
porvair
fuel cell technology

SCALE-UP OF CARBON/CARBON BIPOLAR PLATES

DE-FC36-02AL67627

2005 DOE Hydrogen Fuel Cells & Infrastructure Technologies Program Review

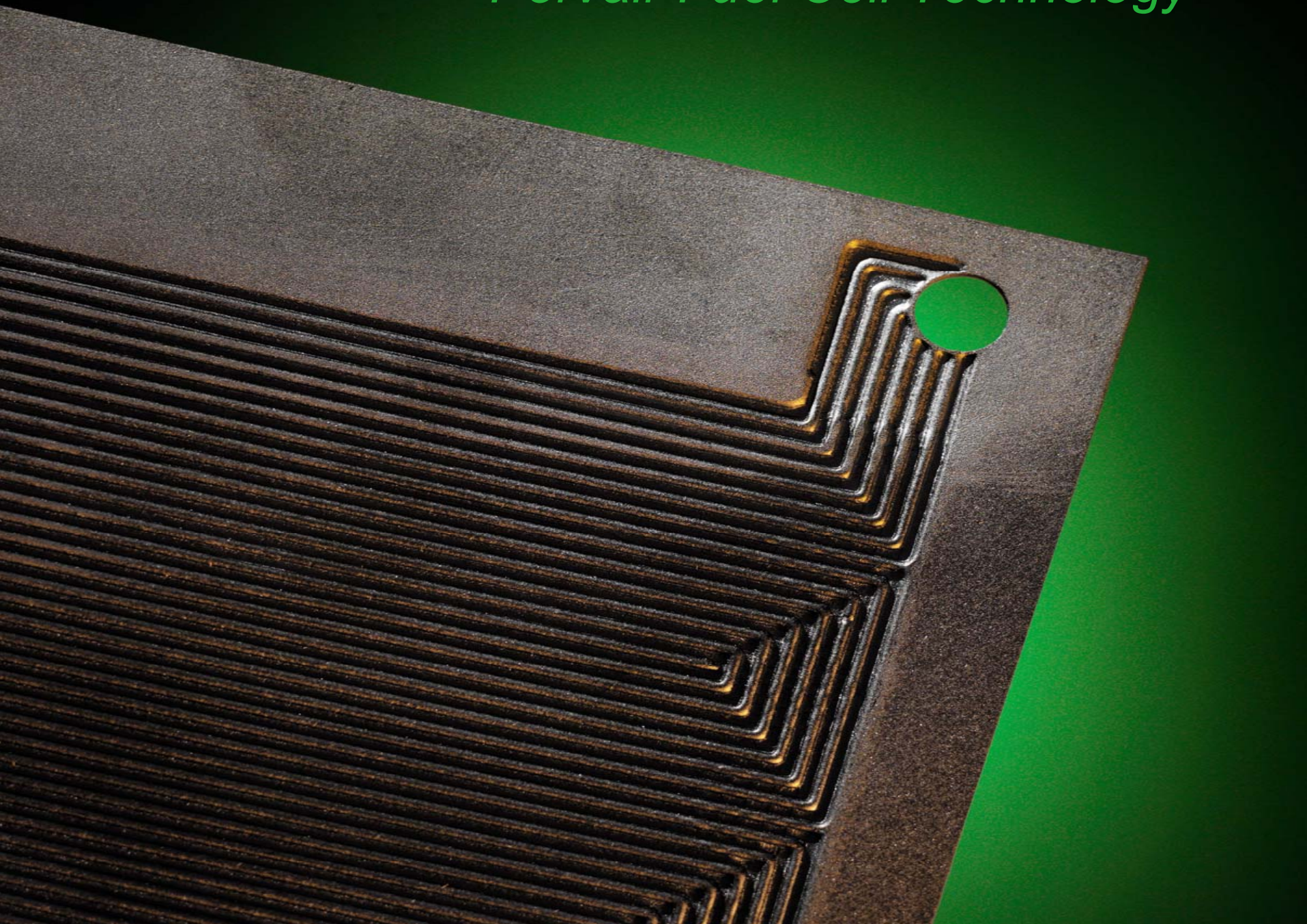
David P. Haack
Porvair Fuel Cell Technology

May 25, 2005

This presentation does not contain any confidential or proprietary information.

Project ID# FC22

Porvair Fuel Cell Technology



PROGRAM OVERVIEW

Scale-up of Carbon/Carbon Bipolar Plates

porvair fuel cell technology

Timeline

- **Project Start Date: May 2002**
- **Project End Date: May 2005**
- **Percent Complete: 100%**

Partner

UTC Fuel Cells

Budget

50% Porvair Cost Share	FY2004	Program Total
Porvair Contribution	$831,600	$3,338,539
DOE Contribution	$831,600	$3,057,000
Total	$1,663,200	$6,395,539

porvair
fuel cell technology

DOE TECHNICAL BARRIERS AND TARGETS

Scale-up of Carbon/Carbon Bipolar Plates

Bipolar Plate Technical Barriers, from HFCIT Program Multi-Year Program Plan

Technical Barrier	Units	Status 2004	Target 2010	Target 2015
Component Cost	$/kW	10*	$6	$4
Component Weight	kg/kW	0.36	<1	<1
Hydrogen Permeability	cc/cm^2/sec (x10^-6)	<2	<2	<2
Conductivity	S/cm	>600	>100	>100
Resisivity	ohm/cm^2	<0.02	<0.01	<0.01
Flexural Strength	MPa	>34	>4 (crush)	>4 (crush)
Flexibility	%	1.5-3.5	3-5	3-5

* As published in HFCIT Program

porvair
fuel cell technology

PROJECT OBJECTIVES 2004

Scale-up of Carbon/Carbon Bipolar Plates

- **Develop Improved Manufacturing Process to Enable Net Shape Molding and Low-Cost Product Manufacture**
- **Manufacture 10 kW Fuel Cell Sealed Plate Demonstration Stack**
- **Demonstrate Fuel Cell Performance in Stack Built with Molded Plates**
- **Develop Cost Model for High Volume Production**

TECHNICAL APPROACH

Scale-up of Carbon/Carbon Bipolar Plates

- **Develop Highly Uniform and Repeatable Manufacturing Process**
  - Materials
  - Process Investigation
  - Quality documentation and statistical evaluation
- **Manufacture 10 kW Fuel Cell Sealed Plate Demonstration Stack**
  - Materials development
  - Bonding and sealing development
  - Manufacture product

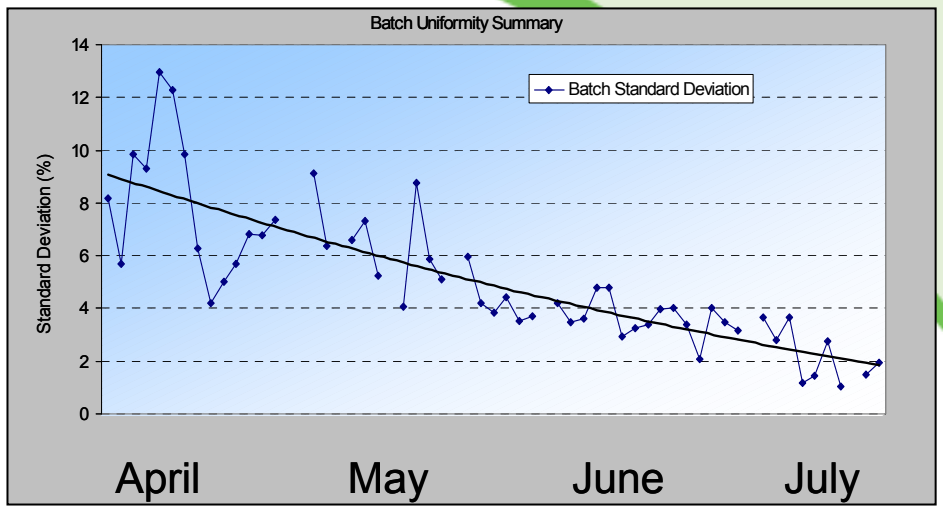
TECHNICAL ACCOMPLISHMENTS

Scale-up of Carbon/Carbon Bipolar Plates

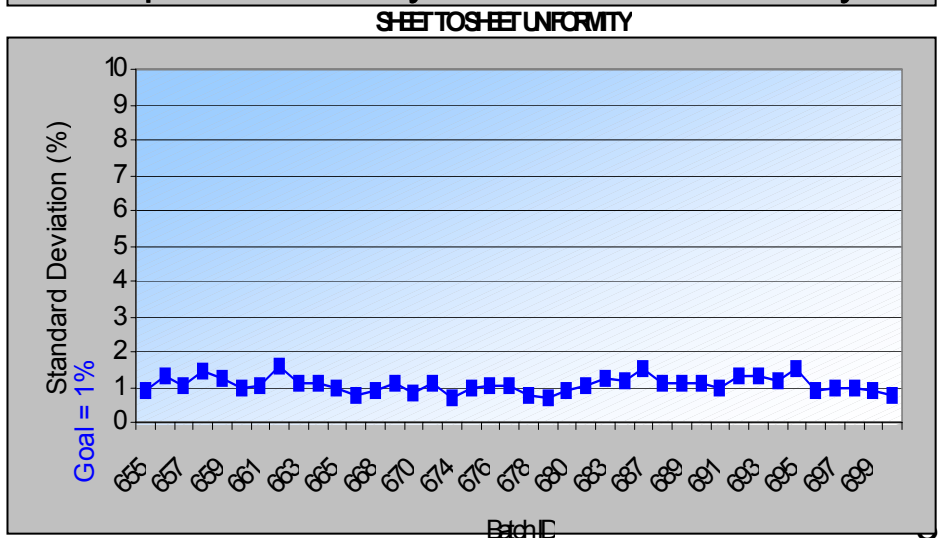
porvair fuel cell technology

- **Development of Highly Controlled Manufacturing Process**
  - **Steady improvement shown over time as process improvements incorporated**
  - **Improvements were in both processing details and material design**

Mid 2004 Capability



Late 2004 Capability

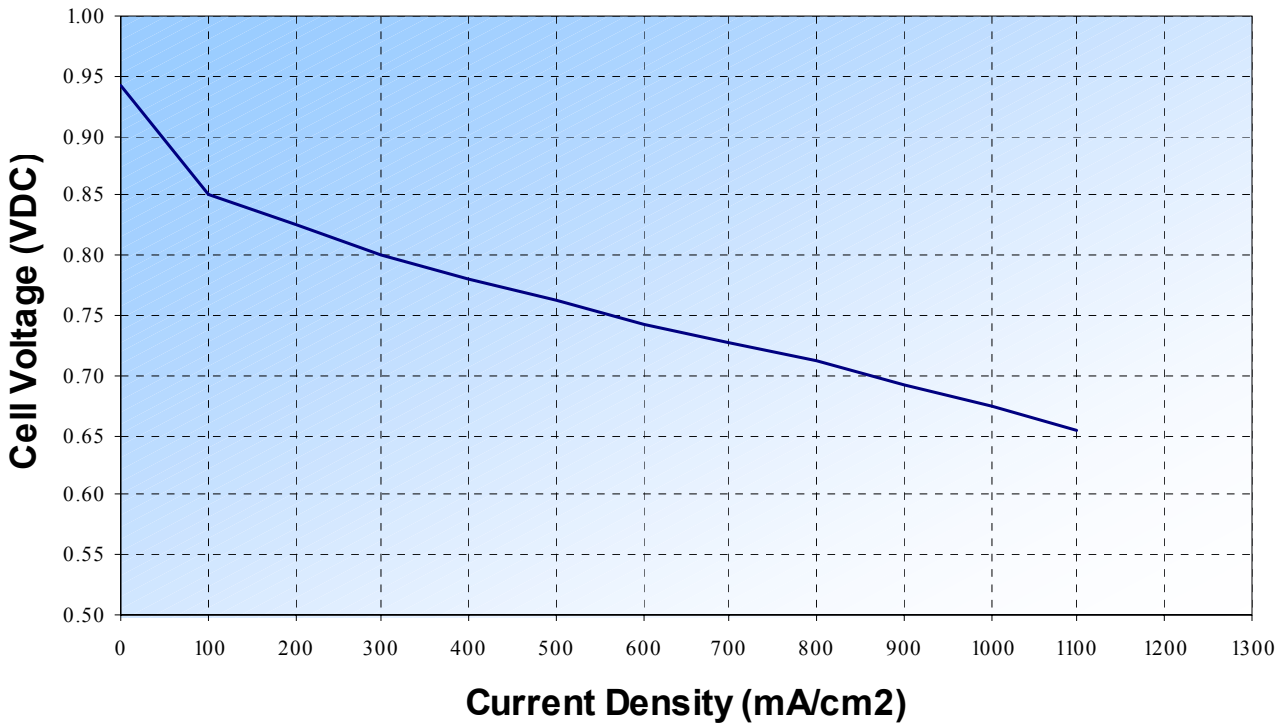


TECHNICAL ACCOMPLISHMENTS

Scale-up of Carbon/Carbon Bipolar Plates

porvair fuel cell technology

- **Fuel Cell Performance in 20-cell Stack**
  - **Performance as good or better than machined graphite**

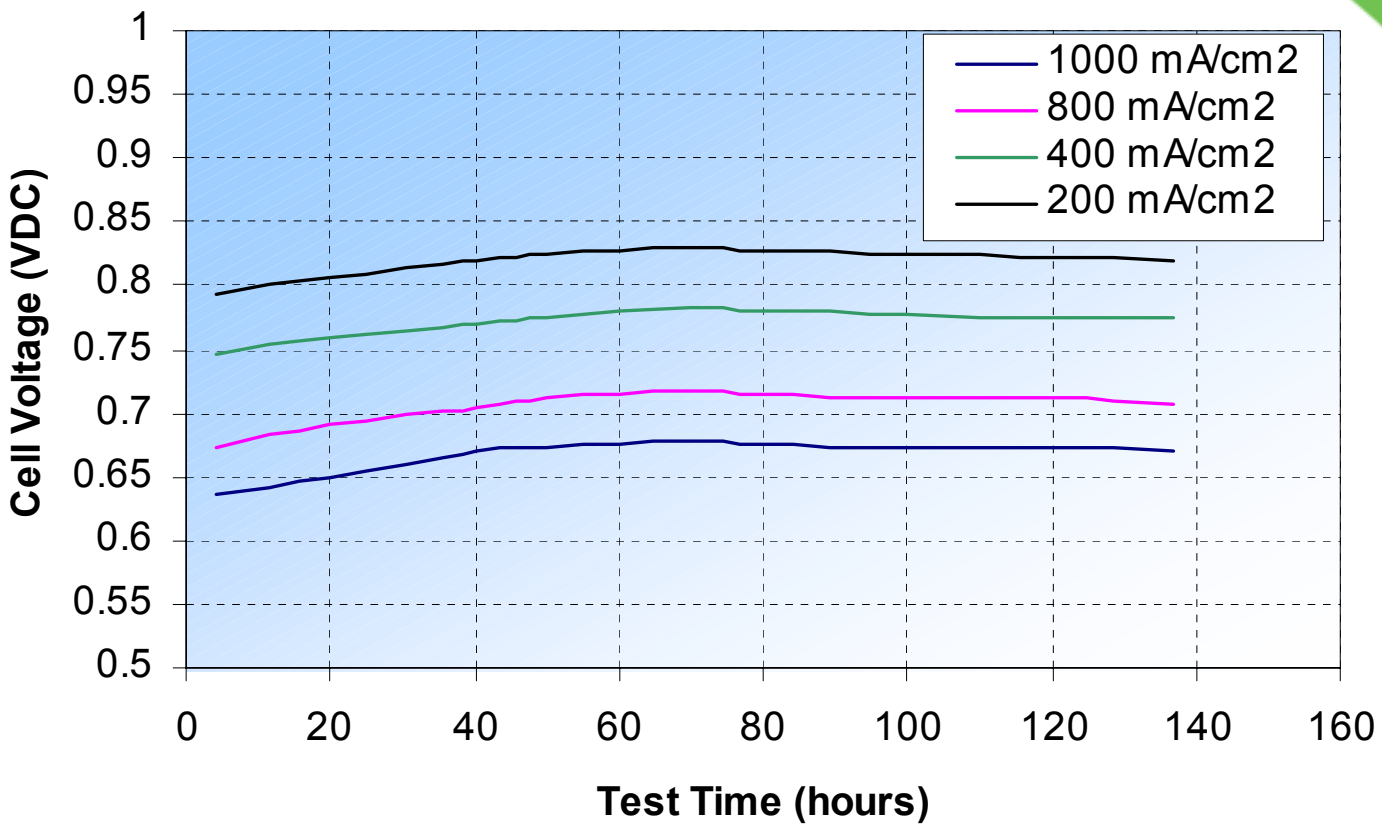


TECHNICAL ACCOMPLISHMENTS

Scale-up of Carbon/Carbon Bipolar Plates

porvair fuel cell technology

- **Fuel Cell Performance in 20-cell Stack**
  - **Good stability**



TECHNICAL ACCOMPLISHMENTS

Scale-up of Carbon/Carbon Bipolar Plates

porvair fuel cell technology

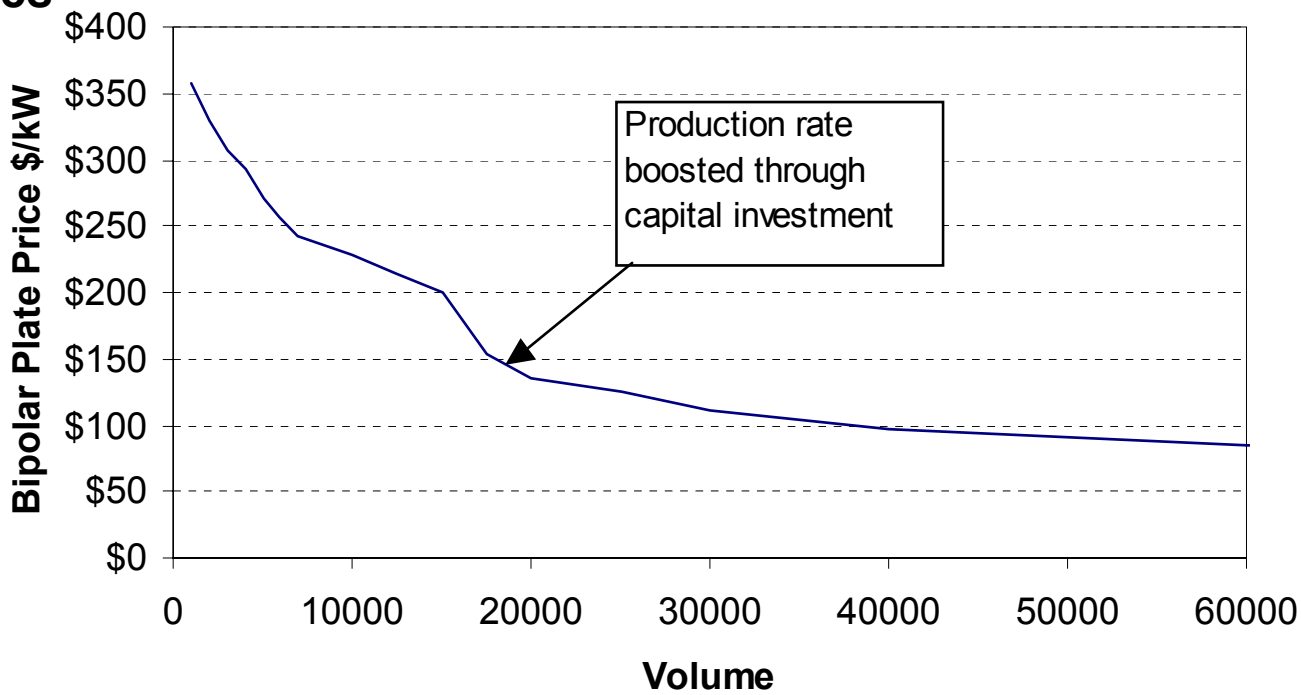
- **Product Cost Evaluation – near-term (to 250,000 plate pairs per year**
  - **Assumptions**
    - **Continued process improvement and development activities required to reduce processing times without increasing required manufacturing labor or materials costs**
    - **Four phases of manufacture**
      - **Small volumes to 60,000 plate pairs per year, labor-intensive processing**
      - **Intermediate volumes 60,000 to 250,000 plate pairs per year, moderate technology advances required to increase production rate**
      - **Large volumes 250,000 to ~1 million plate pairs per year. Significant automation and investment required in single line manufacture**
      - **Mass production to 1 billion plate pairs per year. Multiple plants and manufacturing lines, complete process automation for ultra-low manufacturing costs.**

TECHNICAL ACCOMPLISHMENTS

Scale-up of Carbon/Carbon Bipolar Plates

porvair fuel cell technology

- **Low-Volume Manufacturing to 60,000 bipolar plate pairs per year**
  - **Labor costs dominate product cost**
  - **Production time limited by molding step**
  - **Cost sensitive to production rate filling production shifts fully**
  - **Low capital investment (<$500,000) required to increase production rates**

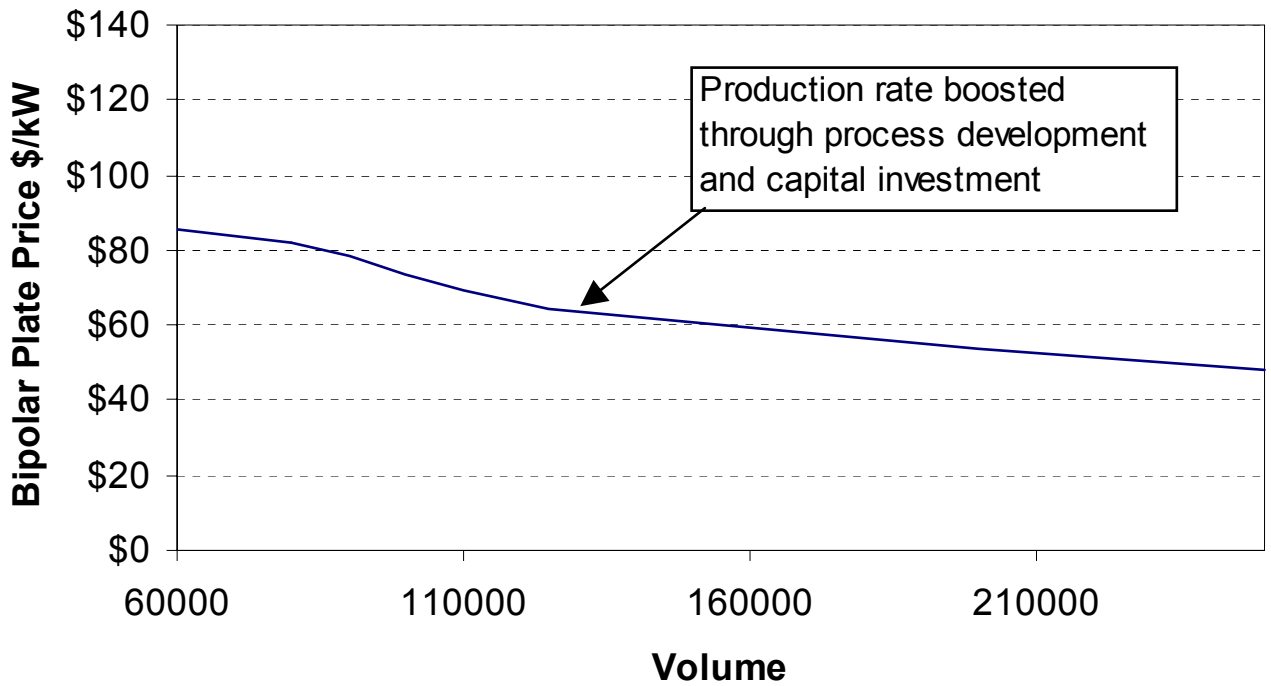


TECHNICAL ACCOMPLISHMENTS

Scale-up of Carbon/Carbon Bipolar Plates

porvair fuel cell technology

- **Intermediate-Volume Manufacturing to 250,000 bipolar plate pairs per year**
  - **Labor costs significant portion of product cost**
  - **Moderate technology development required to eliminate molding time bottleneck**
  - **Single line production rate of 1 monopolar plate every 42 seconds**
  - **Moderate capital investment (<$3 million) required to enable production rates**

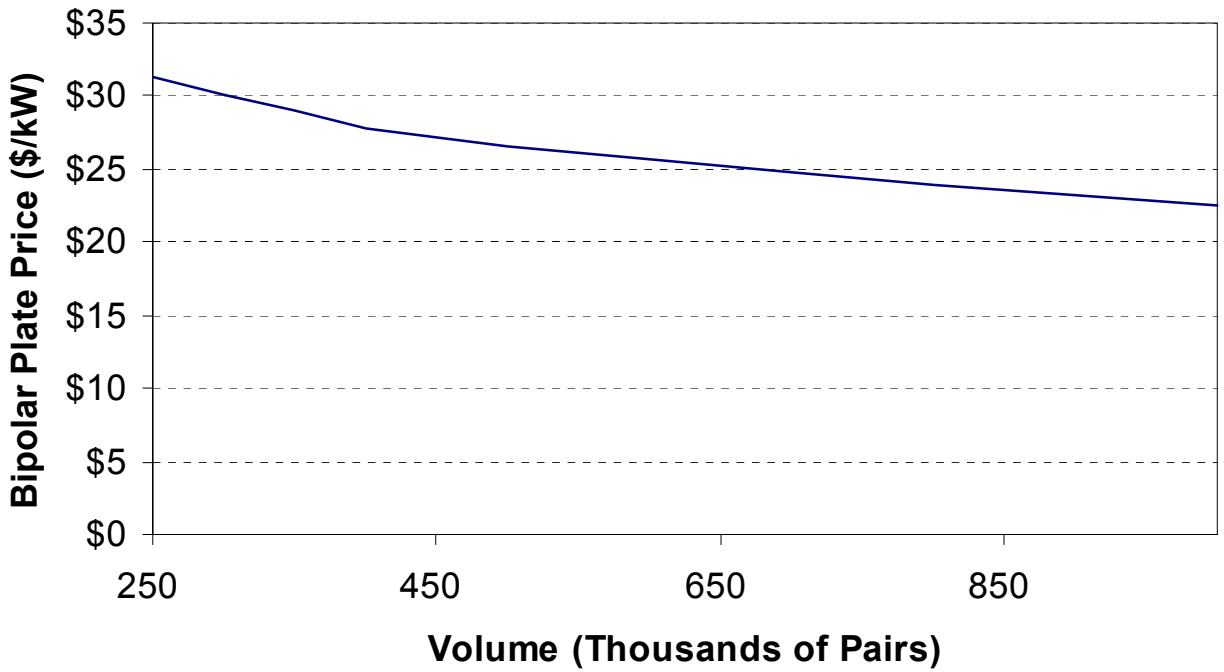


TECHNICAL ACCOMPLISHMENTS

Scale-up of Carbon/Carbon Bipolar Plates

porvair fuel cell technology

- **High-Volume Manufacturing to 1,000,000 bipolar plate pairs per year**
  - **Materials costs greater than labor costs**
  - **Significant investment required in technology development to enable high rate of product manufacture**
  - **High capital investment (>$15 million) in equipment and infrastructure per line**

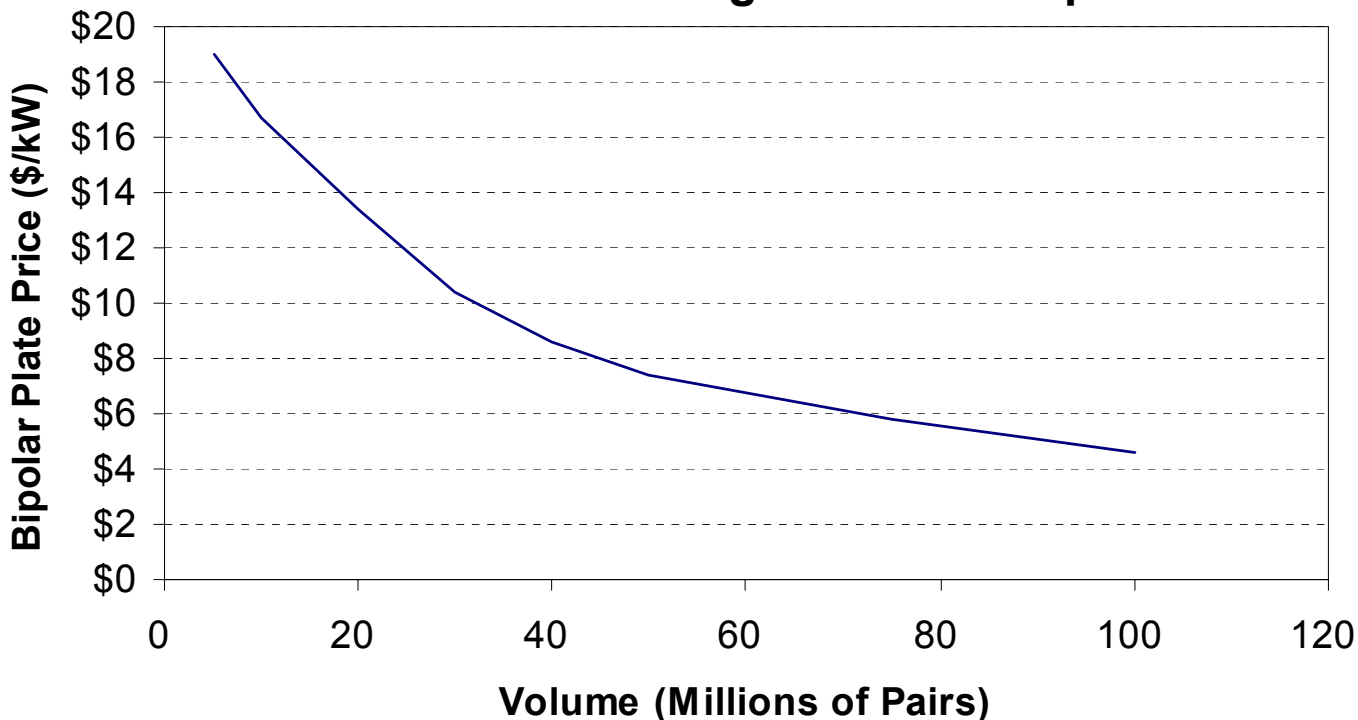


TECHNICAL ACCOMPLISHMENTS

Scale-up of Carbon/Carbon Bipolar Plates

porvair fuel cell technology

- **Mass Production Manufacturing to 50,000,000 bipolar plate pairs per year per production line**
  - **Materials costs dominate product cost**
  - **Significant investment required for processing development and production line engineering**
  - **Significant capital investment in equipment and infrastructure**
  - **At 1,000,000 fuel cell cars per year quantities, would require construction of 16 manufacturing lines in multiple facilities.**



REVIEWER QUESTIONS

Scale-up of Carbon/Carbon Bipolar Plates

- **Automation of process going forward may not be straight-forward, additional work should be done on process scale-up**
  - Acknowledged, but the significant investment needed to develop this capability requires the assurance of sufficient plate sales to coincide with the investment
- **Emphasis should be place on product improvement rather than process scale-up**
  - Product improvement activities have been given significant attention. Key development details are proprietary
- **Larger stacks (>10 kW) should be demonstrated**
  - Large stacks (to 60 kW) have been demonstrated with our product. Additional trials are being negotiated.

FUTURE PLANS

Scale-up of Carbon/Carbon Bipolar Plates

- **Concluded Original DOE Project (end date April 30, 2005)**
  - Met key project goals
  - Delivery of demonstration stack following completion of testing
  - Cost model shows potential to meet DOE cost targets
- **Development Work Continuing at Porvair**
  - Continuing product and process improvement activities
  - Working on product qualification with a number of fuel cell customers
  - Investigating high production rate process steps to enable technology to move to next level in cost-reduction

PUBLICATIONS AND PRESENTATIONS

Scale-up of Carbon/Carbon Bipolar Plates

- **Poster Paper at 2004 Fuel Cell Seminar (San Antonio**
  - **CARBON-CARBON BIPOLAR PLATE MANUFACTURE: ACHIEVING COST GOALS IN MULTI-STEP MANUFACTURING**

HYDROGEN SAFETY

Scale-up of Carbon/Carbon Bipolar Plates

- **The process for manufacturing bipolar plates does not use or generate hydrogen gas, so we do not have specific hydrogen safety issues.**
- **However, in our other businesses, we use hydrogen gas on a regular basis in the material processing of porous metals. To handle the use of this gas we have adopted the NFPA requirements for the type of systems that we use. We have regular safety audits and equipment inspections to ensure continued safe use of the hydrogen gas.**