Carbon Composite Bipolar Plate for PEM Fuel Cells

T. M. Besmann, J. J. Henry, J. W. Klett, and E. Lara-Curzio
Metals and Ceramics Division
Oak Ridge National Laboratory

National Laboratory R&D Review
DOE Fuel Cells for Transportation Program
Denver, Colorado May 9-10, 2002

Objective

To develop a slurry-molded, carbon fiber material with a carbon chemical vapor infiltrated (CVI) sealed surface as a bipolar plate that would meet cost and property goals.

Property	*Specification*
Bulk Conductivity	> 100 S/cm
H_2 permeability	$<2 \times 10^{-6}$ cm^3/cm^2-sec
Corrosion rate	<16 $\mu A/cm^2$
Cost	<$10/kW

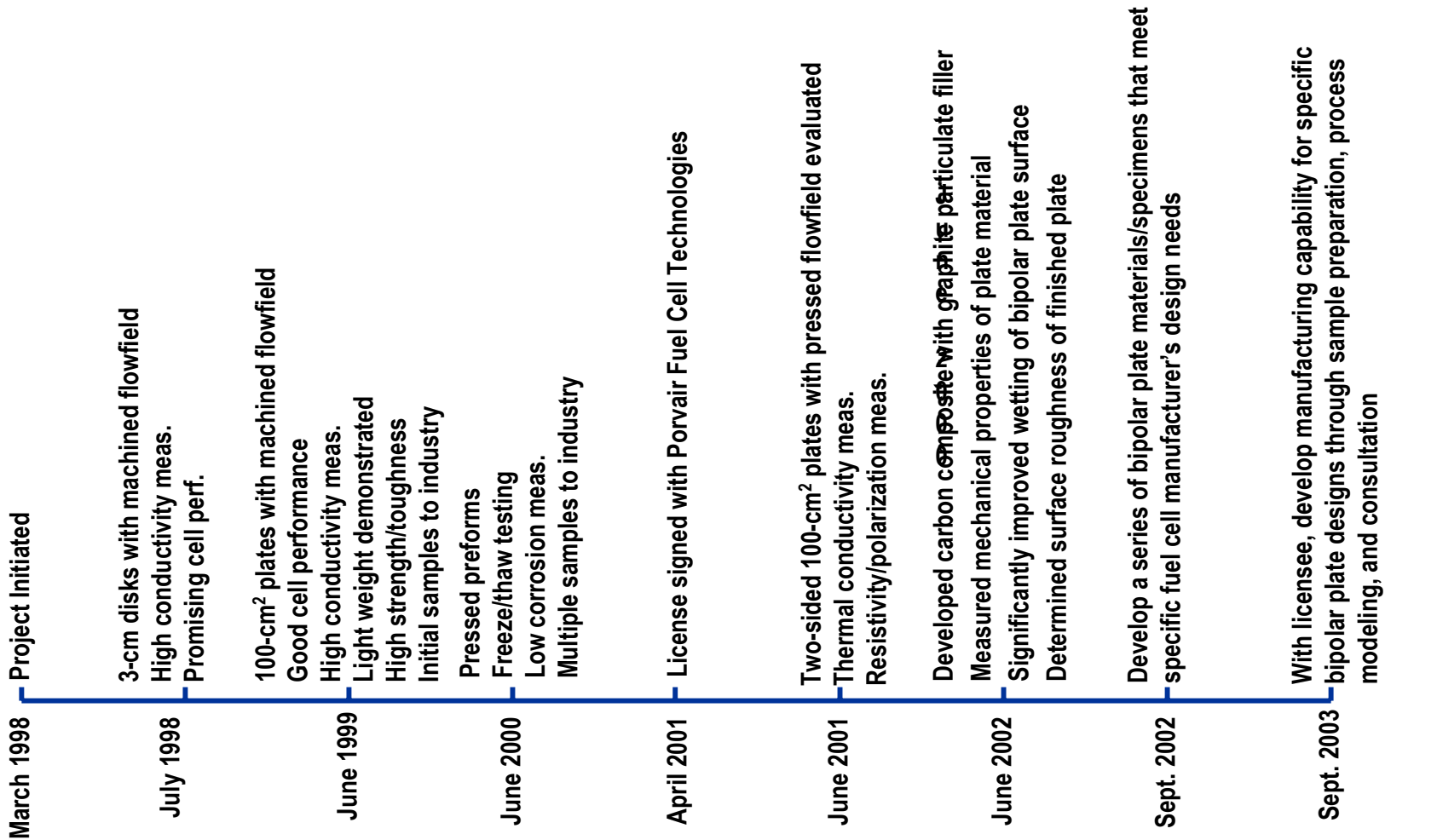
Approach

- Bipolar plate utilize carbon/carbon concept
- Preform is slurry-molded carbon fibers
  - similar to paper or felt production
  - fibers ~100 μm
  - features stamped/embossed into preform
- CVI with carbon
  - seals and makes hermetic high-density surfaces
  - provides continuous, high-conductivity material

Advantages of Approach

- Preforms prepared from slurry-molded carbon fibers
  - net shape process/press-in features
  - process can be continuous (i.e., papermaking)
  - low-cost materials
- Appropriate surfaces sealed via deposition of carbon
  - high-conductivity (graphitic) carbon coating all surfaces
  - infiltration makes component fully integral
  - potential for continuous or semi-batch processing
- Negligible impurities/poisons with no corrosion
- Strength and toughness of carbon/carbon
- Very light weight (about half that of other approaches)
- Potential for integral diffuser/catalyst support, therefore, lower ohmic losses

Timeline of Project Accomplishments

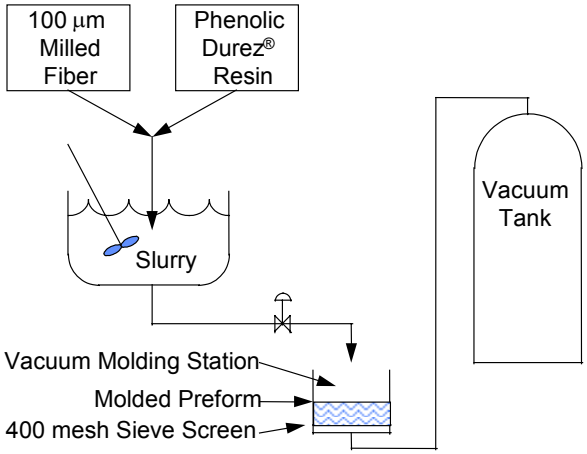


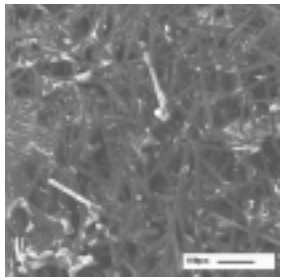
Current Accomplishments

- Developed carbon composite material with graphite particulate filler to control pore size and speed surface sealing
- Further characterized and measured mechanical properties of carbon composite plate material
- Significantly improved wetting of bipolar plate surface
- Determined surface roughness of finished bipolar plate components
- Supported scale-up efforts at Licensee Porvair Fuel Cell Technology
- Developing unique plate design with industrial partners

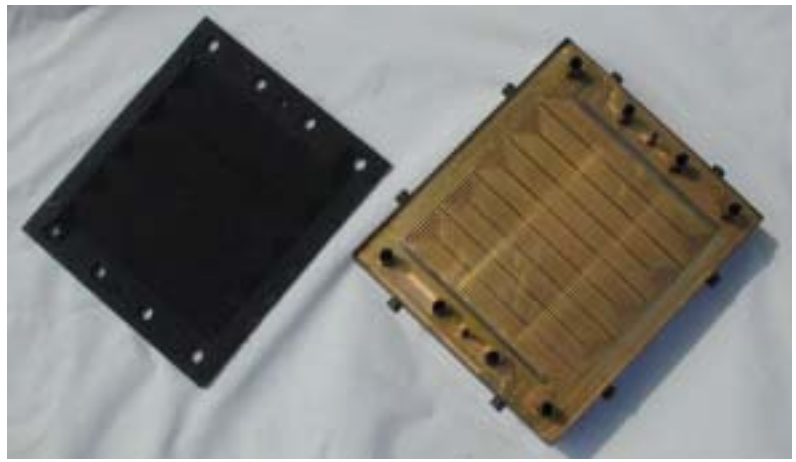
Carbon Composite Plate Fabrication

Slurry Molding of Preforms

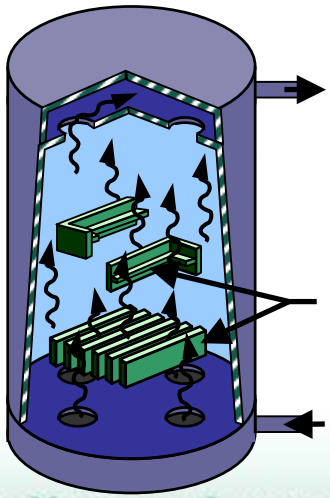




Press or Stamp Features



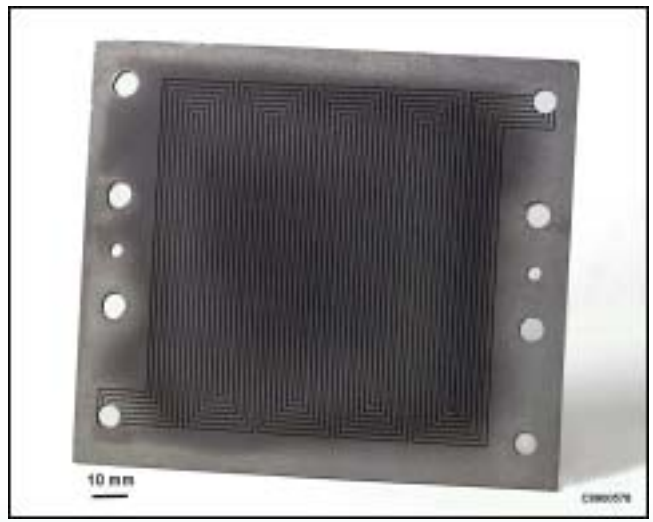
CVI Carbon



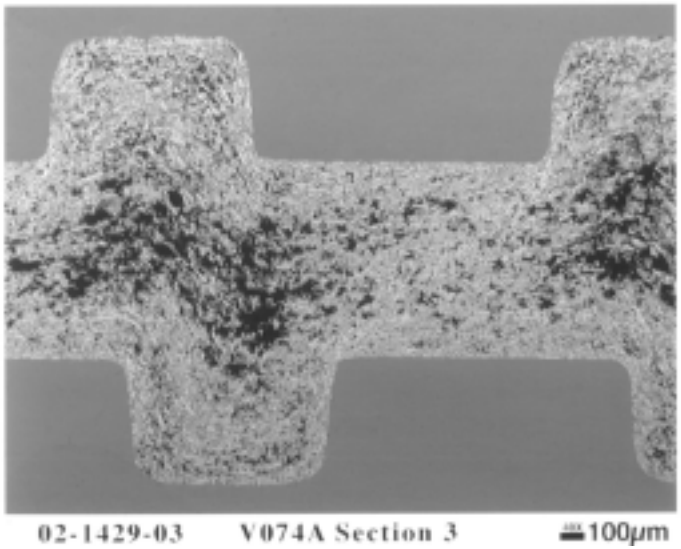
EXHAUST GASES TO VACUUM SYSTEM

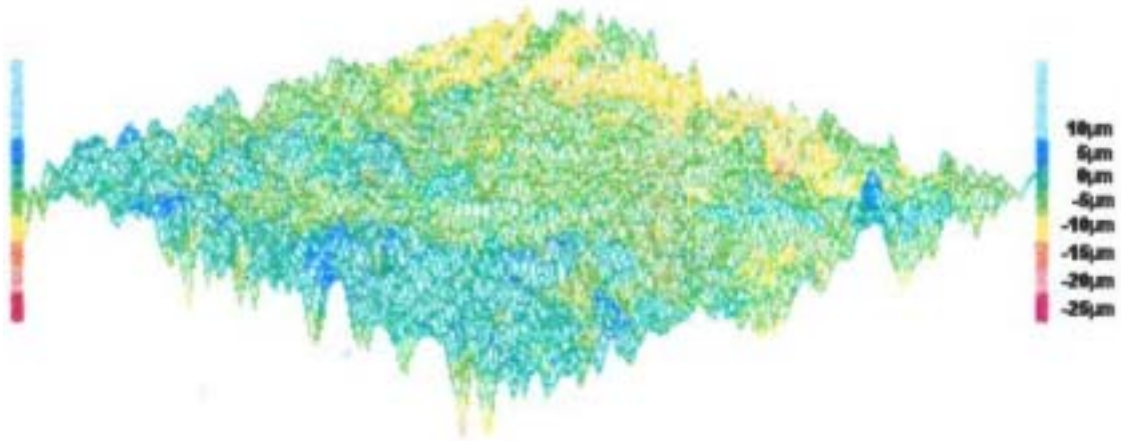
COMPONENTS BEING INFILTRATED

REACTANT GASES IN

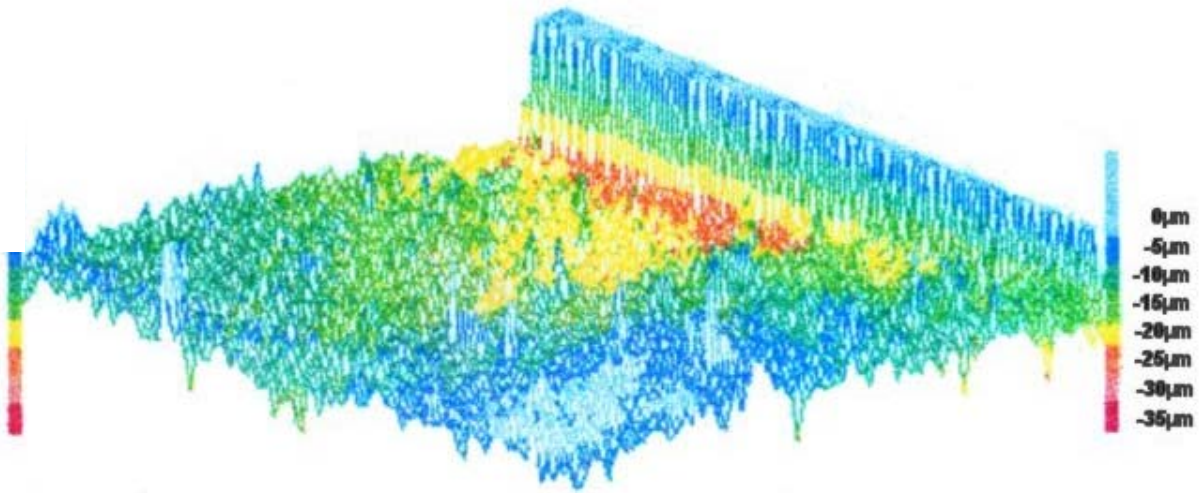


Bipolar Plate RMS Surface Roughness is 2.5-4.5 µm





Flat area around plate edge



Bottom of channel and side-wall

Air Oxidation Improves Wetting

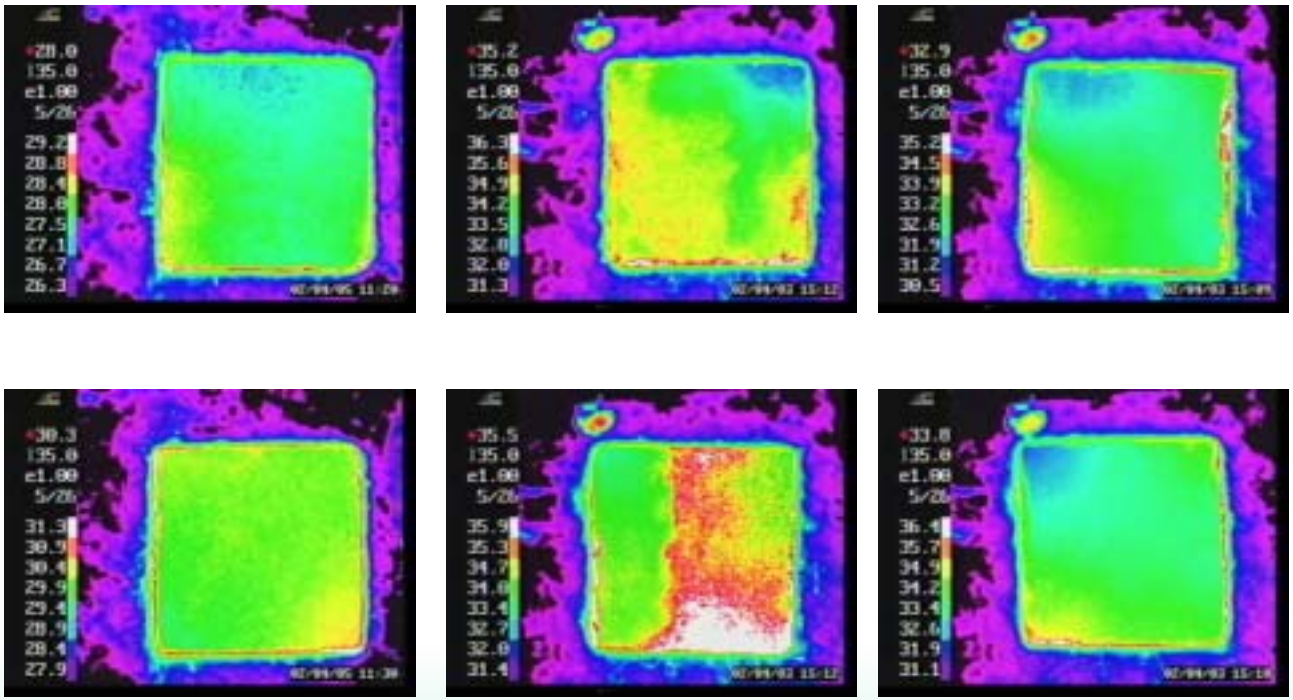
- As-processed carbon composite is insufficiently wet by water and therefore water management in a PEM fuel cell is problematic
- Brief air oxidation (1000°C for 30 sec) significantly changes surface properties to improve wetting
- Wetting characteristics would be expected to persist in PEM cell environment
- Air oxidation step can be performed during cool-down from CVI, and therefore require no additional processing

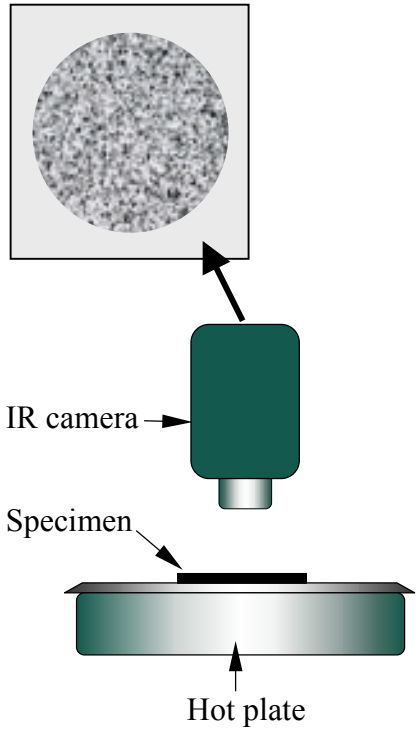
Before Oxidation

After Oxidation

Infra-Red Imaging Identified Few Defects

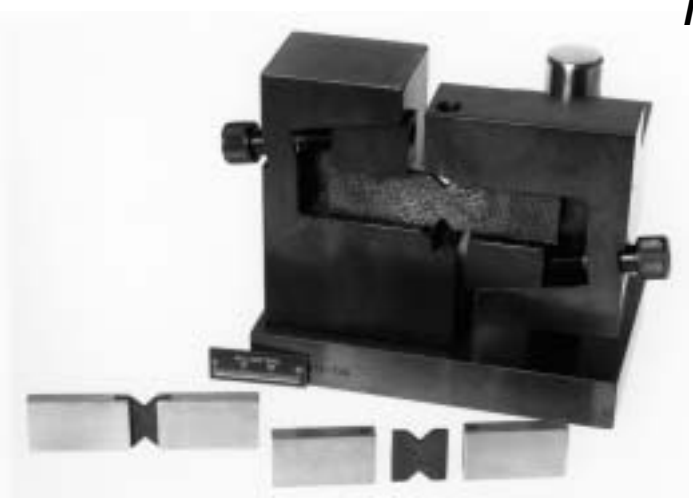
The density of the plates were fairly uniform, as illustrated by the images. Areas of delamination were evident along the edges. The surface topography of some plates also contributed to differences in the IR signal.



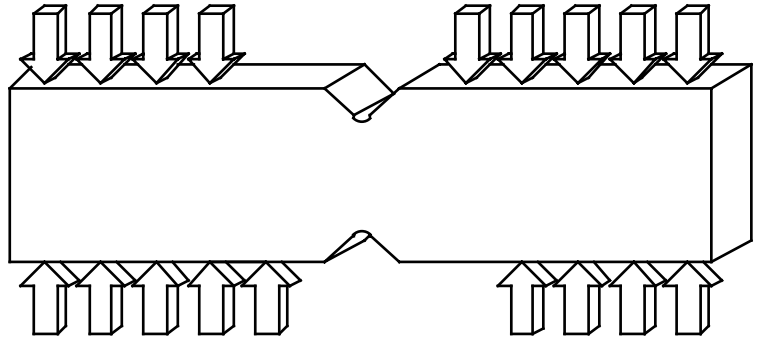


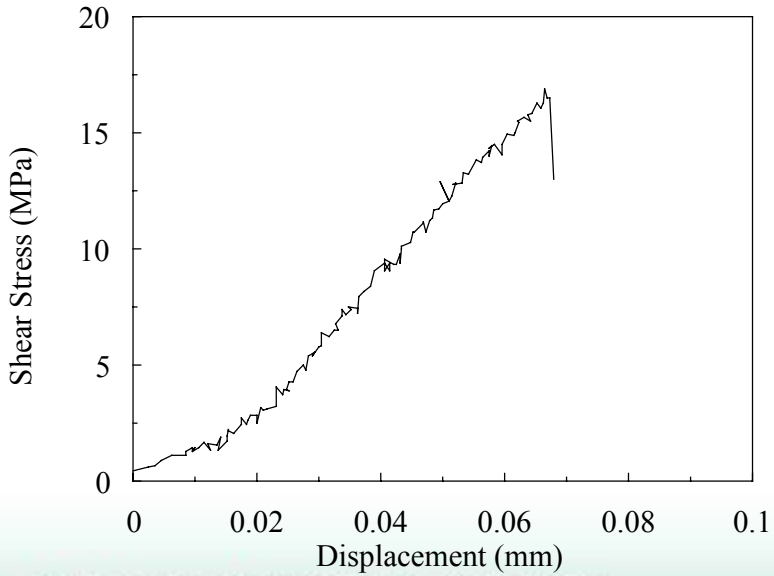
5 cm x 5 cm x 2 mm

Shear Stress is a Good Indicator of Torsion Behavior



Iosipescu Fixture: Asymmetric bending for determination of in-plane shear strength



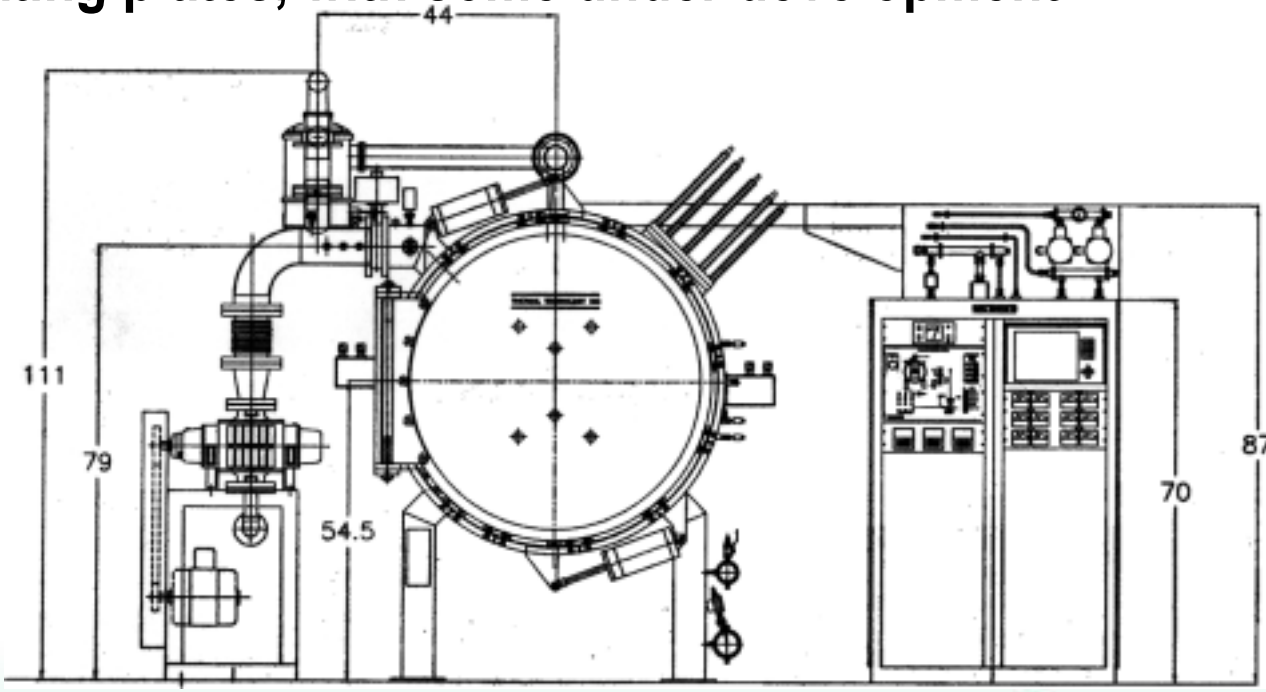


Selected Measurements Show Significant Strength

Sample (% Filler)	Strength Meas.
PMP10R (0%)	25.9 ± 9.9 MPa
PMP10T (0%)	19.3 MPa (1 test)
PMP09K (15%)	24.4 ± 11.8 MPa
PMP11E (30%)	43.3 ± 2.7 MPa
PMP11G (30%)	17.1 ± 1.1 MPa
PMP11H (30%)	18.7 ± 4.7 MPa

Industrial Interactions

- Supporting licensee Porvair Fuel Cell Technology in scaling up technology
- Porvair has been awarded a $6.1 M DOE program for scaling and applying the carbon composite bipolar plate technology
- Other companies evaluating plates, with some under development
  - International Fuel Cells
  - Ballard
  - Plug Power



Porvair Scale-Up CVI Furnace

Continuing Development and Technology Transfer of Carbon Composite Bipolar Plates

- **Milestone FY 02 - Develop a series of bipolar plate materials/specimens that meet specific fuel cell manufacturer's design needs (Sept. 2002)**
  - **Investigating effect of filler on mechanical properties and infiltration**
  - **Determining surface characteristics**
  - **Measuring torsion properties**
- **Develop alternate techniques for improving wetting of carbon composite and characterize behavior**
  - **Exploring durability of oxidized surface**
  - **Evaluating other wetting improvement techniques**
- **Milestone FY 03 - With licensee, develop manufacturing capability for specific bipolar plate designs through sample preparation, process modeling, and consultation. (Sept. 2003)**

Some Advisory Panel Comments From Last Year and Responses

- "Stack assembly is subject to pressure, heat stresses and torsion. Address these issues next"
  - Mechanical property measurements were made to better characterize the material
- "An attempt to seal together bipolar plates should be made"
  - Being addressed by licensee
- "Need to work closely with fuel cell manufacturer"
  - Significant interactions with licensee Porvair are continuing, as well as those with fuel cell companies interacting with Porvair