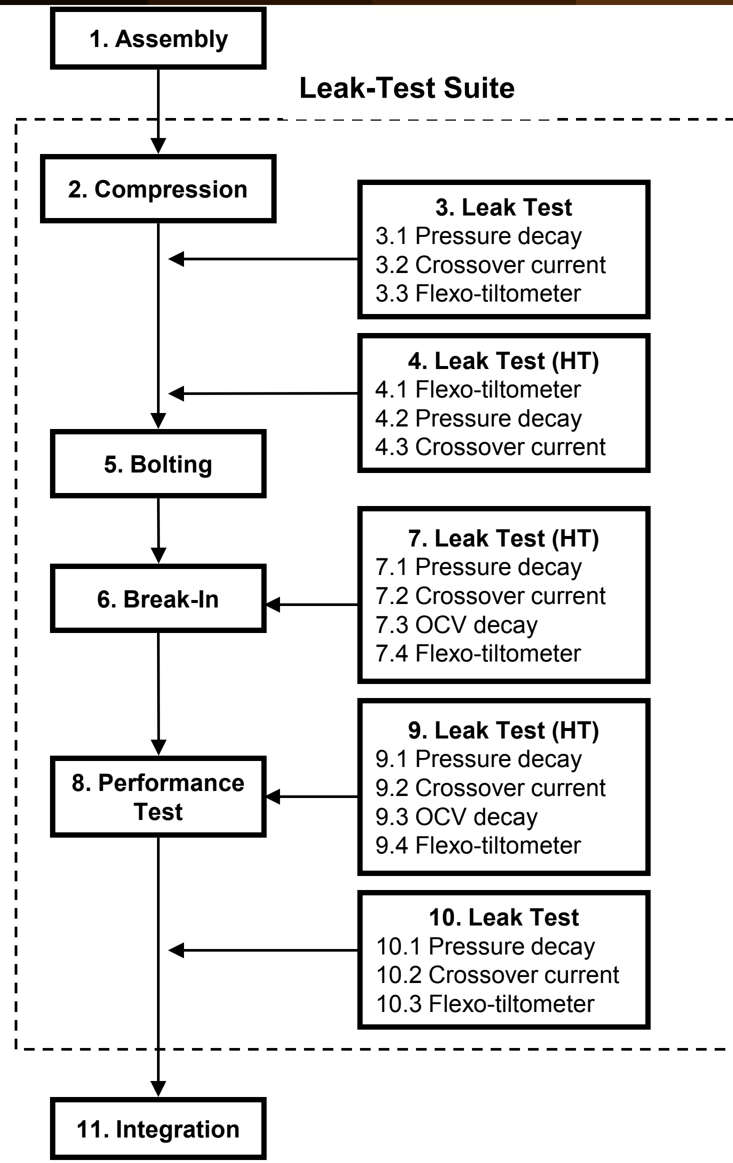
Approach


1. Assembly
Leak-Test Suite
2. Compression
3. Leak Test
3.1 Pressure decay
3.2 Crossover current
3.3 Flexo-tiltometer
4. Leak Test (HT)
4.1 Flexo-tiltometer
4.2 Pressure decay
4.3 Crossover current
5. Bolting
6. Break-In
7. Leak Test (HT)
7.1 Pressure decay
7.2 Crossover current
7.3 OCV decay
7.4 Flexo-tiltometer
8. Performance Test
9. Leak Test (HT)
9.1 Pressure decay
9.2 Crossover current
9.3 OCV decay
9.4 Flexo-tiltometer
10. Leak Test
10.1 Pressure decay
10.2 Crossover current
10.3 Flexo-tiltometer
11. Integration

Approach

Features

- ✓ Automation
- ✓ Inline leak-test during stack manufacturing
- ✓ Multi-functions: combined leak tests, compression, break-in and power performance in one system
- ✓ Diagnostics
- ✓ Safety feature

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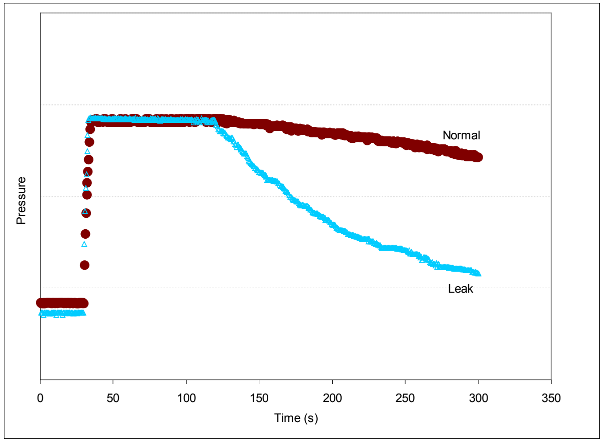
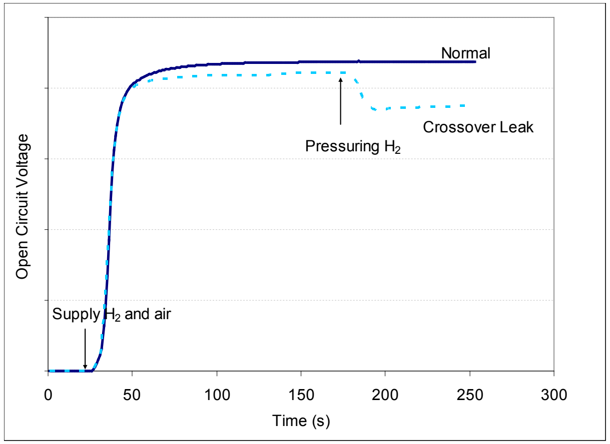
Approach

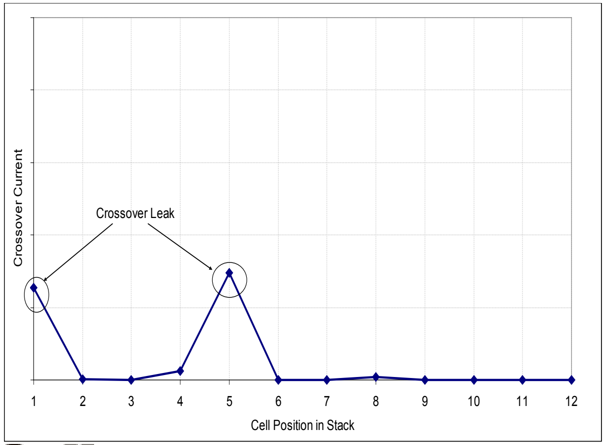
Pressure Decay Test

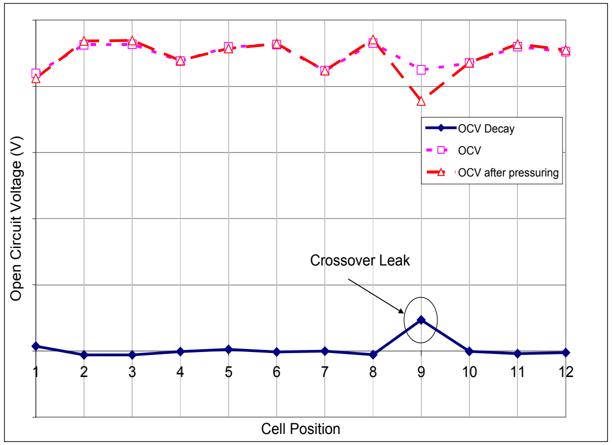


OCV Decay Test



Crossover Current Test





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Approach

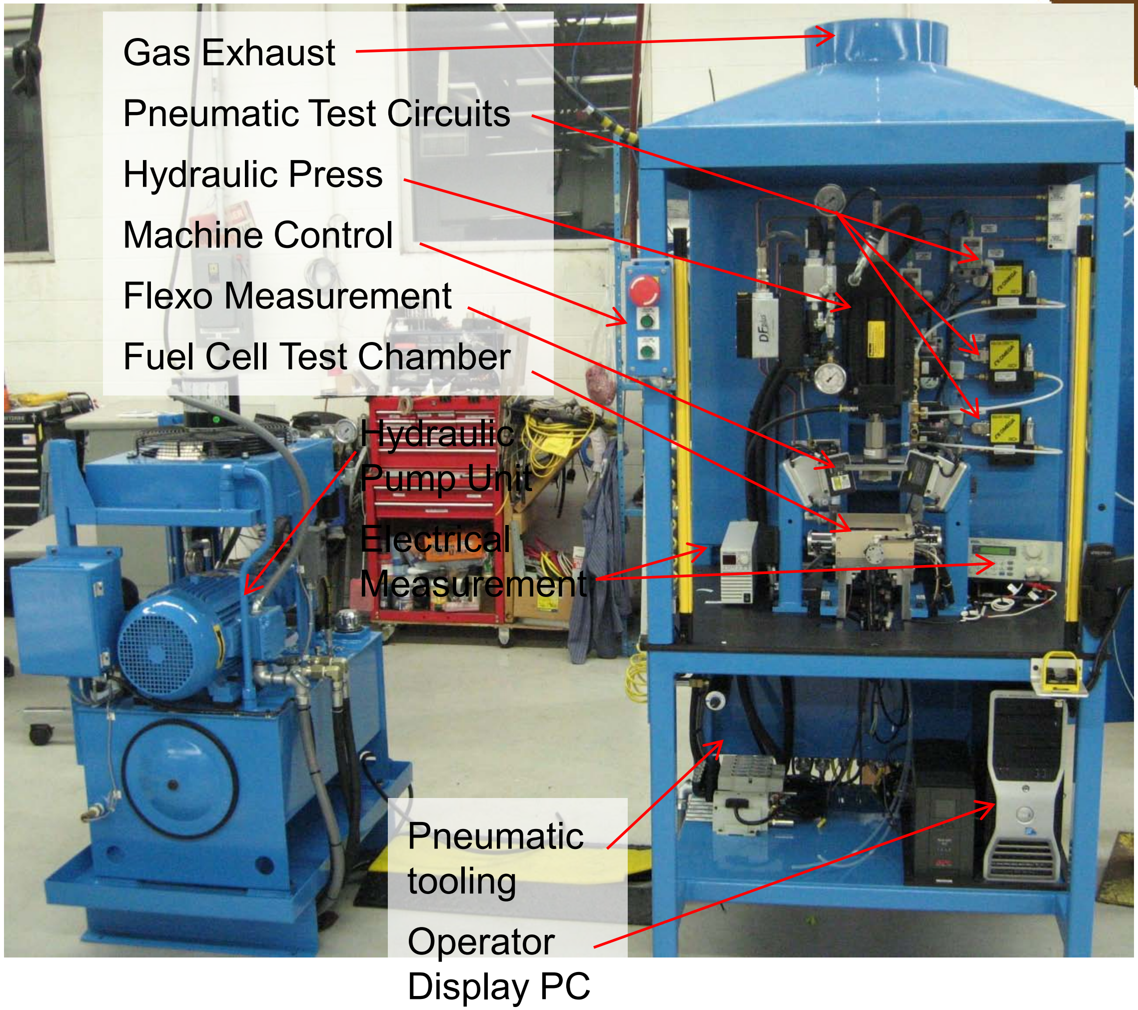
- **Milestones (FY10)**
  - 11/08 Manufacturing process analysis
  - 07/09 Demonstrate leak check accuracy
  - 07/09 Go/No-Go: Flexo-Tiltometer accuracy
  - 11/09 Complete design review package
  - 12/10 Achieve 5 pph capacity on prototype leak test suite
  - 12/10 Go/No-Go: design of 50 pph leak test suite

- **Progress**
  - Analyzed fuel cell stack manufacturing process procedure, throughput time, labor time, yield, failure modes
  - Investigated leak-test methods
  - Investigated fuel cell stack components
  - Designed and fabricated leak-test suite lab prototype
  - Validated leak-test suite lab prototype

Technical Accomplishments

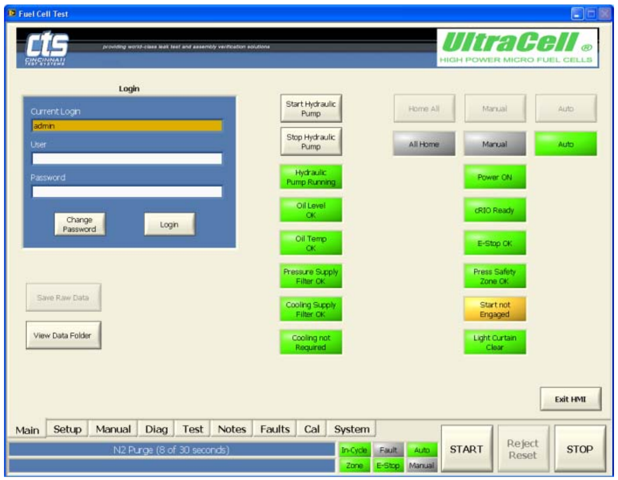
The leak-test suite lab prototype is a combination of the following main areas:

1. Machine Control
2. Fuel Cell Test Chamber
3. Hydraulic Press with Pump
4. Pneumatic Tooling
5. Pneumatic Test Circuits
6. Flexo-tiltometer Measurement
7. Electrical Measurement
8. Gas Exhaust System

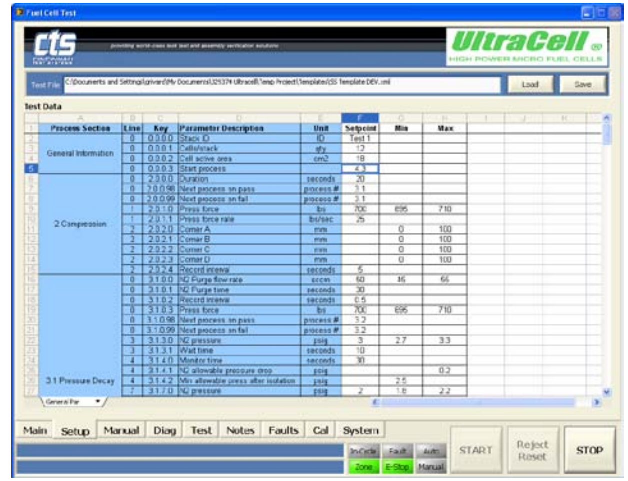


Technical Accomplishments

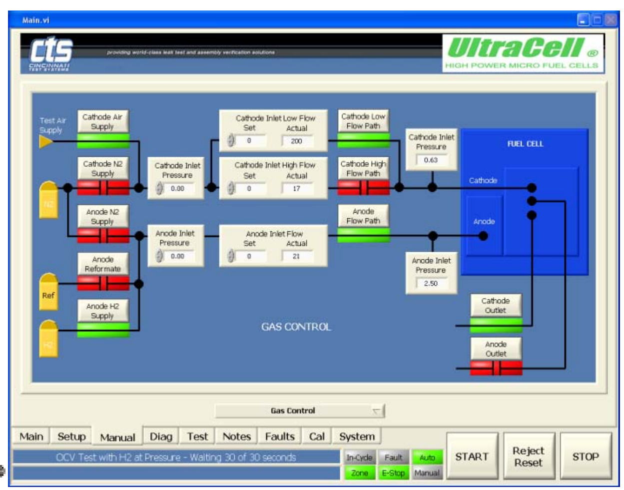
Main



Setup



Control



Test

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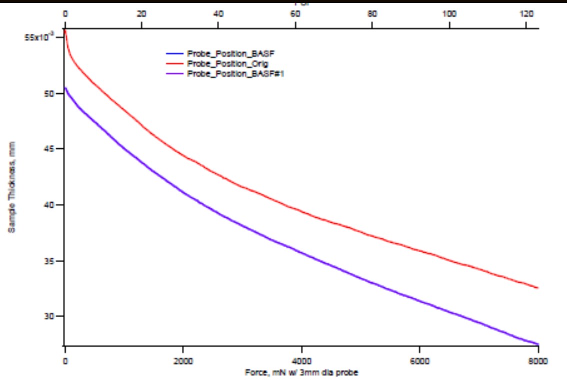
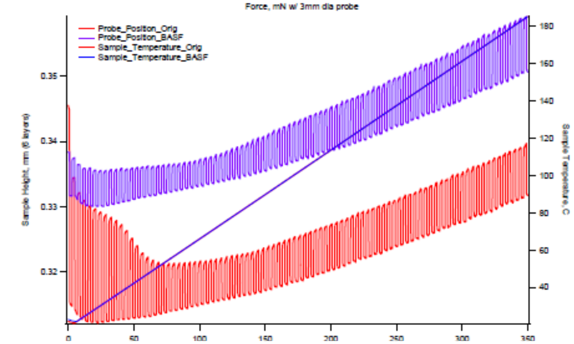
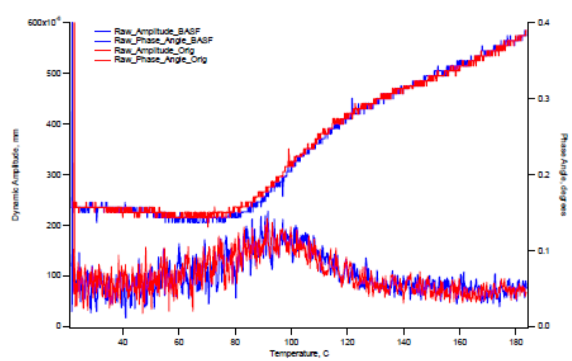
Mechanical Analysis of Stack Materials



Static Compression. Relevant to initial stack compression



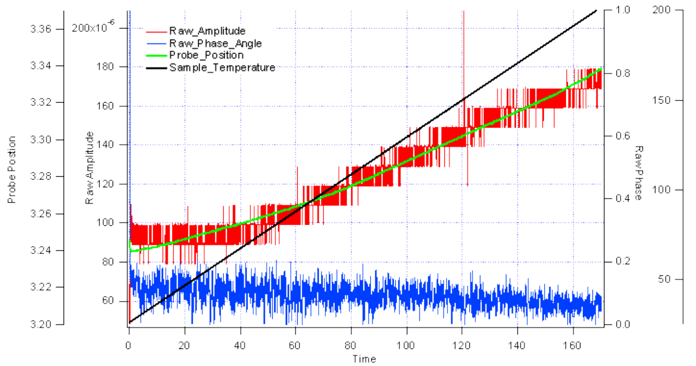
Creep & Recovery. Relevant to slow changes in stack structure



Dynamic Mechanical Analysis vs. Temperature. Differentiation of materials based upon glass transition temperature.

1) Variety of mechanical analysis techniques
2) Data base of individual properties
3) Used in modeling mechanics of assembled stack

3 mm probe tip allows high local pressures with minimal force but is not useful for assemblies



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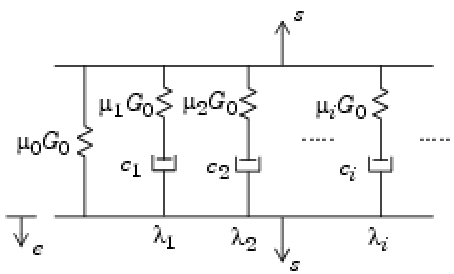
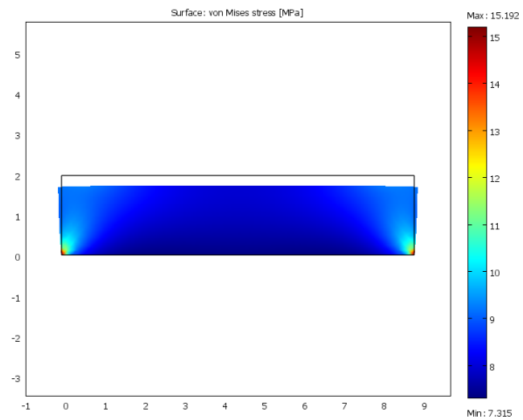
Modeling Stack Mechanical Properties

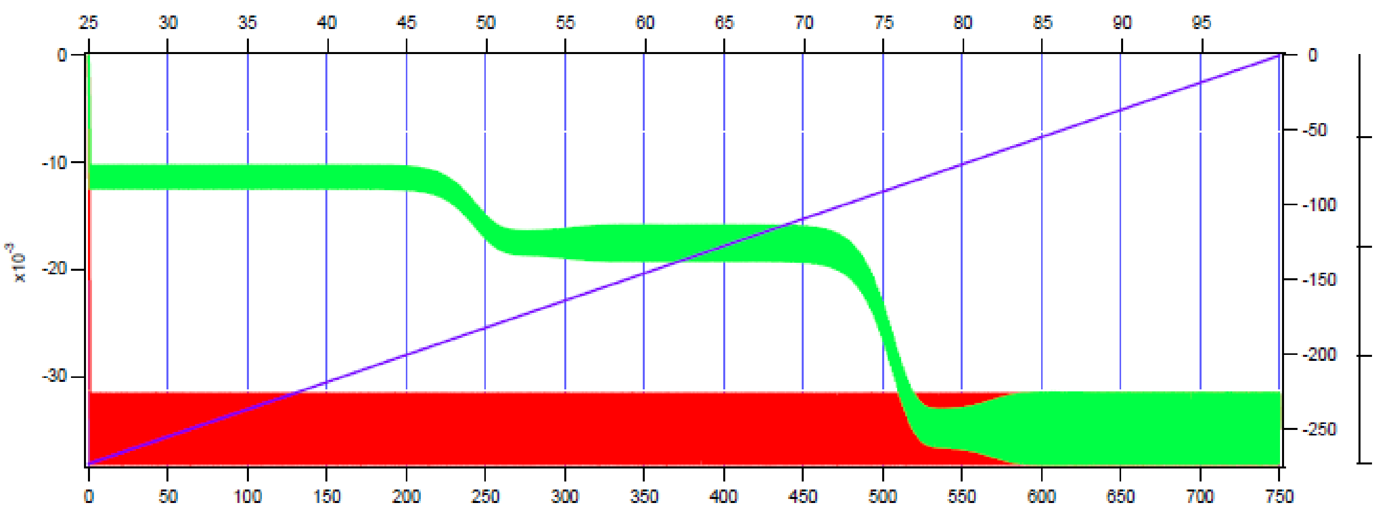


Maxwell spring dashpot assembly used to model each material



Snap shot of a Maxwell spring dashpot material showing the von Mises stresses with 1 Hz oscillation

Mechanical model needed to interpret data from complex stack assembly



Response of 2 stacked materials with glass transition temperatures of 50°C and 75°C.

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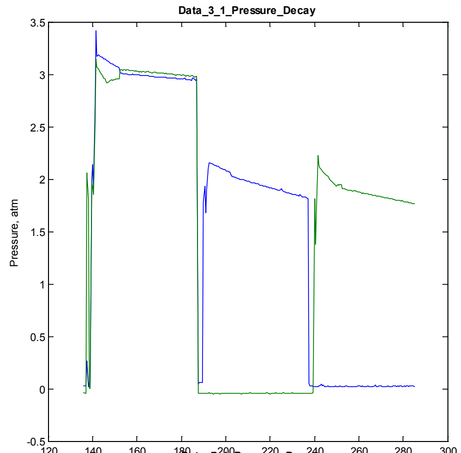
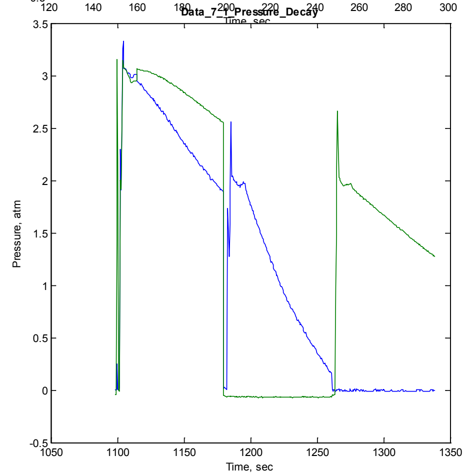
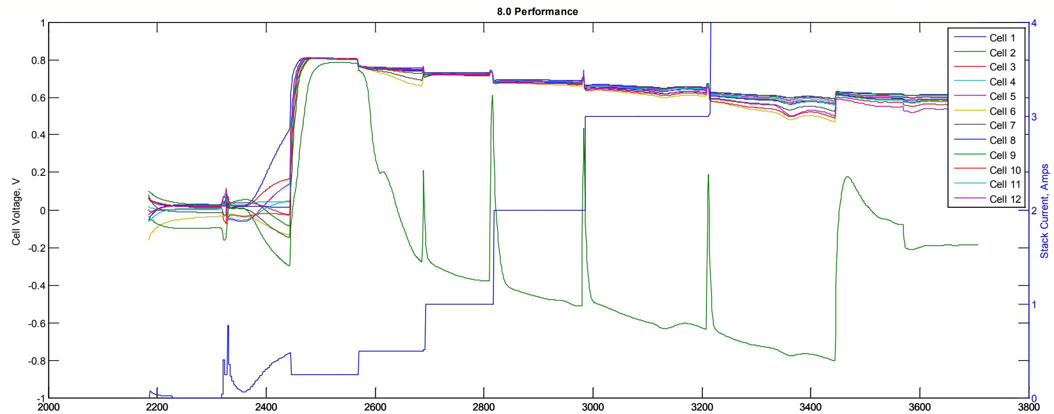
Comparison of Automated and Manual Testing
(with a specific stack)





Stack developed an external leak at temperature which seal upon cooling



As documented in the manual test Cell 9 failed under load with reformate fuel. All others passed.

1) Significant reduction in testing time
2) Increase in test reproducibility
3) Time dependent data acquired
4) More tests performed
5) Leak test performed at high temperatures

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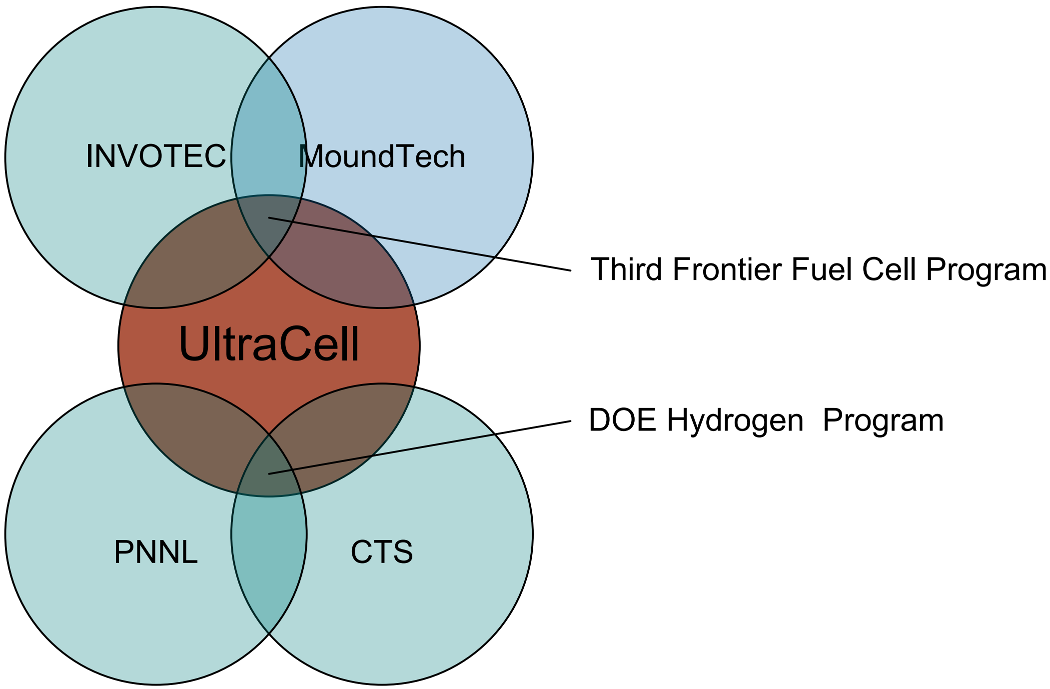
Collaborations



- **UltraCell Corporation**
  Project lead.
  Leading producer of fuel cell systems for remote or mobile devices.
- **Pacific Northwest National Laboratory**
  Stack properties, method selection, quality metrics
- **Cincinnati Test Systems**
  Leak-test suite design, fabrication, and installation
- **Invotec Engineering, Inc.**
  Design, fabrication, and installation of fuel cell stack robotic manufacturing system
- **Mound Technical Solutions, Inc.**
  Design and fabrication of fuel cell performance test fixture and automated test data analysis

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Future Work

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

Summary

- **Objectives**
  - Design a modular, high-volume fuel cell leak-test suite capable of testing in excess of 100,000 fuel cell stack per year (i.e., 50 fuel cell stacks per hour).
  - Perform leak tests inline during assembly and break-in steps
- **Progress**
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- **Future Work**
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