DOE Hydrogen Program

Low Cost, Durable Seals For PEM Fuel Cells

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FCP5

Overview

DOE Hydrogen Program

Timeline

- Start: Apr 2007
- End: Mar 2009
- 50% Complete

Barriers

- A: Fuel cell seal durability
- Fuel cell seal cost reduction is also being pursued

Budget

- Total Project Funding
  - DOE: $1,980K
  - Contractor: $1,320K
- Funding Received in FY07
  - $750K
- Funding for FY08
  - $710K

Partners

Henkel Technologies

Freudenberg NOK™

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Objectives

DOE Hydrogen Program

Develop advanced, low cost, durable seal materials and sealing techniques amenable to high volume manufacture of PEM cell stacks.

DOE Targets/Goals/Objectives	Project Goal
Durability Transportation: 5,000 hr Stationary: 40,000 hr	Durability Improve mechanical and chemical stability of seals to achieve 40,000 hr of useful operating life.
Low Cost No specific goal provided	Low Cost A material cost equivalent to or less than the cost of high performance silicones in common use.

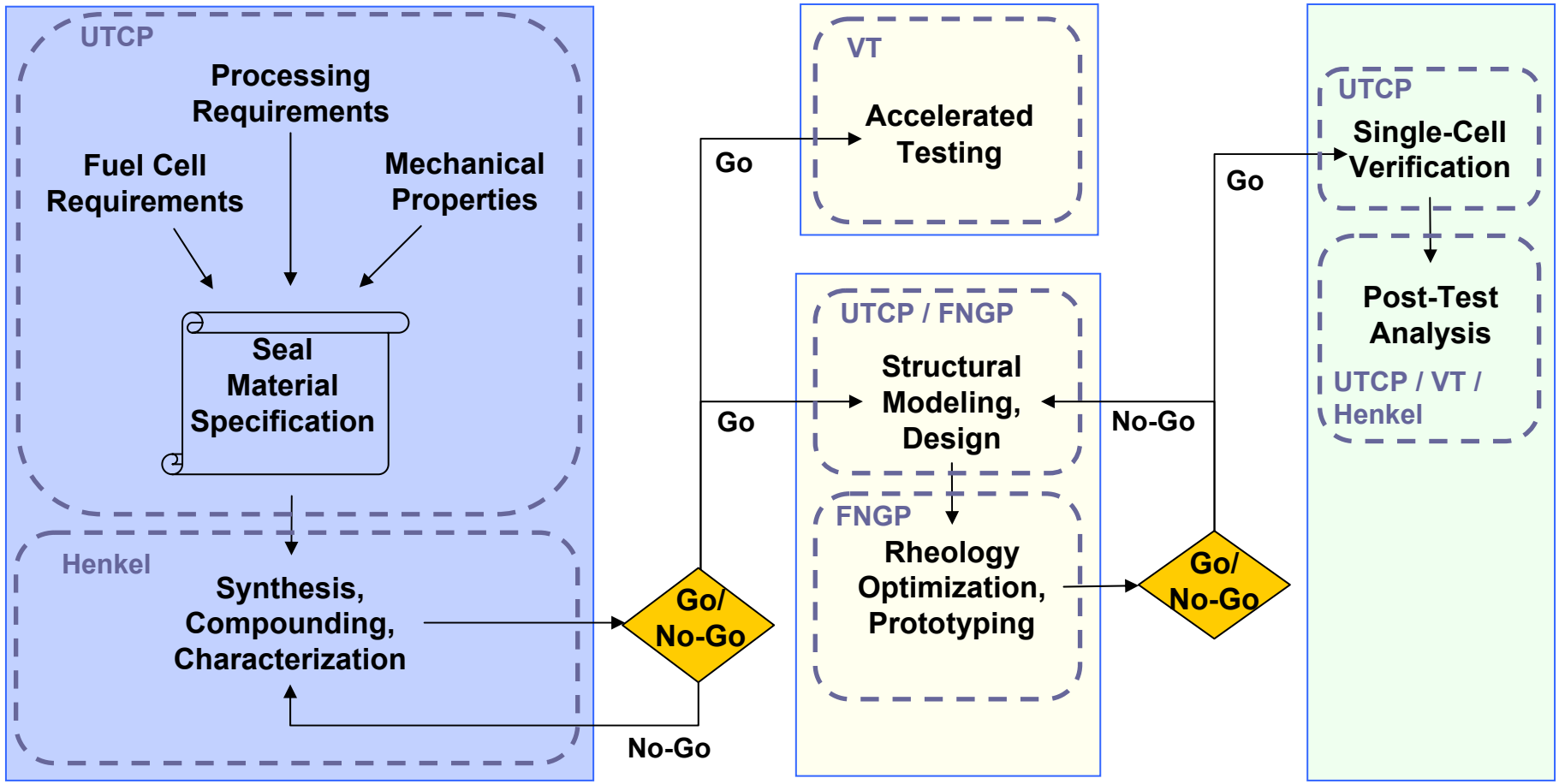
Milestones

DOE Hydrogen Program

Month/year	Milestones or Go/No-Go Decision
Jun-07 (Complete)	Milestone: Complete and submit a material specification to guide material development efforts on the project.
Nov-07 (Complete)	Milestone: Complete the production of a molding tool to produce test specimens for use in accelerated aging tests. (indicate complete)
Jun-08	Go/No-Go: Release and characterize the final material candidate to fully develop under the current program scope. Determine the candidate to carry forward for in-cell testing
July-08	Milestone: Complete and submit the full initial properties characterization report for the leading candidate material

Approach

DOE Hydrogen Program



Material Specification and Development	Seal Modeling and Prototyping	Single-Cell Verification

Company ← Indicates partner with primary task responsibility

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Definitions

DOE Hydrogen Program

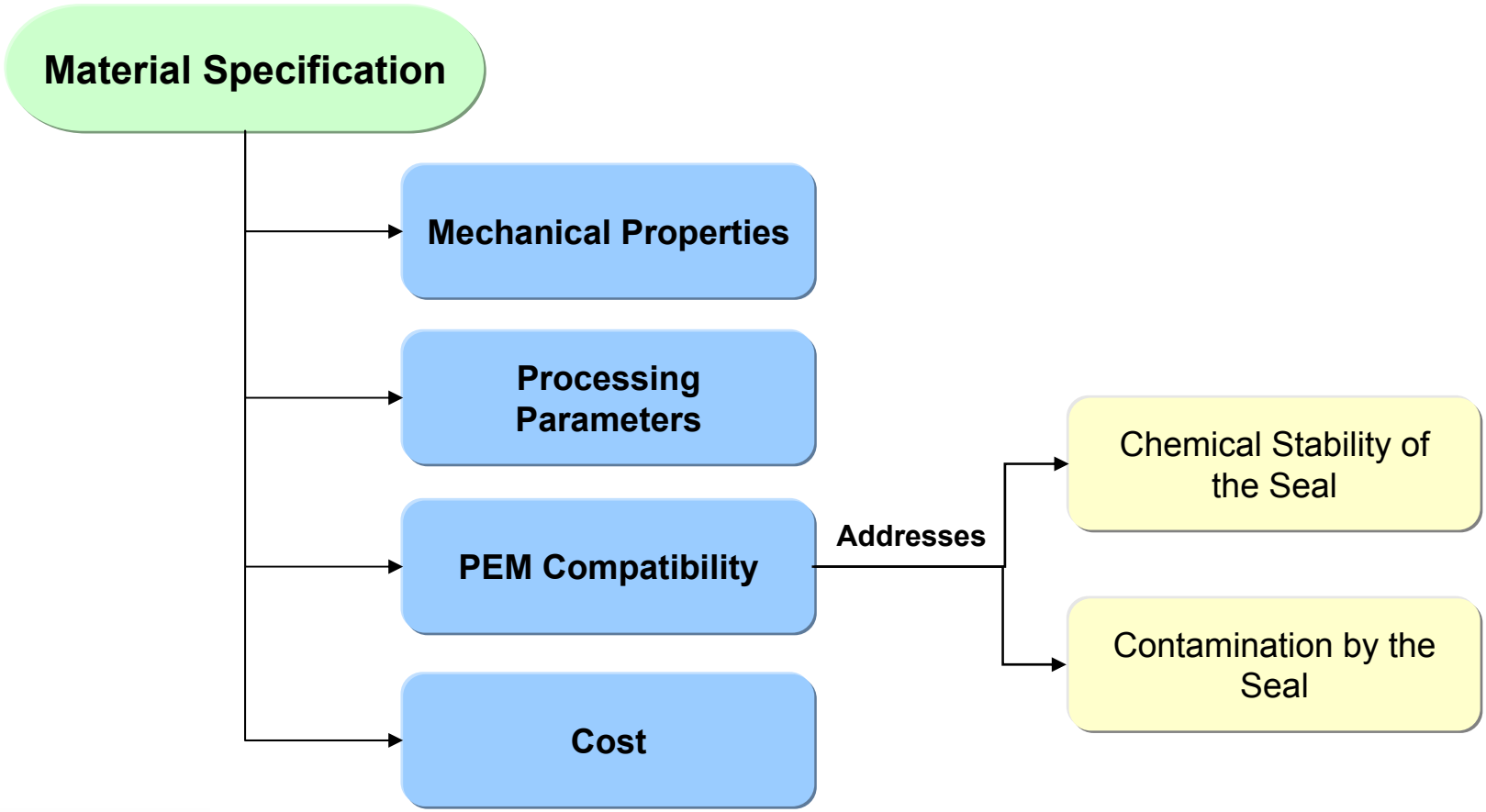
- **SMORS**: Sub-scale Molded O-Ring Seal
- **FCS**: Fuel Cell Sealant
  - Each iteration that makes it out of initial screening with be cataloged as FCS1, FCS2, etc.
- **CSR**: Compressive Stress Relaxation
- **CS**: Compression Set

Progress

Material Selection and Development

DOE Hydrogen Program

- Specification developed to guide material development
  - Document addresses key requirements



Progress

Material Selection and Development

DOE Hydrogen Program

- Two materials have been released to the program for testing
  - FCS0: A one-part material
    - Kept frozen until point of use
  - FCS1: A two-part material
    - Room temperature storage compatible
- Expectations for FCS2, the next material candidate
  - Development underway
  - Design matrix of > 100 experiments
  - The primary goal:
    - 50 to 100% improvement (increase) in tear strength
      - This would exceed the ultimate goal for the program
    - Early results indicate this is achievable
  - Down-selection currently planned for end of 3QGFY08

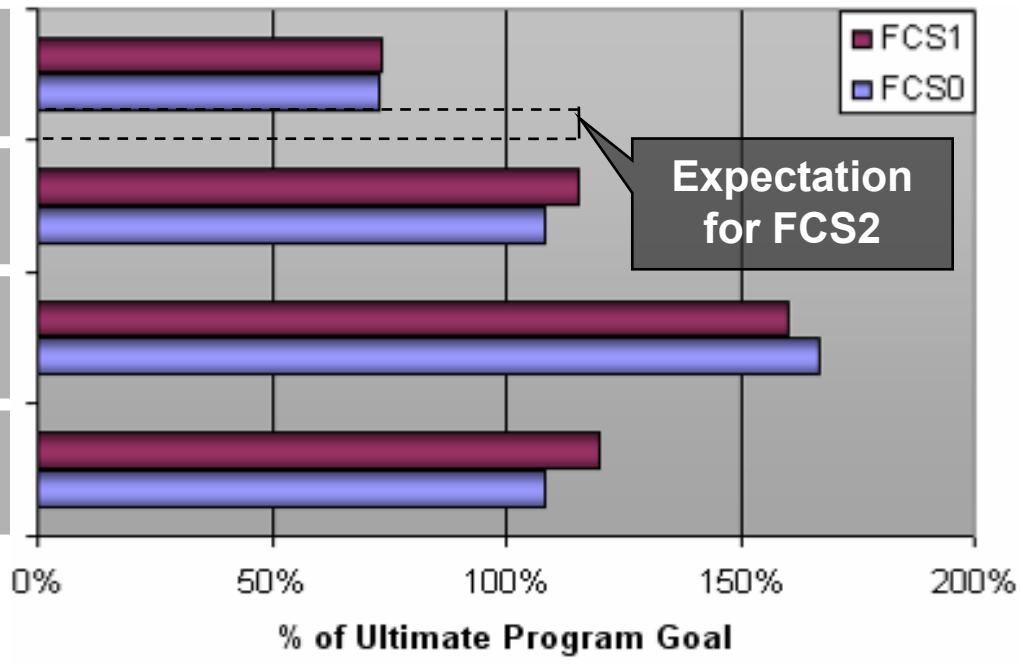
Progress

Material Selection and Development

DOE Hydrogen Program

- Both FCS0 and FCS1 meet or exceed all minimum program goals
- In terms of key initial properties, both also meet or exceed most of the ultimate program goals
- FCS1 shows notable improvements in elongation and cure temperature

Property	Ultimate Program Goal
Tear Strength (kN/m)	> 5.0
Elongation, %	> 150
Tensile Strength (MPa)	>0.8
Cure Temperature (°C)	< 110



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Progress – Material Testing

Component Development

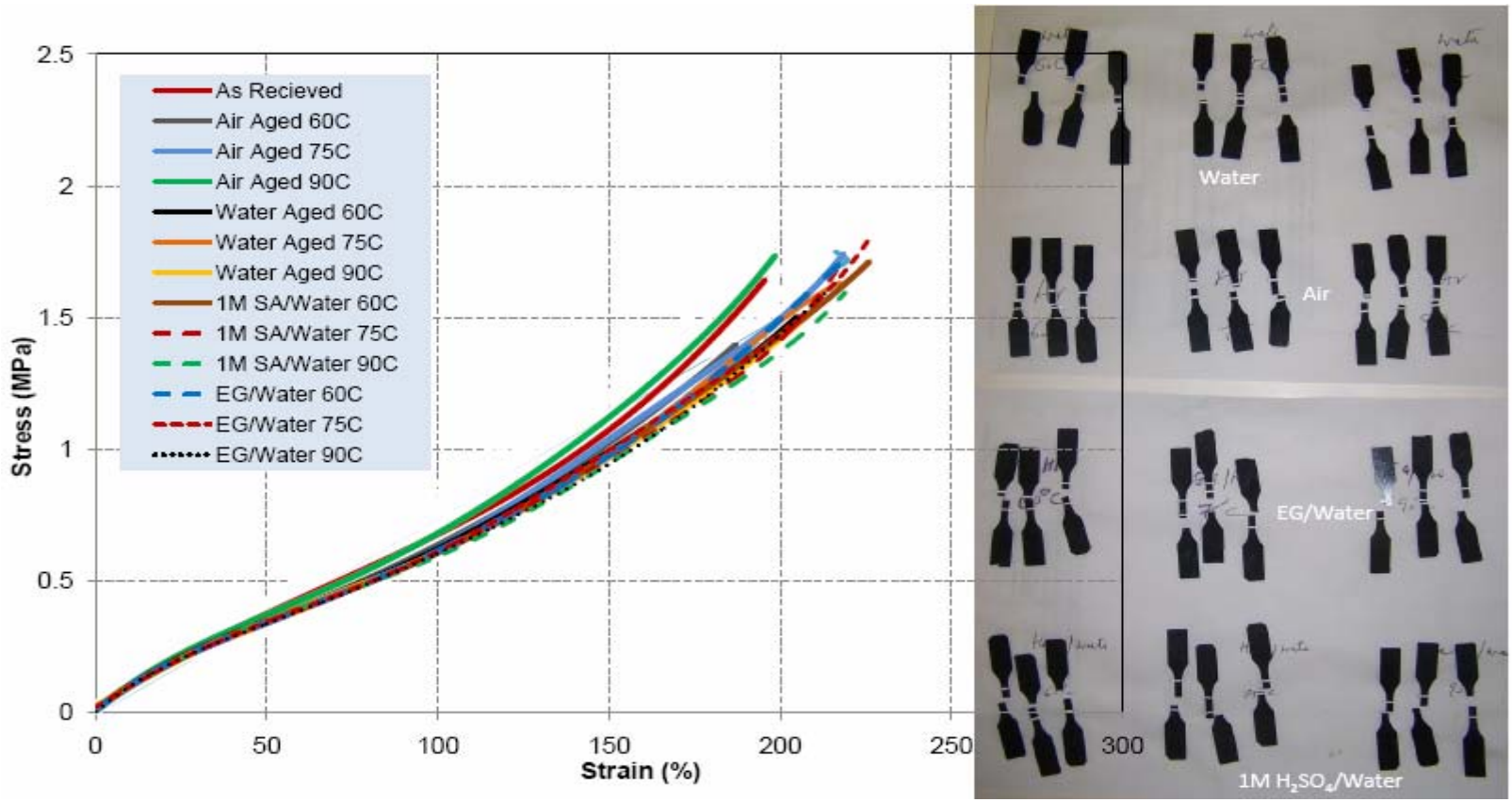
DOE Hydrogen Program

- Two primary material configurations
  1. Slabs: 200mm x 200mm x 2mm thk
     - Used to produce tensile, tear and shear test specimens
  2. Sub-scale Molded O-ring Seals (SMORS)
     - Used for compression and leak testing
     - Cross-section mimics expected full-size prototype configuration
     - Net-shape molded component

Progress – Material Testing

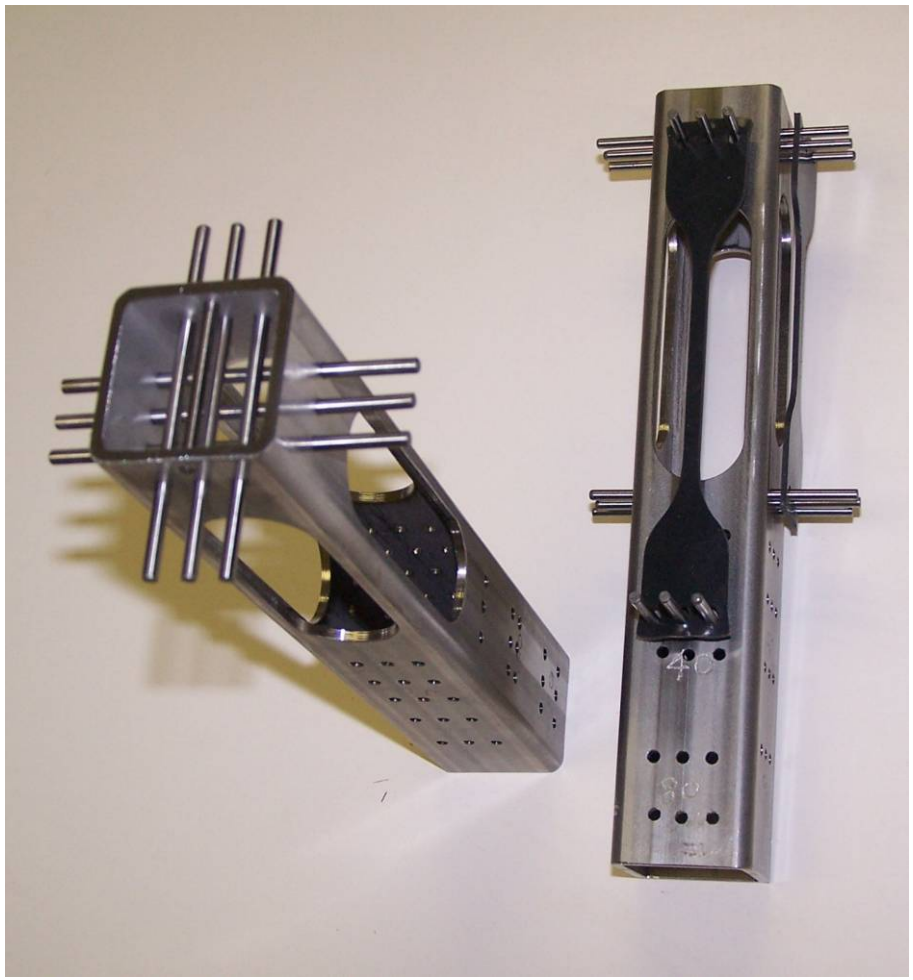
Tensile testing: FCS0 – 336hrs in various environments

- Within the bounds of typical tensile strains experienced by seals, there is no statistically significant change in tensile strength.



Progress – Material Testing

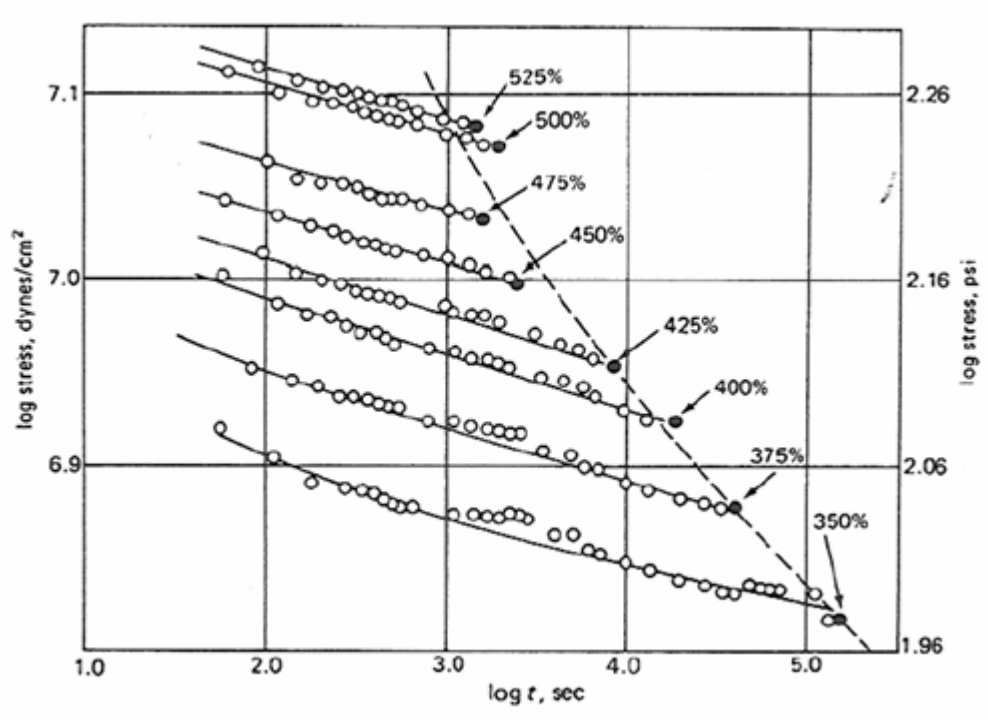
Test Fixture Development – Strain Aging



- Used to down-select environments for use in long-term accelerated aging
- Purpose is Two-Fold
  1. Investigate the susceptibility to viscoelastic rupture in different chemical environments
  2. Measure the amount of permanent set in different chemical environments

Progress – Material Testing

Test Fixture Development – Strain Aging



Reproduced from: L. H. Sperling, Introduction to Physical Polymer Science, 4th ed., Wiley, New Jersey, 2006

- Importance of Viscoelastic Rupture
  - Can occur during creep or stress relaxation
    - stress relaxation case shown
  - Series of tests at high strains can be used to predict time to failure at low strains
- Importance of Equilibrium Set
  - Permanent set can be used to estimate the dominant mode of degradation
    - environmentally induced cross-linking or chain scission

Progress – Material Testing

Test Fixture Development – CSR Testing

DOE Hydrogen Program

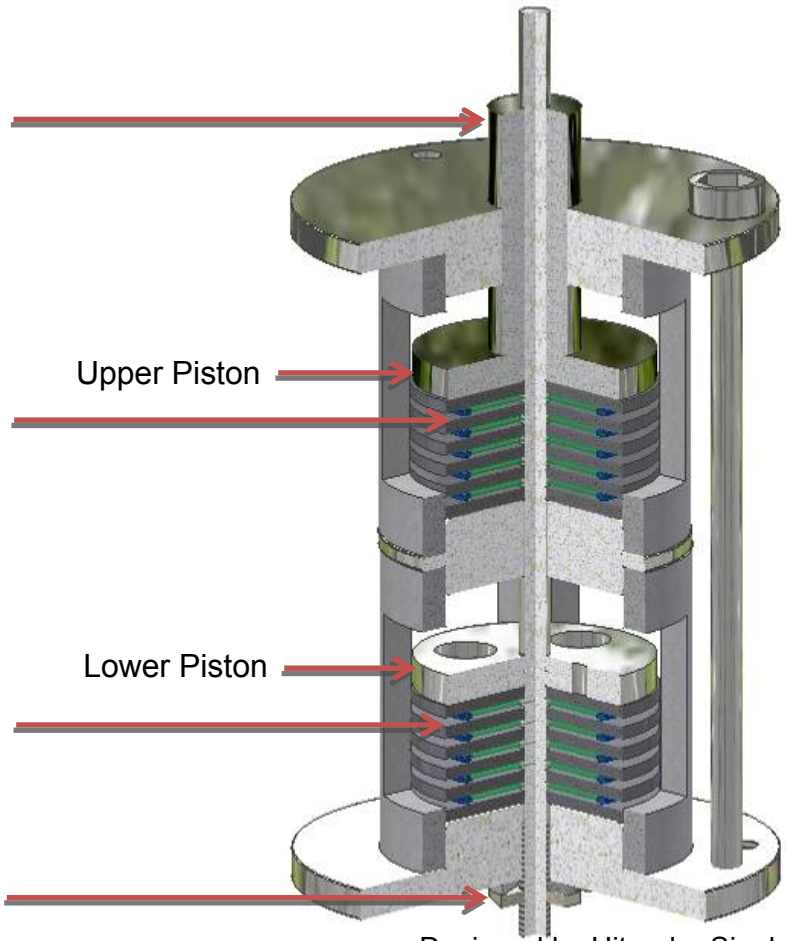
Key Design Features

Concentric Shafts
- For independent compression of upper and lower seal stacks

Upper Seal Stack
- Uncompressed while aging
- For measurement of instantaneous compressive properties at the test temperature

Lower Seal Stack
- Maintained at constant compression during aging
- For CSR measurement at the test temperature

Locking Nut and Spacer
- To set and maintain constant compression on the Lower Seal Stack



Designed by Hitendra Singh
Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

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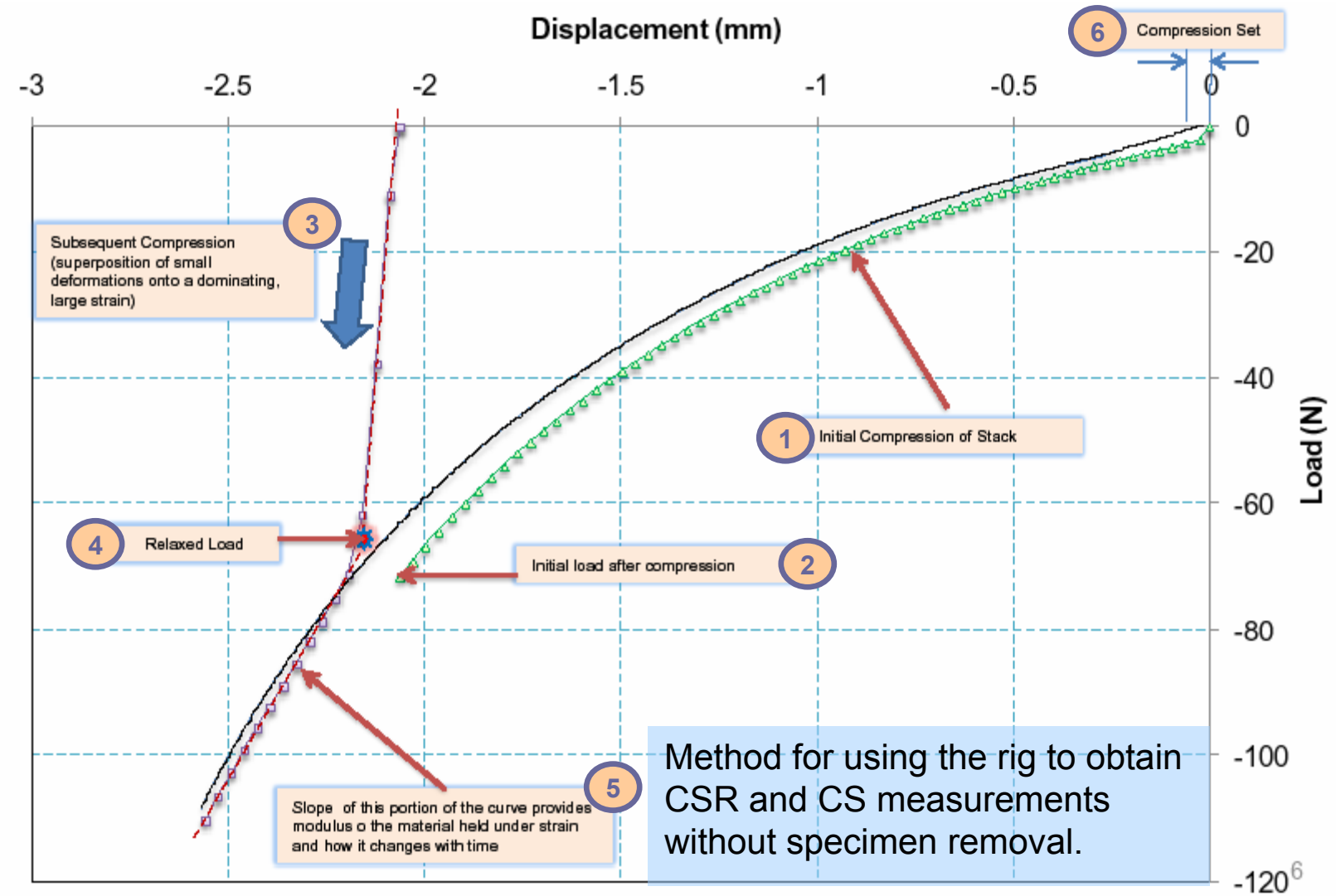
Progress – CSR Testing

Method for using the CSR rig

DOE Hydrogen Program



(Note: data shown here is to be viewed as illustrative of the method only. No representations are being made regarding actual performance)

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Progress – Material Testing

Test Fixture Development – Leak Testing

DOE Hydrogen Program

- Simple and robust design
  - Valve for filling
  - Pressure sensor
    - Stock pressure sensor modified for greater sensitivity
    - Used to monitor pressure decay
    - Removed from environment by a small ID tube
  - Stubs to mount in aging fixture
  - Shims to set the compression
- Purpose
  - To correlate failure to decay in sealing force as measured through CSR testing
- Design allows for:
  - Continuous pressurization and measurements
  - Pressure as acceleration factor
    - High initial pressures to accelerate the observance of failure

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Progress – Material Testing

Compatibility - Migration and Deposition of Organics

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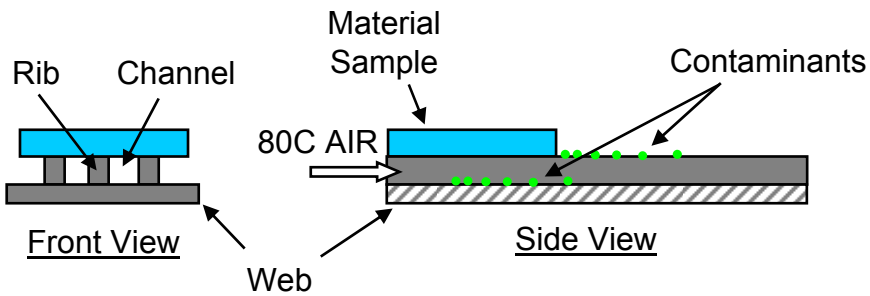
- Uses a ribbed plate
- Tracks two migration paths for organic contaminants
  1. Gas or vapor-phase migration
  2. Surface migration



Results for FCS0	
Parameter	**Pass/Fail**
Vapor Phase Deposition	PASS
Surface Migration	PASS

- Results for FCS0
  - No vapor deposition observed
  - No surface migration observed past the region of contact

Progress – Material Testing

Compatibility Testing – Inorganic Leachate

DOE Hydrogen Program

- Soak test
  - Resulting solution tested for inorganic contaminants with potential for affecting fuel cell performance or durability
- Results for FCS0
  - Overall, one of the cleanest materials tested by UTC Power
  - Passed key test parameters

Results for FCS0	
Parameter	**Pass/Fail**
Total metallic and ionic leachate	PASS
pH	PASS
Conductivity	PASS
Surface Tension	PASS

Future Work

DOE Hydrogen Program

- Materials selection and development
  - Continue development work on FCS2
  - Down-select the best candidate for FCS2 by end of 3QGFY08
  - Finalize no-cost extension to pursue high temperature PEM fuel cell targets

- Accelerated out-of-cell testing
  - Complete the production of test fixtures
  - Begin full-scale accelerated testing of FCS1

- Seal prototype development
  - Finalize the design for the full-size cell prototype seal
  - Begin full-size molding tool production before the end of GFY08

Summary

DOE Hydrogen Program

- Goal
  - Develop a durable and low-cost PEM fuel cell seal material
- Materials selection and development
  - Material properties meet most ultimate program goals
  - FCS2 expected to meet all program goals
- Accelerated out-of-cell testing
  - Initial data from short-term aging and testing is encouraging
- Seal prototype development
  - First full-size parts expected by end of 1QGFY09