# Hydrogen Generation From Electrolysis


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**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

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# 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

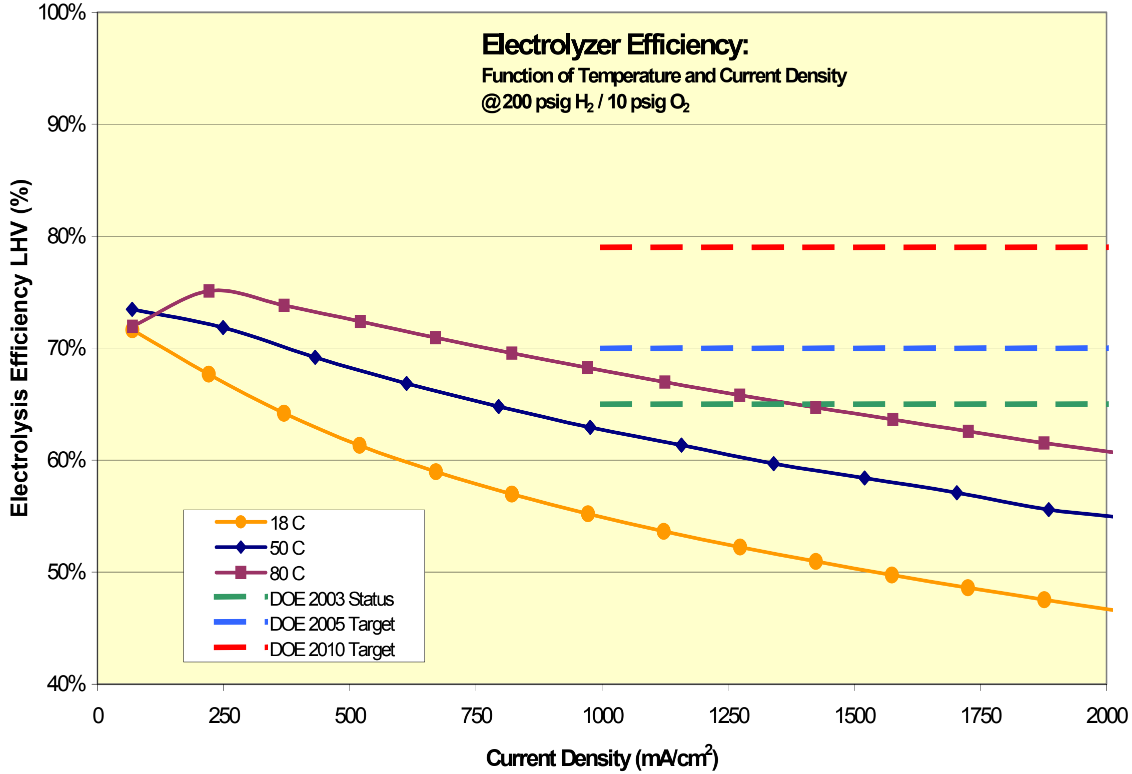
## Combination of Opportunities Require Test

# 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**

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# Accomplishments / Cell Stack Cost Reduction

## Optimization of Catalyst Loading for Performance and Cost

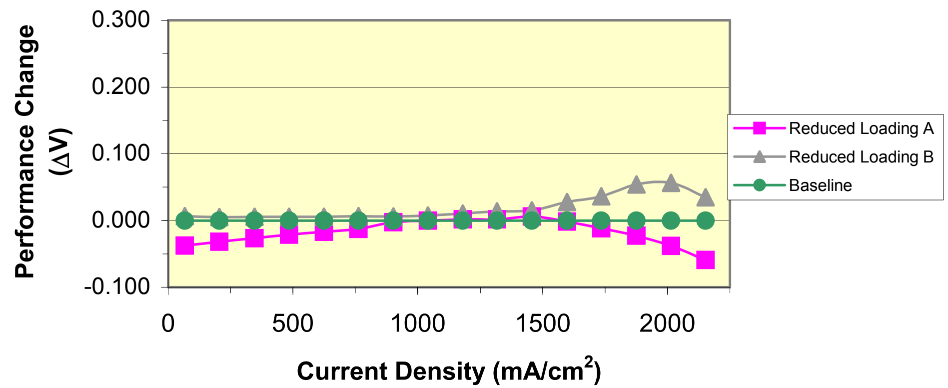
### Two Reduced Catalyst Scenarios Tested

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

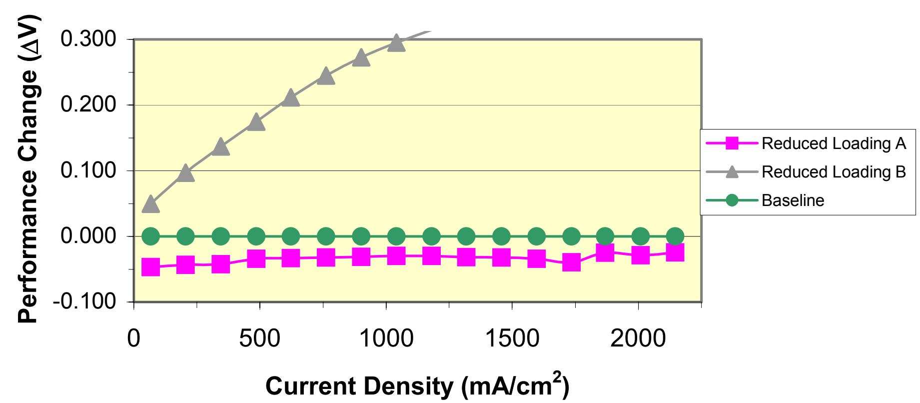
### Confirmed Rational for Long Term Testing to Determine True Performance

### 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**

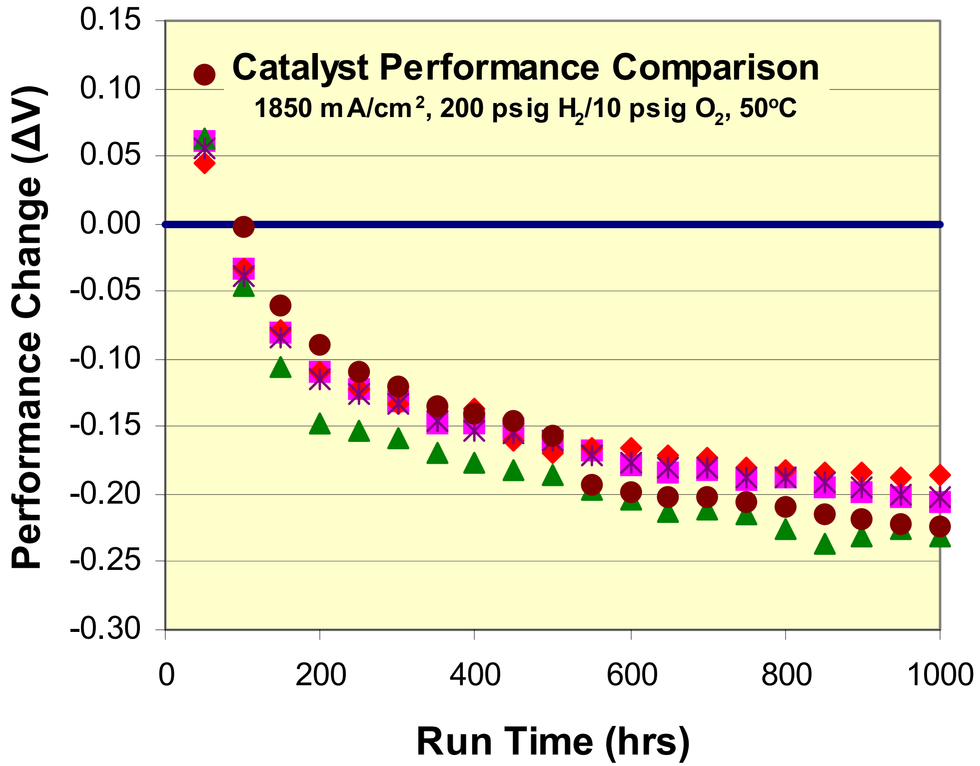
- Physical Characterization
- Electrode Fabrication
- MEA Fabrication
- Electrochemical Performance

**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

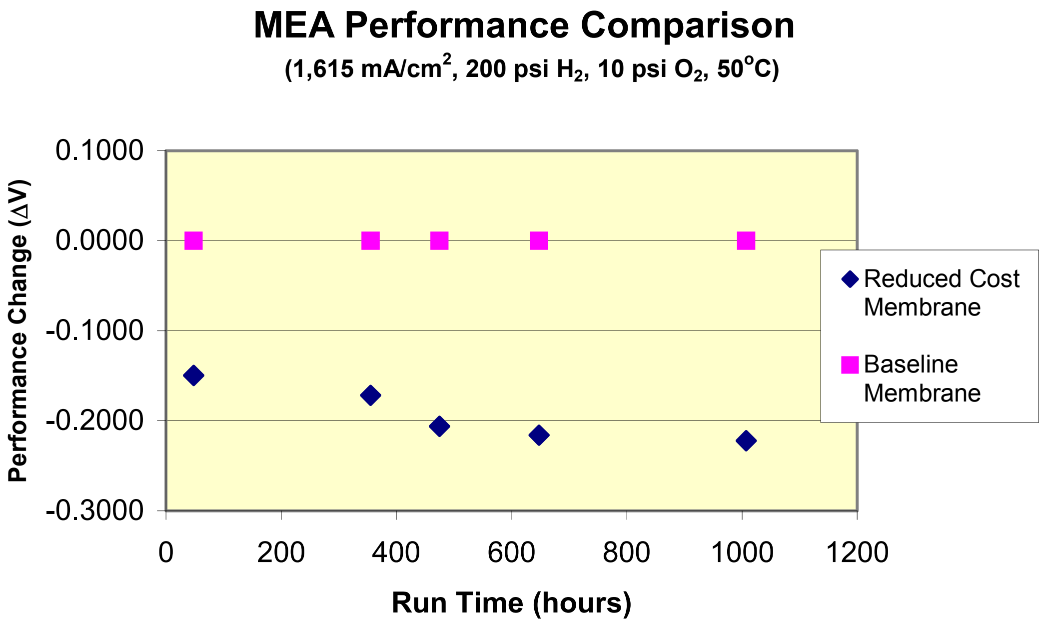
**Thinner Membranes (30%) Evaluated**

- 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**

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# Accomplishments / Electrochemical Compressor

**Electrochemical Compressor Feasibility Study Completed**

**Tests Performed on Single Cell Electrolyzer Hardware**

**Ambient to 2,400 psi Compression**

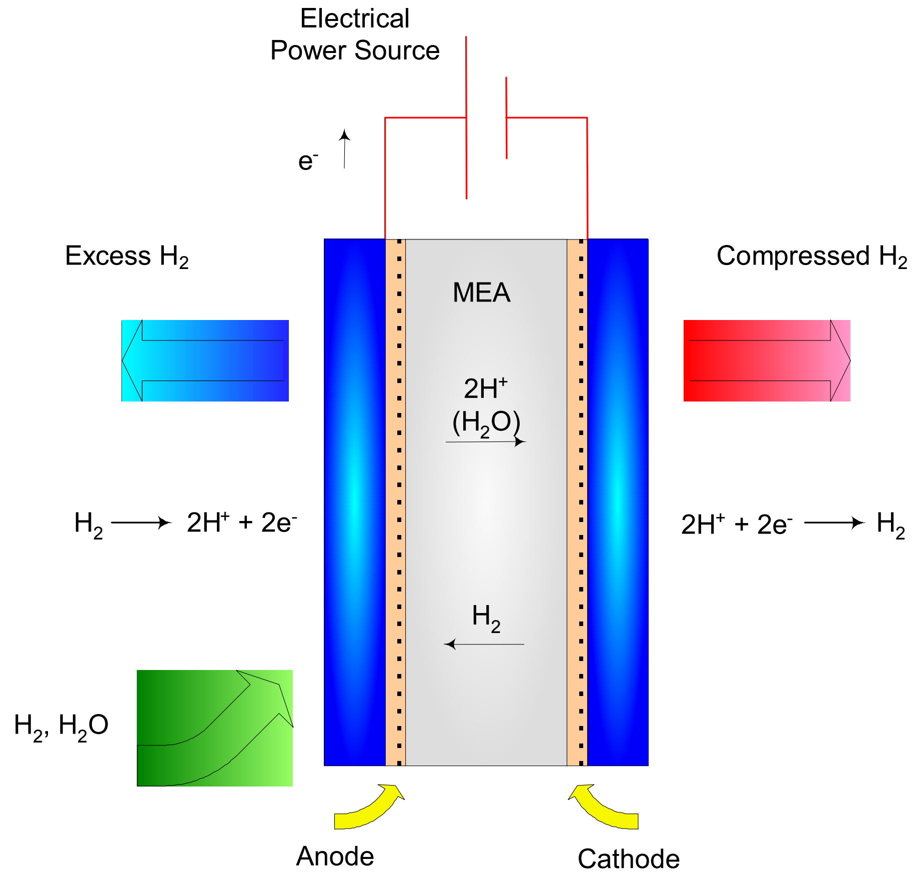
**Parameters Affecting Performance Identified**

**Preliminary Study results Encouraging**

- Throughput
- Efficiency

**Merits Further Study**

- Optimization of Cell Stack for Compression

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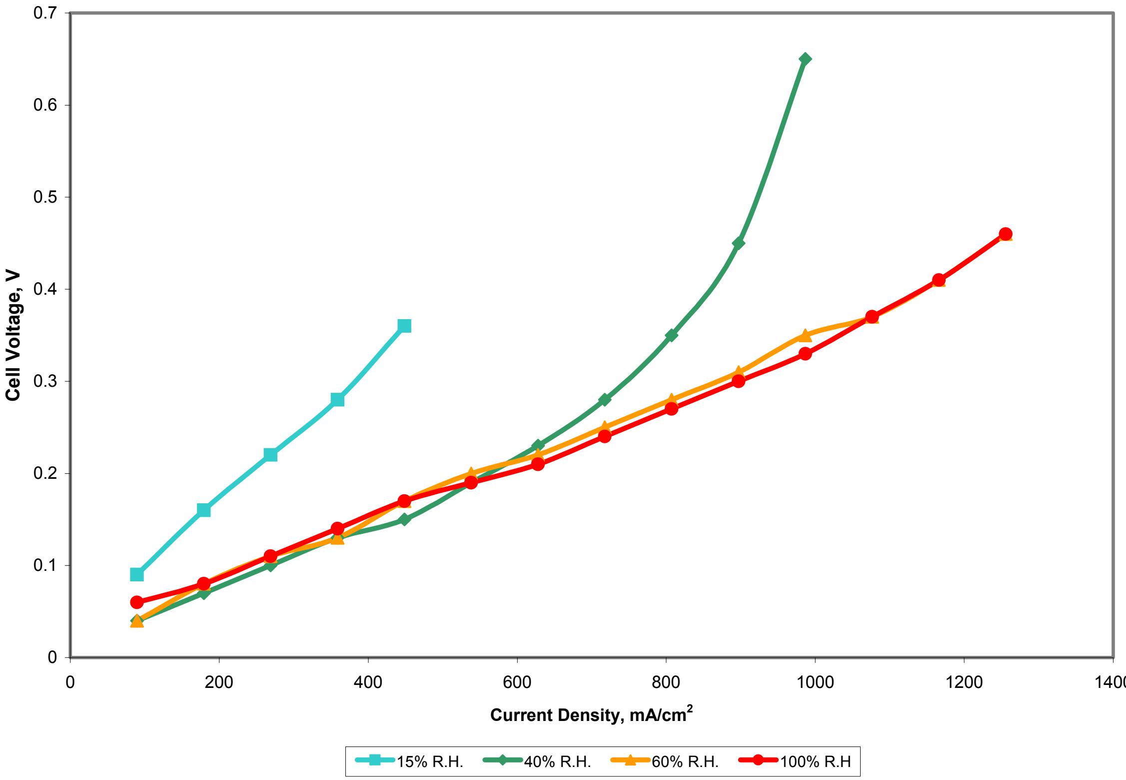
# Accomplishments / Electrochemical Compressor

## 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)**

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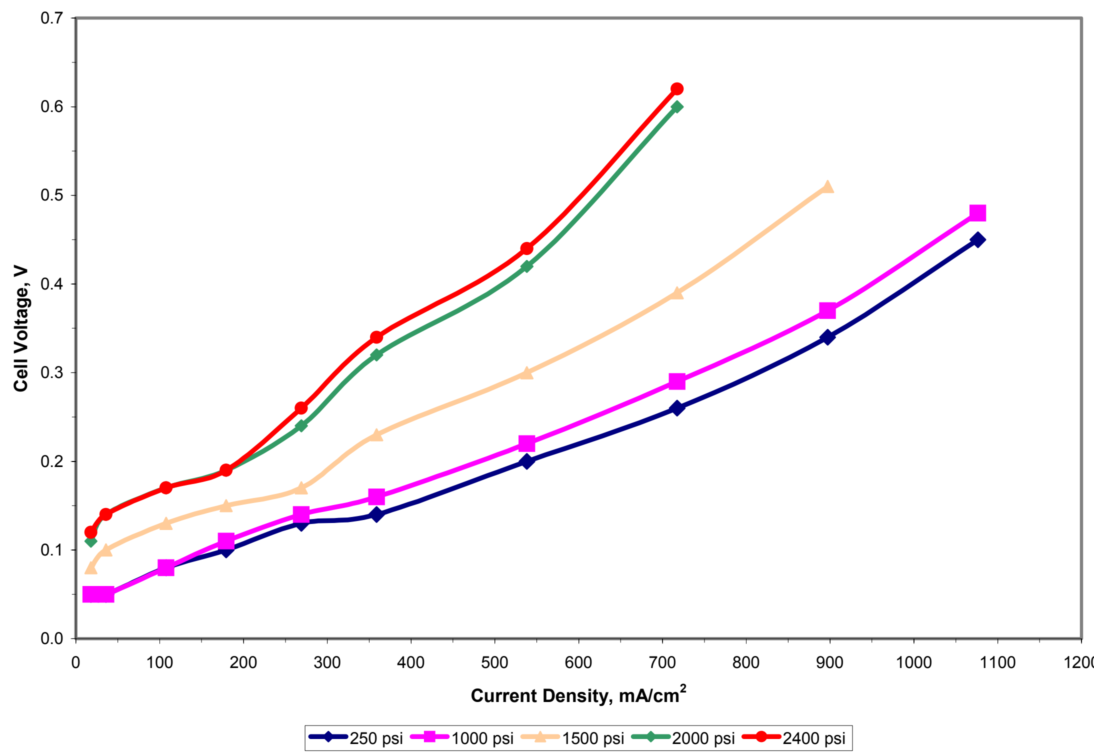
# Accomplishments / Electrochemical Compressor

## 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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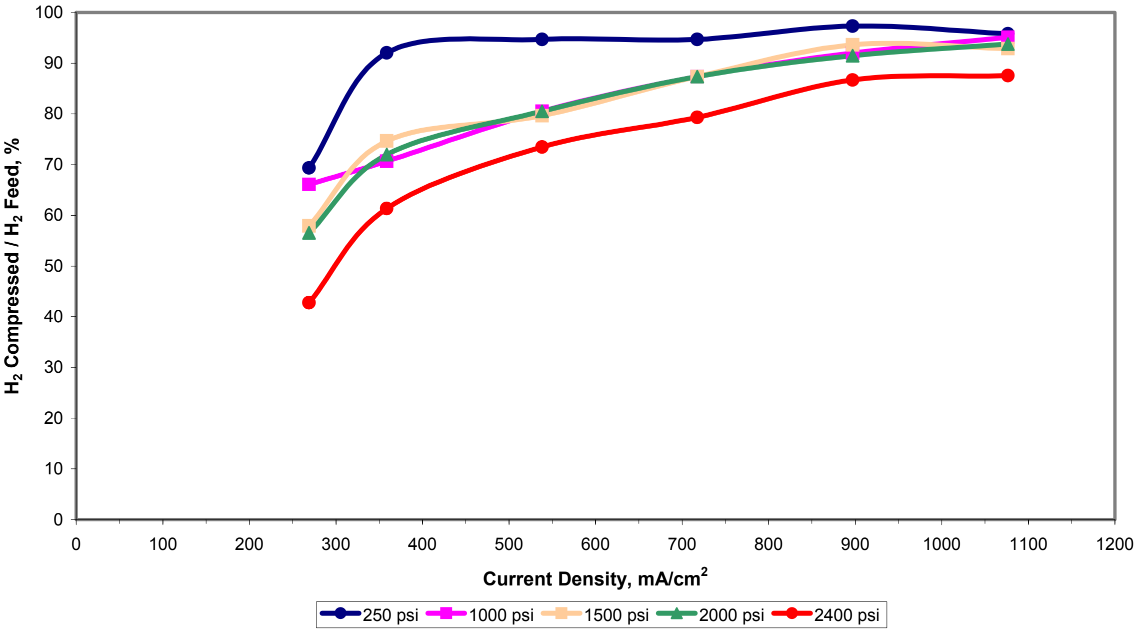
# Accomplishments / Electrochemical Compressor

## 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**

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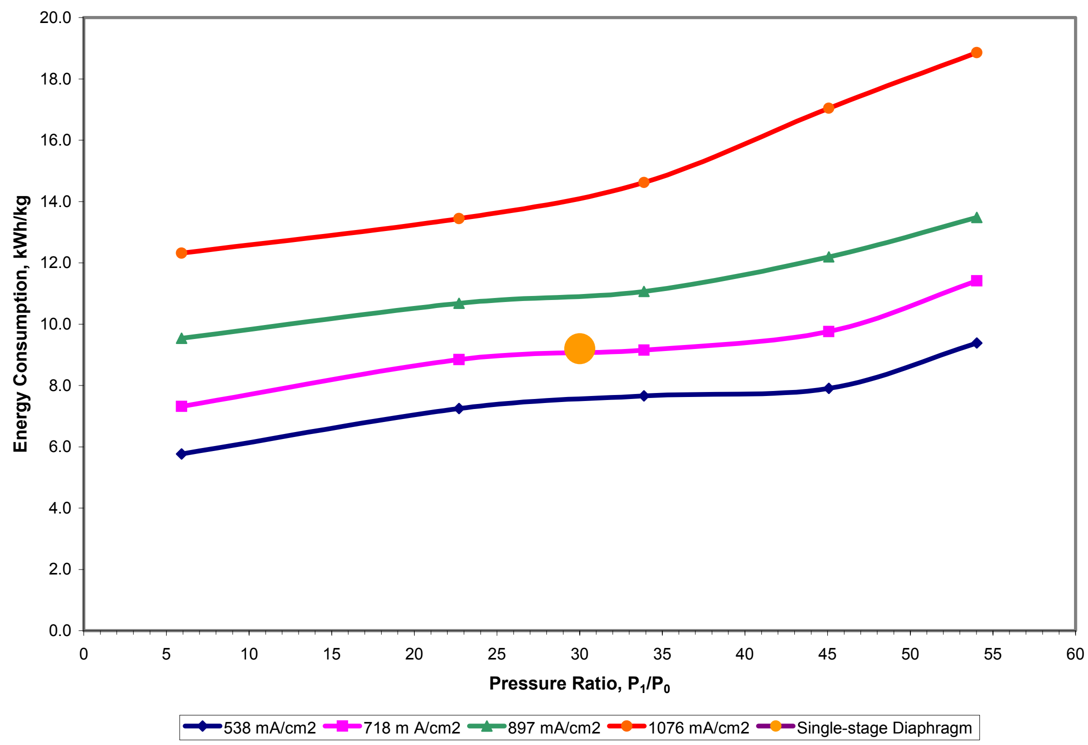
# Accomplishments / Electrochemical Compressor

## Energy Consumption by Hydrogen Electrochemical Compression

**Energy Consumption Vs. Current Density Evaluated**

**At Current Density of 720 $mA/cm^2$ ECC Comparable to a Measured Single Stage Diaphragm Compressor**

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# 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

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# 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.**