Hydrogen Generation From Electrolysis

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Hydrogen Technology Group

Proton Energy Systems

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Proton®
A Distributed Energy
Systems Company

PDP41

Overview

Timeline

- Start Date March 2004
- End Date September 2007
- 10% Complete

Barriers

- Q. Cost
- R. System Efficiency
- S. Grid Electricity Emissions
- T. Renewable Integration

Budget

- Total Project $3.8 million
  - 50% Cost Share
- $245K Funding in FY04
- Limited FY05 Funding

Partners

- Air Products and Chemicals Inc.
- University of California, Irvine

Objectives

Develop an Efficient, Low-cost, Electrolysis Based Generation System Capable of Delivering 5000 psi Hydrogen to a Vehicle

- Determine Pathway to Optimum Electrolysis Based H2 Fueling
- Improve Subsystem / Component Performance, Cost, Durability
- Emphasis on Efficiency, Low-cost, and High Pressure
- Incorporate Renewable Wind Generated Power

Approach

Establish Fueling System Requirements

- Determine Daily Production / Storage Requirements for System
- Determine Applicable Codes and Standards, Present and Future
- Verify Range of Vehicle Fueling Requirements Including Pressure

Perform Conceptual Systems Design and Analyses

- Generate System Cost Vs. Performance Analysis Model
- Develop Conceptual System Design
- Perform Design Trades for Subsystems and Components

Perform Development Test on Key Subsystems / Components

- Prototype and Test to Substantiate Analytically Predicted Performance
- Development Tests of Low Cost Materials and Assembly Techniques

Accomplishments / System Analysis

Completed System Model Structure

- Output Directly Maps to the RD&D Technical Targets
- Compare System Benefits of New Concepts for Subsystems
- Two Discrete Station Sizes, 2 Kg/day and 100 Kg/day
- Basis of Cost Is 100 Units Produced Annually

Completed First Pass of Subsystem Models

- Basic Features Incorporated, Ready for Integration

Accomplishments / Cell Stack Cost Reduction

Completed Milestone On Schedule

Four Cost Reduction / Efficiency Opportunities Examined

- Efficiency Gains Through High Temperature Operation
- Optimization of Catalyst Loading for Performance and Cost
- Evaluation of Lower Cost / Higher Performance Catalyst
- Evaluation of Lower Cost / Higher Performance Ion Exchange Membranes

Changes Evaluated Have Potential of

- 7% Gain in Cell Stack Efficiency
- 30% Cost Reduction of MEA
- 8 to 10% Cost Reduction of Cell Stack

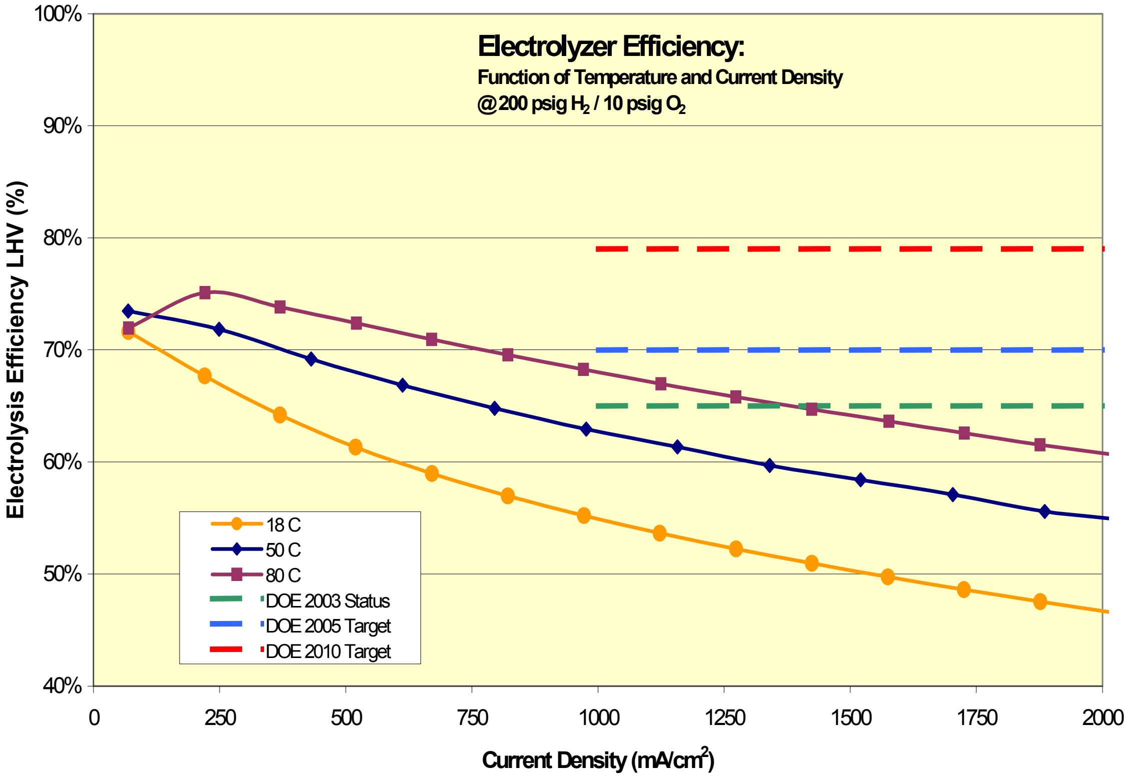
Combination of Opportunities Require Test

Accomplishments / Cell Stack Cost Reduction

Efficiency Gains Through High Temperature Operation

Demonstrated Higher Efficiency at Elevated Temperature

7% Gain in Efficiency Realized by Higher Operating Temperature



Accomplishments / Cell Stack Cost Reduction

Optimization of Catalyst Loading for Performance and Cost

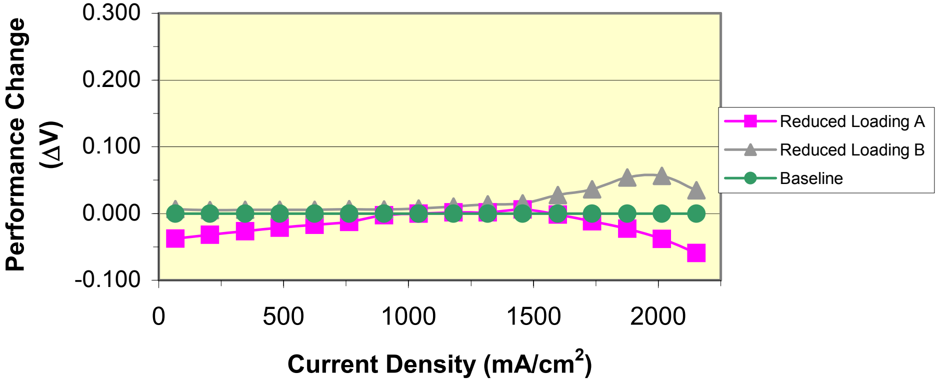
Two Reduced Catalyst Scenarios Tested

- 33% Anode, 25% Cathode
- 66% Anode, 50% Cathode

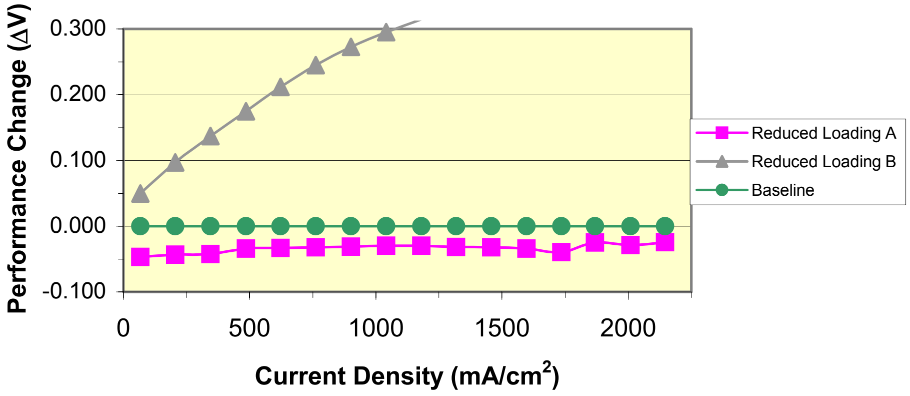
Confirmed Rational for Long Term Testing to Determine True Performance

30% Cost Reduction in Catalyst With Equal Performance

Reduced Catalyst Loading Perfomance Comparison
(24 hours, 50°C, 200 psi H_2)



Reduced Catalyst Loading Perfomance Comparison
(924 hours, 50°C, 200 psi H_2)



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Accomplishments / Cell Stack Cost Reduction

Evaluation of Lower Cost / Higher Performance Catalyst

Evaluated Five Alternate Cathode Electrode Catalysts

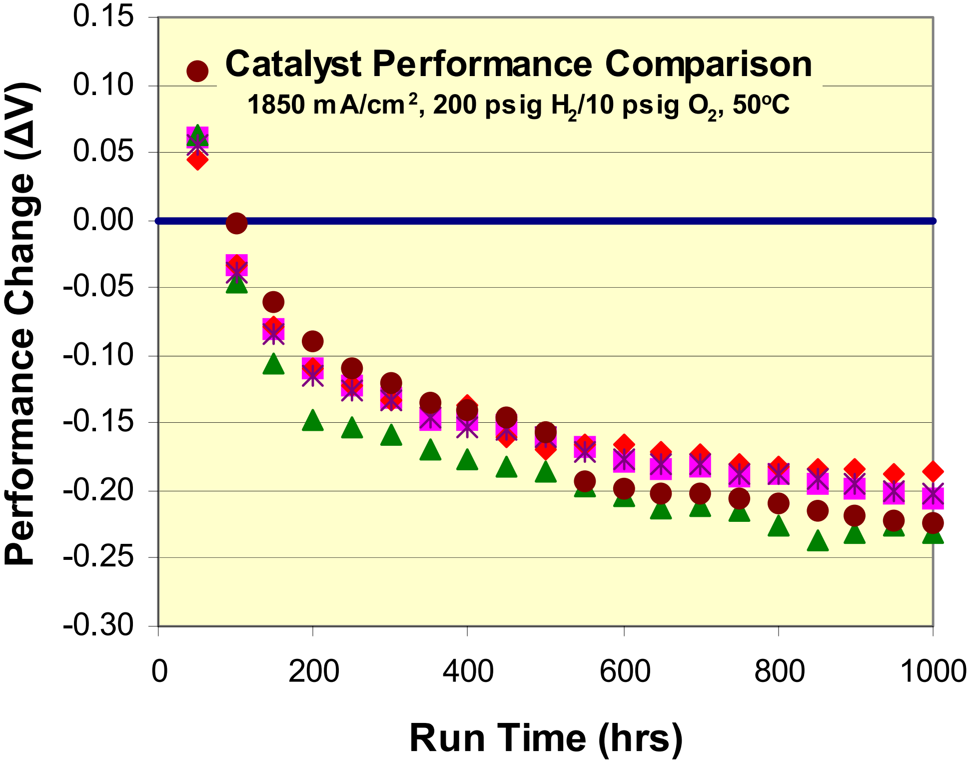
- Physical Characterization
- Electrode Fabrication
- MEA Fabrication
- Electrochemical Performance

Cell Voltage Efficiency Gains

Catalyst Cost Saving of 30%

Catalyst Synthesis Processing Ease Resulted in 50% Labor Reduction

Approximately 10 Fold Process Throughput Improvement



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Accomplishments / Cell Stack Cost Reduction

Lower Cost / Higher Performance Ion Exchange Membranes

Thinner Membranes (30%) Evaluated

- MEA Manufacturability
- Cross-MEA Resistance
- Electrochemical Performance
- Chemical Stability / Durability

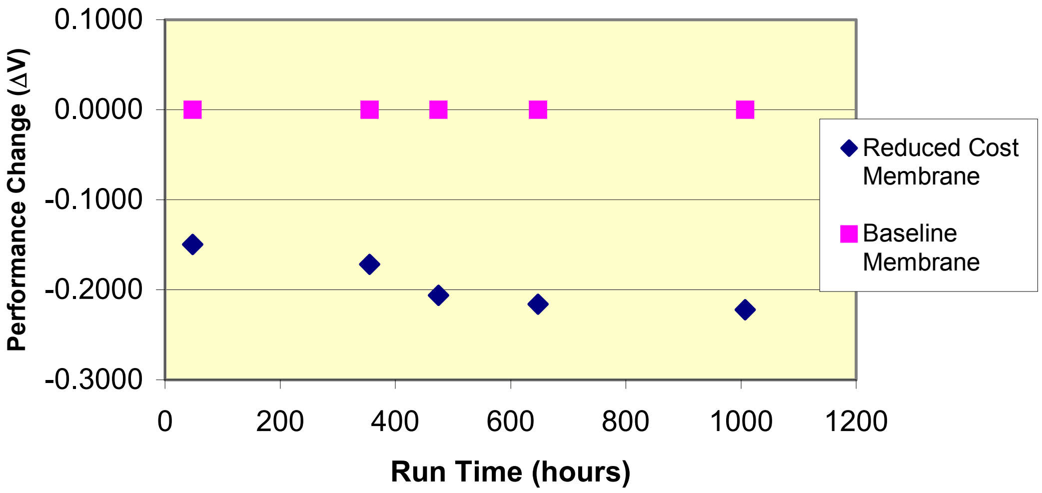
Handling of Thinner Membrane More Delicate

30% Cost Savings on Membrane Material Possible

Long Term Durability Needs to be Evaluated

MEA Performance Comparison

(1,615 mA/cm^2, 200 psi H_2, 10 psi O_2, 50°C)



Accomplishments / Electrochemical Compressor

Electrochemical Compressor Feasibility Study Completed

Tests Performed on Single Cell Electrolyzer Hardware

Ambient to 2,400 psi Compression

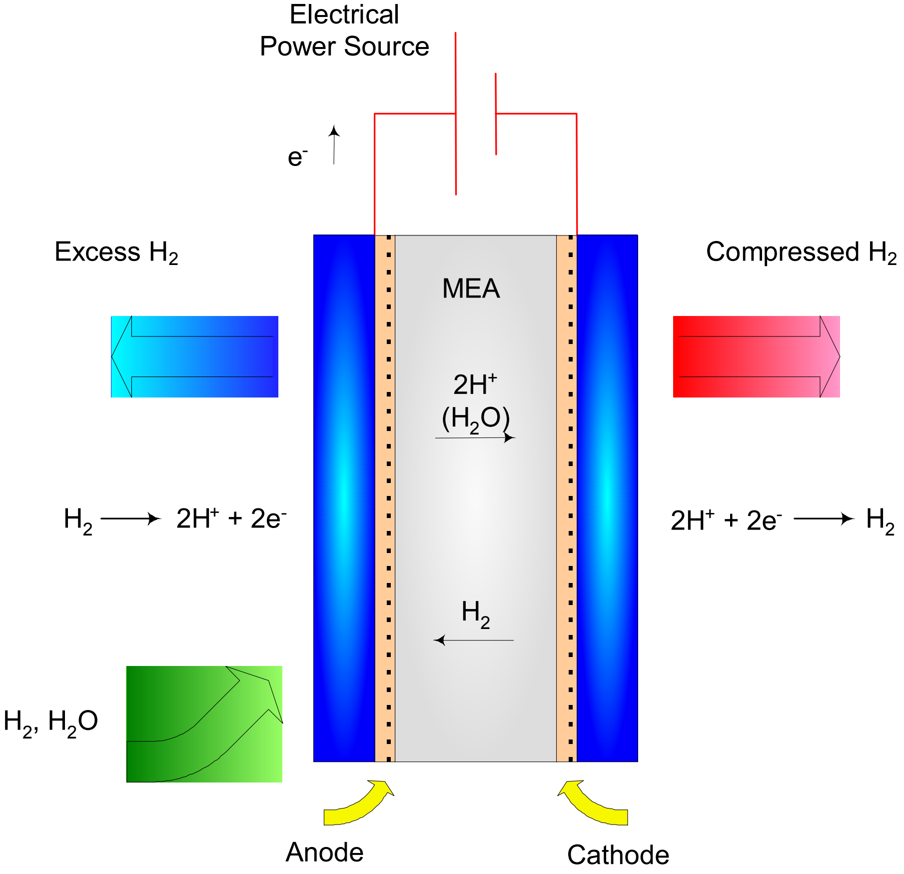
Parameters Affecting Performance Identified

Preliminary Study results Encouraging

- Throughput
- Efficiency

Merits Further Study

- Optimization of Cell Stack for Compression

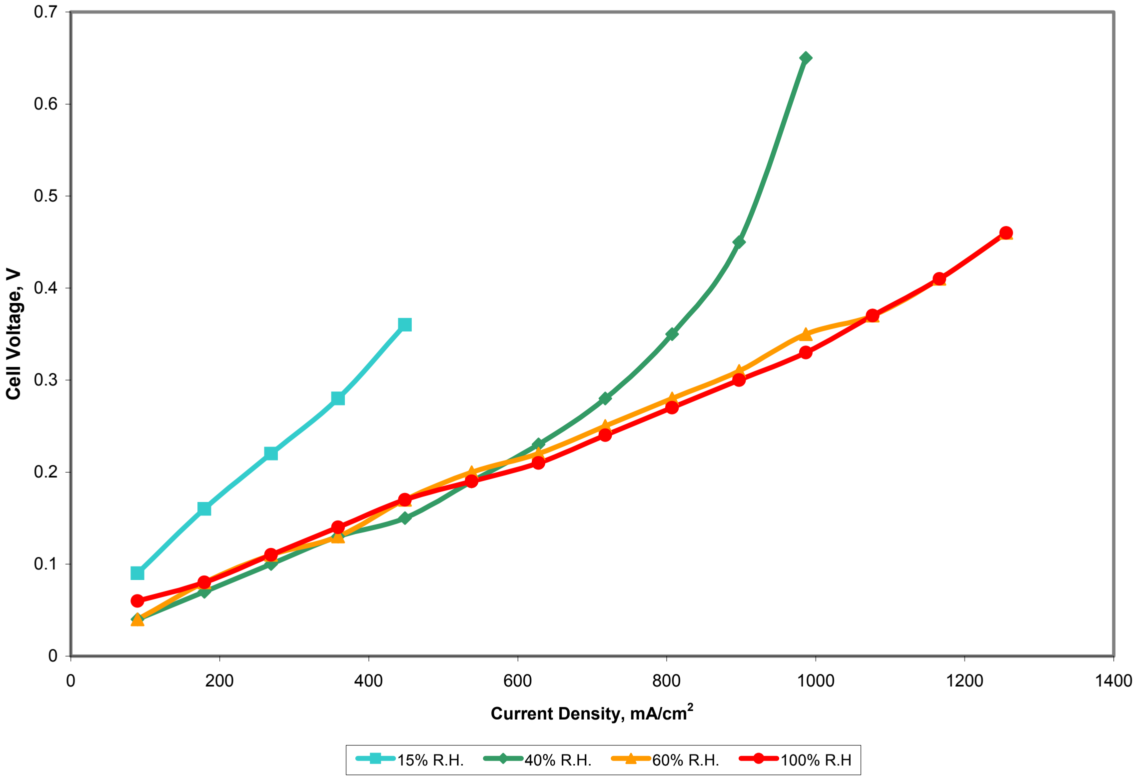


Accomplishments / Electrochemical Compressor

The Effect of Humidification on Electrochemical Compression Cell

Examined the Competing Effects of Maintaining Cell Hydration and Over Humidification

Stable Performance at 60% to 100% RH (60°C)



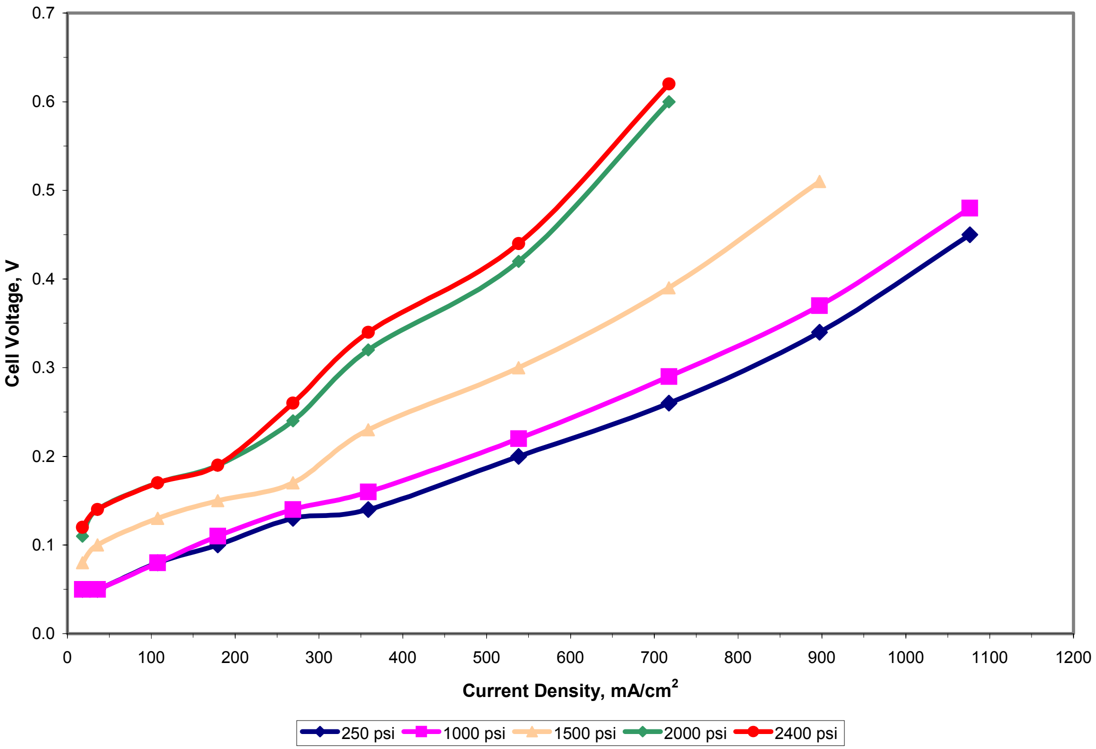
Accomplishments / Electrochemical Compressor

Polarization of the Electrochemical Compression Cell

Cell Voltage Increased With Pressure As Expected

Increment Was Proportionally Larger at Higher Current Density

- Larger Than Those Predicted by the Nernst Potentials
- Contact Resistance Increase Due to Internal Changes in Pressure



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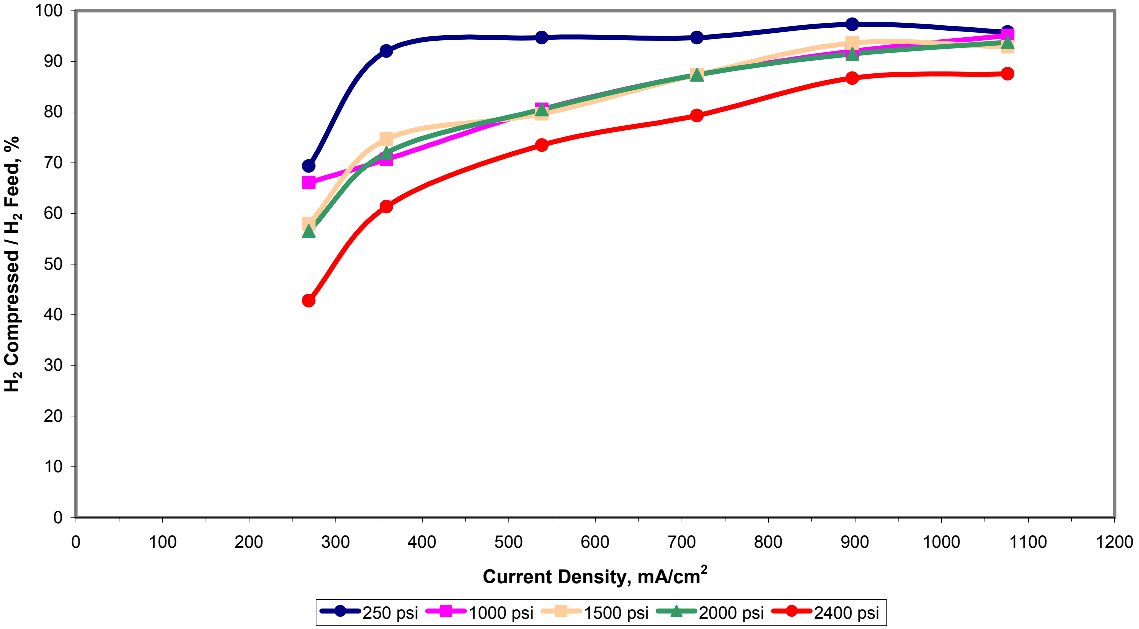
Accomplishments / Electrochemical Compressor

Compressed Hydrogen Throughput Capacity

Evaluated Compression Throughput Vs. Output Pressure From 250 psi to 2,400 psi

High Throughput Obtained With Usable Current Densities

Increased Permeation at Higher Pressures But Proportionally Less of an Overall Effect at Higher Current Densities

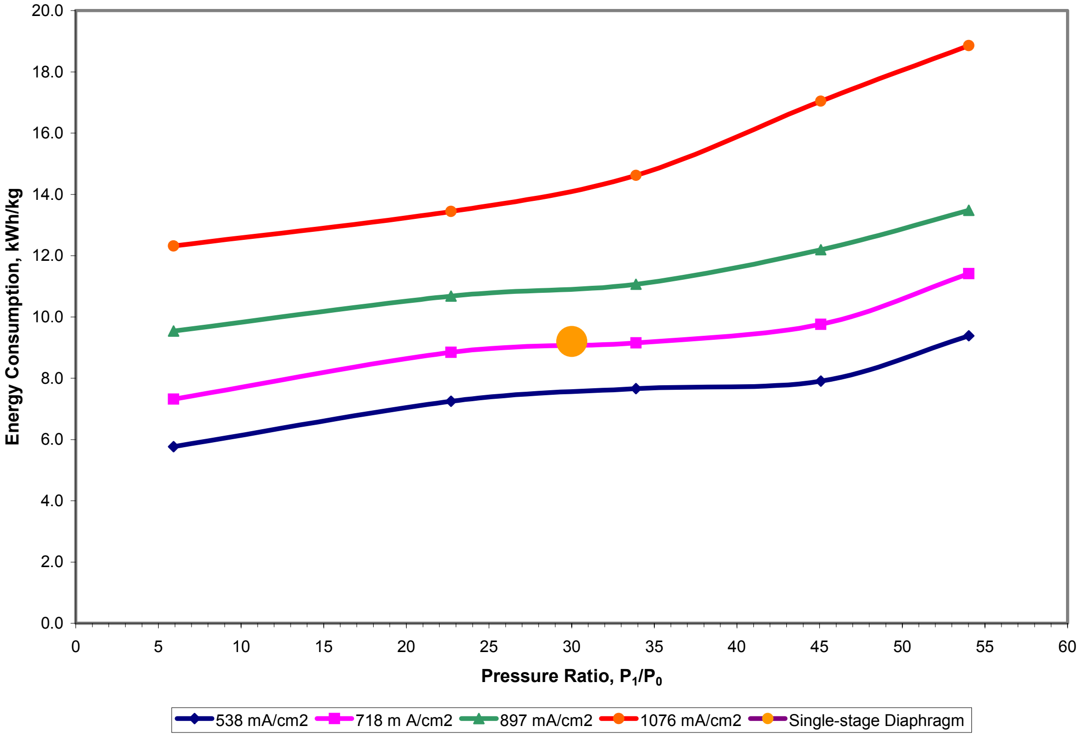


Accomplishments / Electrochemical Compressor

Energy Consumption by Hydrogen Electrochemical Compression

Energy Consumption Vs. Current Density Evaluated

At Current Density of 720 mA/cm² ECC Comparable to a Measured Single Stage Diaphragm Compressor



Reviewer’s Comments From 2004

Would Benefit From DFM Analysis of the Entire System in Addition to the Planned Volume Manufacture Analysis

Agree With Clarification

- System Analysis Captures Effect of Subsystem Technology Changes on Adjoining Subsystems and the Overall Conceptual System
- Design for Manufacturing Analysis Would Be Performed As Part of the Detailed Design of the Selected Subsystems In Combination

Future Work

Remainder of FY 2005

Station Design and Analysis

- Complete Fueling Station Analysis Model
- Complete Fueling Station Requirements
- Complete Conceptual Designs for 100 and 2 kg/day Stations

Cost Reduction Activity

- Renewable Interface / Power Conversion Study
- Dispensing System Cost Reduction Study
- Integrated System Cost Reduction Opportunity Study

FY 2006

- Scale Up of Promising Subsystems / Components
- 100kg/day System Size
- Prototype Testing

Publications and Presentations

None

Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

This phase of the project is being conducted under laboratory conditions. The most significant hydrogen hazard is that typically associated with the laboratory use of high-pressure hydrogen. The hazard is a release of hydrogen due to loss of containment. This presents two hazards of about equal severity. First is the potential for injury due to exposure to a high-pressure (2,400 psig) gas stream or debris. Second, is the potential for fire upon release of hydrogen creating a combustible atmosphere.

Hydrogen Safety

Our approach to deal with this hazard is:

The hydrogen overpressure and release hazard for the test stand is mitigated in three ways. First, the system is proof pressure tested for leaks. Second, relief valves that are appropriately sized are placed at locations where there is a potential for over pressurization. Third, is the use of impact shields around the high-pressure portions of the system under test. In addition, the area where the test stations are located is monitored for proper ventilation, flame detection, and combustible gas detection. The monitoring system is hardwired into the main power feed and shuts down all test stations if there is an event.