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Pacific Northwest
NATIONAL LABORATORY

cts
CINCINNATI TEST SYSTEMS

U.S. DEPARTMENT OF ENERGY

# D.O.E. Program Review

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


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**Cincinnati Test Systems**


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# Introduction to UltraCell

- Founded 2002
- Mission
  - To provide compact and portable grid-independent power to the global market
- Core Technology
  - Reformed Methanol Fuel Cells (RMFC)
  - Originally invented at the U. S. Department of Energy's Lawrence Livermore National Laboratory (LLNL).
- Locations
  - Livermore, CA (HQ), Vandalia, Ohio (Manufacturing)
- Existing product line
  - XX25 fuel cell
  - XX55 fuel cell
  - Various fuel tanks and accessories

# Implementation of this project's goals will be implemented in our current/future product line

- XX25: currently produced in low volume at our Dayton plant.



- XX55: Currently limited availability. Will be produced in Dayton

The technology developed under this project will be installed in our plant and go right into our existing product like for reduced costs and faster production rates

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# Why is this project important?

- There is an acute, demonstrated and mission critical weight problem with current battery technologies that can be addressed by our technology
- 20W mission for 72-hrs benchmark shows great potential for the XX25 architecture
- Getting more units, faster and with greater reliability to the field is critical


***XX25™***

Energy density = 360 Whr/Kg
72 hr mission wt. = 4.0 Kg (8.8 lb)

***Group II Lead Acid***

Energy density = 36 Whr/Kg
72 hr mission wt. = 40 Kg (88 lb)

***BA-5590 (Primary Lithium)***

Energy density = 221 Whr/Kg
72 hr mission wt. = 6.5 Kg (14.3 lb)

***BA-2590 (Li-Ion)***

Energy density = 130 Whr/Kg
72 hr mission wt. = 12.2 Kg (27.1 lb)

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# Overview

## Timeline

- Start: 09/01/2008
- End: 08/31/2011
- 20% complete

## Barriers

F: Low levels of Quality Control and inflexible processes

## Budget

- Total project funding
  - DOE $2,411,888
  - Contractor $2,281,603
- Funding for FY09
  - $1,661,881

## Partners

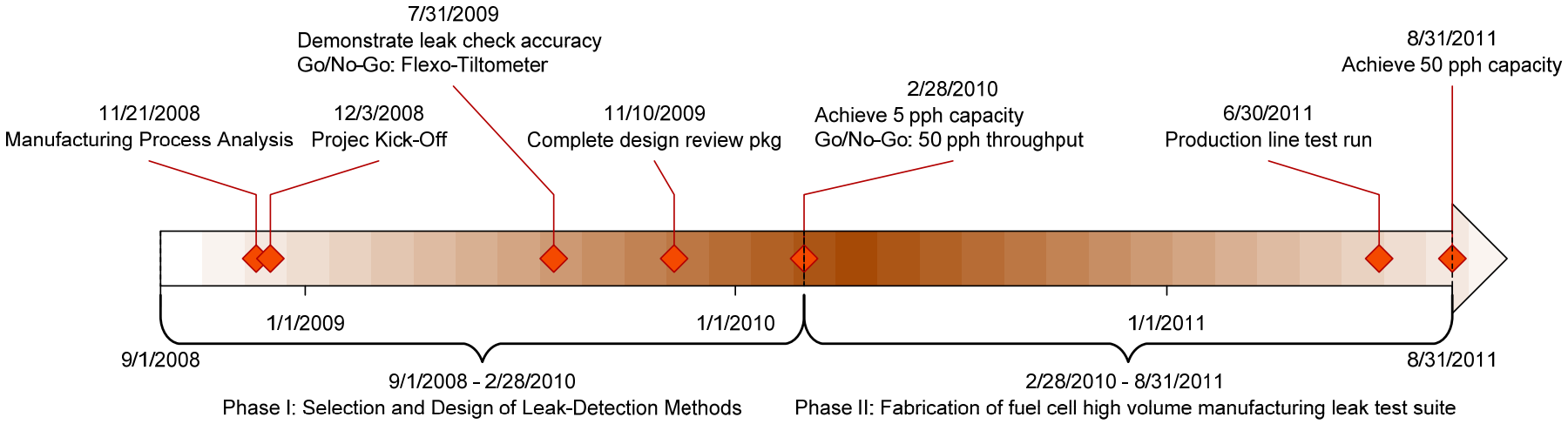
- UltraCell – Project lead
- PNNL – Fuel cell stack properties, method selection, quality metrics
- CTS – Leak-test suite design, fabrication, and installation

# Objectives - Relevance

- **A fuel cell is an excellent leak-sensor: we plan to 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%.
- **Project Phases**
  - Phase I: focus on analysis of manufacturing process, stack failure modes, leak-test methods; prototype design and fabrication; leak test suite design.
  - Phase II: pilot production line modification; leak-test suit fabrication, integration, and verification; limited production test run.

# Milestones - Relevance

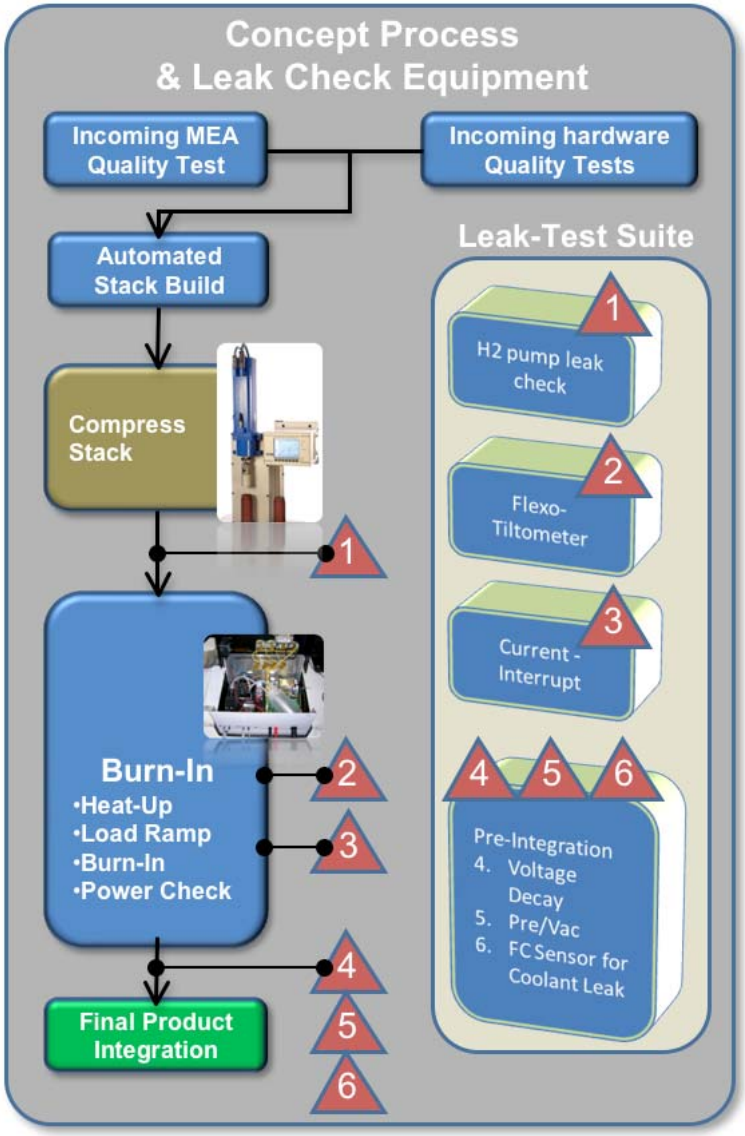


# Approach

**Features**

- Modular structure
- High throughput
- Inline  leak test
- Automation
- Diagnostics

- Add software/hardware mods to existing “test boxes”

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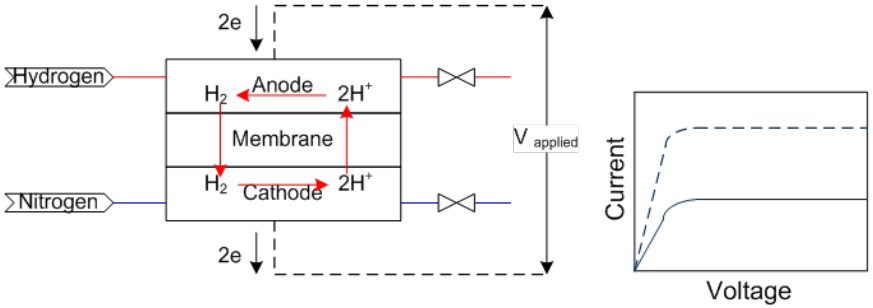
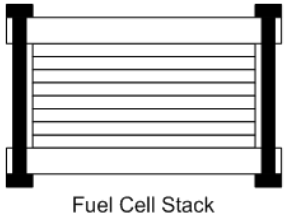
# Approach

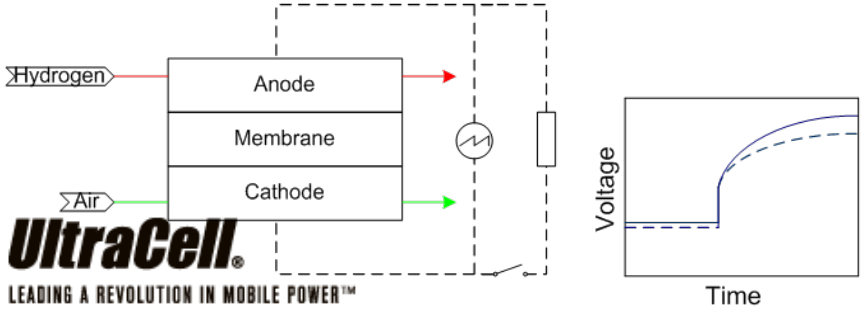
## 1. Crossover Current test



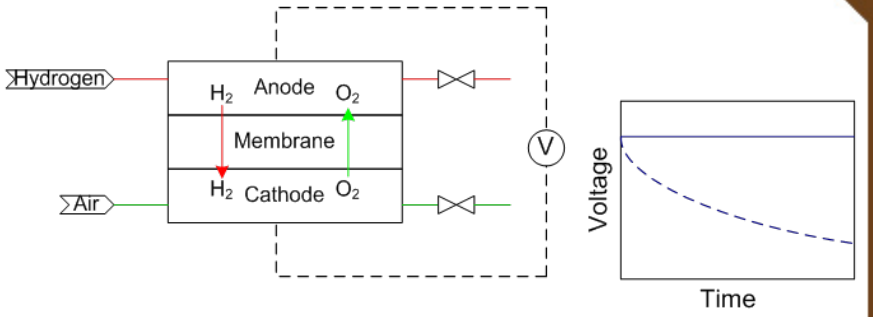

## 2. Flexo-Tiltometer



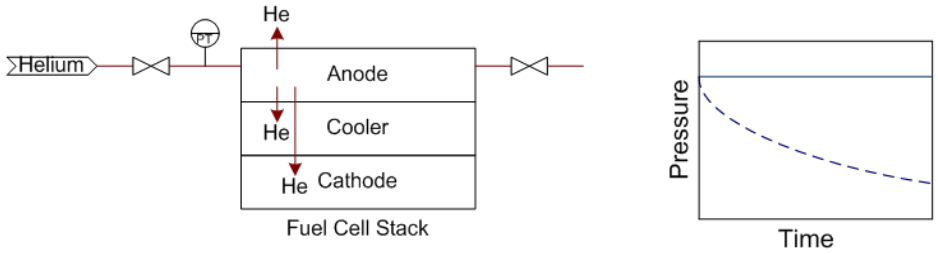

## 3. Current Interrupt



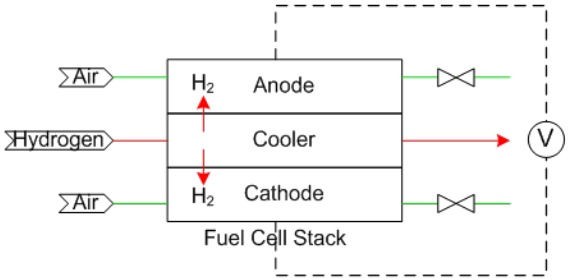

## 4. Voltage Decay




## 5. Pressure/Vacuum Decay




## 6. Fuel Cell Sensor for Coolant Leak



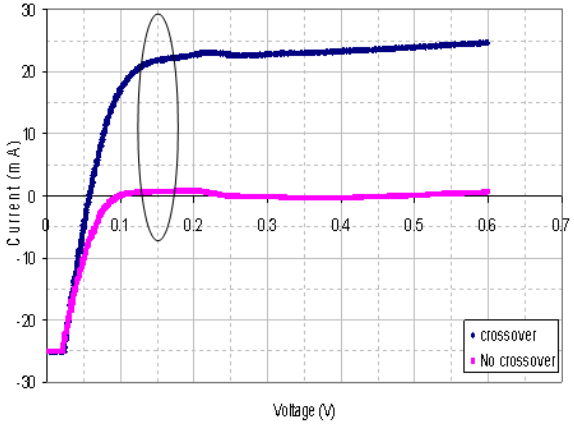
# Approach

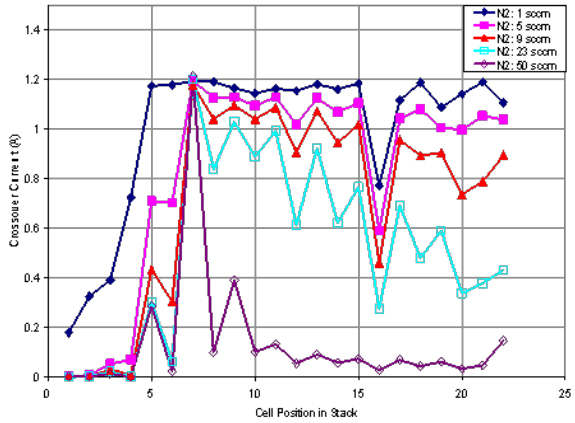
- **Milestones (FY09)**
  - 11/08 Manufacturing process analysis
  - 07/09 Demonstrate leak check accuracy
  - 07/09 Go/No-Go: Flexo-Tiltometer accuracy
  - 11/09 Complete design review package
  - 02/10 Achieve 5 pph capacity on prototype leak test suite
  - 02/10 Go/No-Go: 50 pph throughput

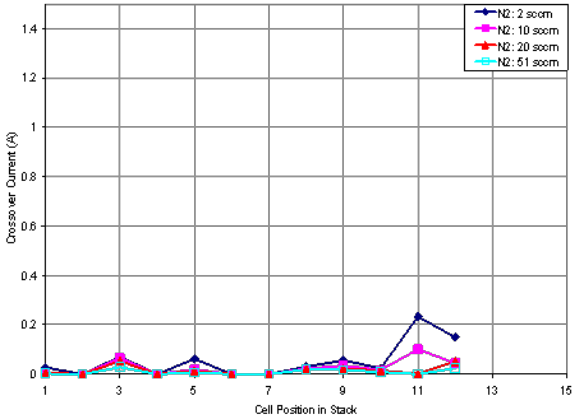
- **Progress**
  - Analyzed fuel cell stack manufacturing process procedure, throughput time, labor time, yield, failure modes
  - Investigated leak-test methods
  - Investigated fuel cell stack components
  - Created specification for leak-test suite lab prototype
  - Started design leak-test suite lab prototype

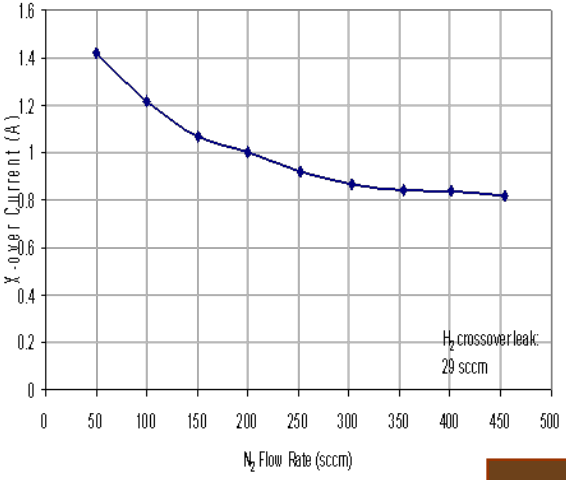
# Technical Accomplishments

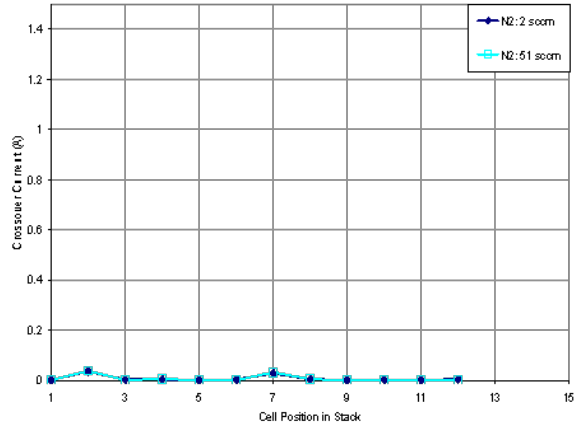
## Crossover Current Test




- Fuel cell with crossover shows higher current
- Sensitivity depends on Nitrogen flow on cathode side

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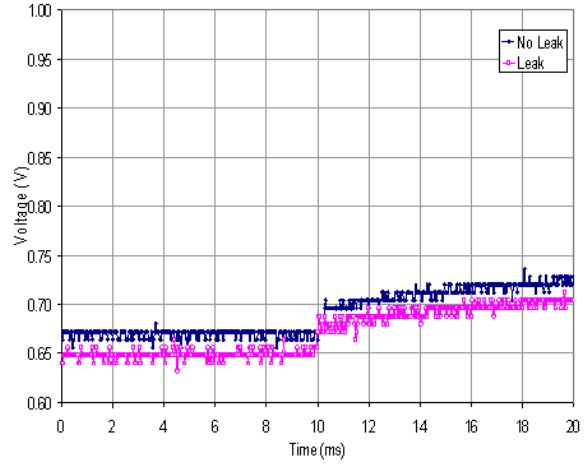
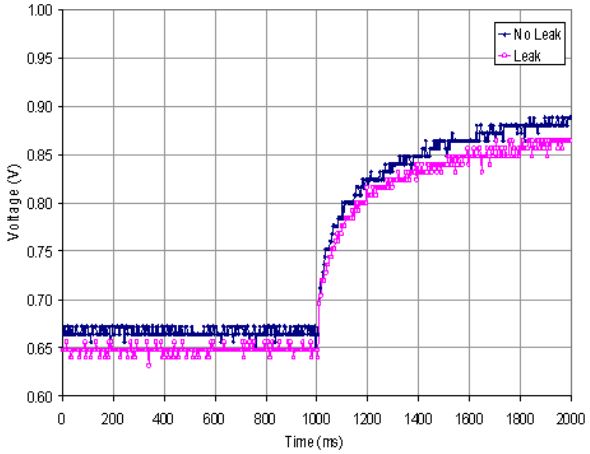
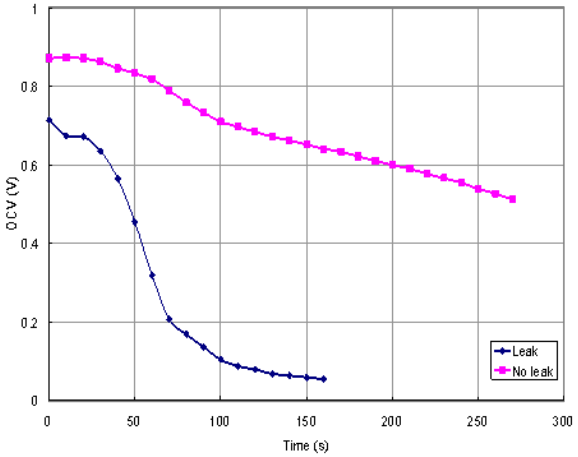
# Technical Accomplishments

## Current Interrupt




## Voltage Decay




- Fuel cell with crossover shows lower OCV and fast decay

- Fuel cell with crossover shows lower voltage and OCV

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# Technical Accomplishments

## Stack Dynamic Mechanical Analysis

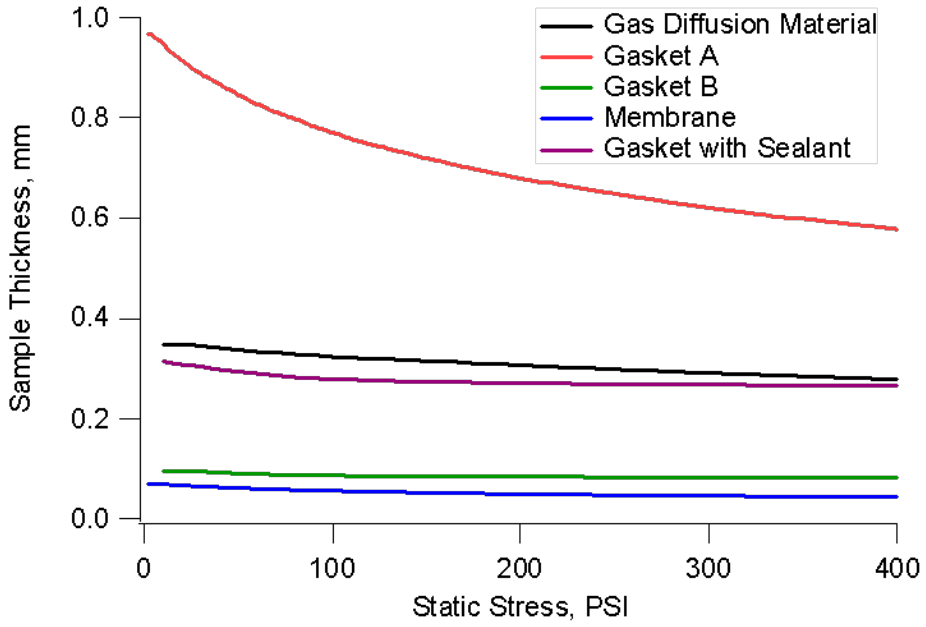
Objective: Understand how DMA techniques can be used to probe pressure distributions, aid in stack assembly protocols, decrease break-in times and identify causes of leaks.

***The "Flexo-Tiltometer"***

- Final static assembly pressure should assure
  - Seal integrity
  - Good electrical contact
  - Correct compression of all components

- Static Stress Scans of stack probes only most compressible component.

- Difficult to determine what final assembly pressure should be.

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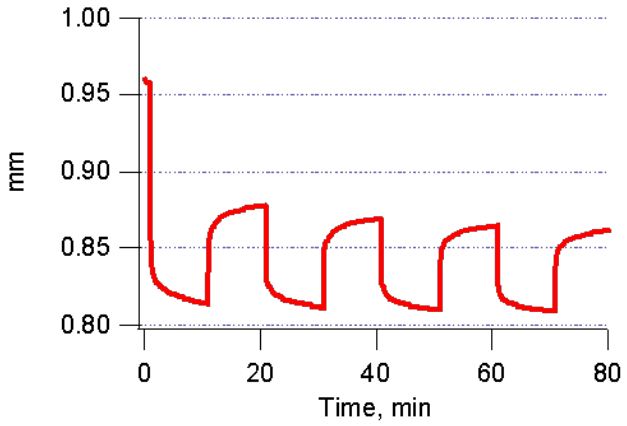
# Technical Accomplishments

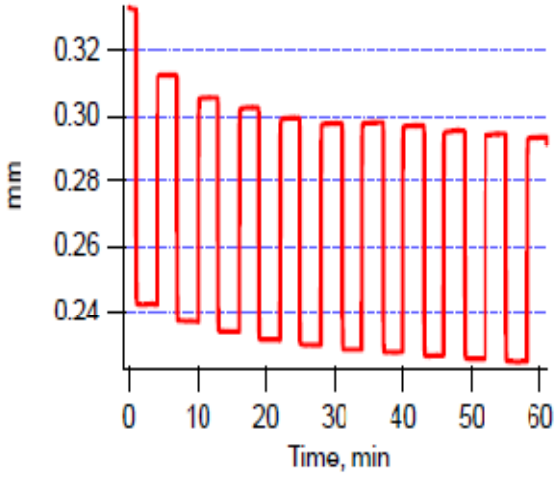
## Creep & Recovery

- Slow reversible and irreversible dimensional changes.
- GDLs have both irreversible and progressive “crush” and a reversible elastic compression.
- Gasket A shows an initial irreversible compression followed by reversible but slow elastic compression and recovery.
- When should stack be “Bolted”?

Gasket A




Gas Diffusion Layers

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# Technical Accomplishments

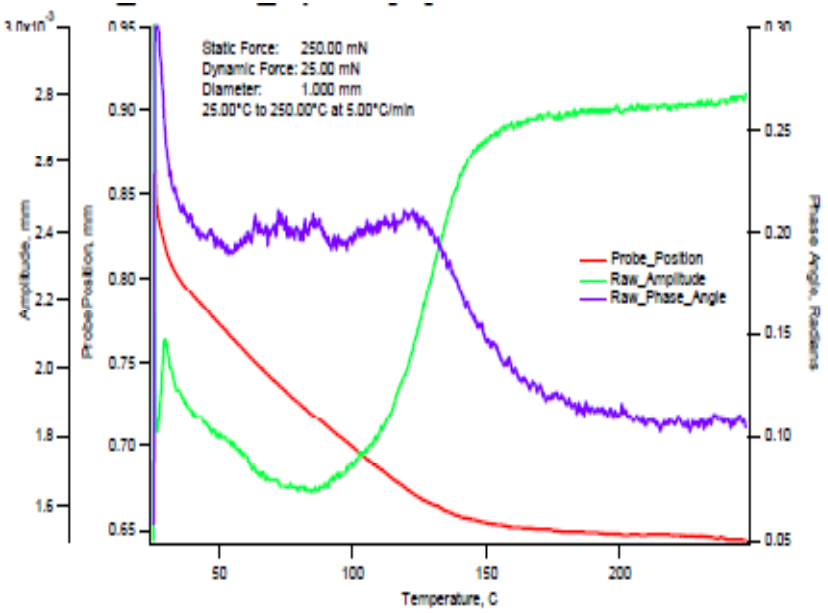
## Dynamic Temperature Scans

- Low temperature relaxation at 30 °C
  Probably due to flattening of wrinkles

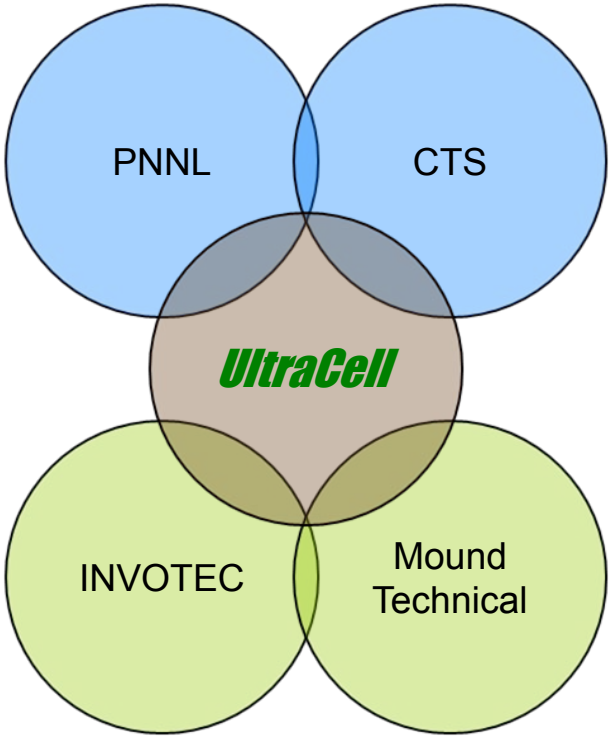
- Features at ~140 °C correlate with glass transition temperature for this material.

- Dynamic pressure oscillations during assembly can help reveal force distributions during stack assembly.

Gasket B



# Collaborations




DOE

Hydrogen Program

Ohio Department of Development, 3rd Frontier

Fuel Cell Program

- **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

**FY09**

- Design and fabricate leak-test suite lab prototype with 5 pph capacity
- Test lab prototype
- Generate stack quality metrics
- Design leak-test suite with 50 pph capacity

**FY10**

- Fabricate leak-test suite
- Modify pilot production line to accommodate leak test suite
- Integrate 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**
  - Analyzed fuel cell stack manufacturing process
  - Investigated leak-test methods
  - Investigated fuel cell stack components
  - Created specification for leak-test suite lab prototype
  - Started design leak-test suite lab prototype
- **Future Work**
  - Design and fabricate leak-test suite lab prototype with 5 pph capacity
  - Test lab prototype and generate stack quality metrics
  - Design and fabricate leak-test suite with 50 pph capacity