2007 Hydrogen Fuel Cells Technology Infrastructure Review Meeting

Low-Cost, High-Pressure Hydrogen Generator

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Project ID# PDP12

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Project Start: Jan 2003
- Project End: Dec 2007
- Percent Complete: 95

Budget

- Total Project Budget: $2.255M
  - DOE Share:$1.117M
  - Cost Share:$1.138M
- FY06 Funding
  - DOE: $350K
- FY07 Funding
  - DOE: $122K
- Cost Share Funding to Date: $1.02M

Barriers

DOE Technical Barriers for Hydrogen Generation by Water Electrolysis

- Q. Cost- capital cost, O&M
- R. System Efficiency

Technical Targets

- $600/kW for 10,000 scfd unit
- Stack efficiency = 76% (LHV)
- $2.85/gge H_2 in 2010

Partners

- General Motors
- Center for Technology Commercialization- Public Outreach and Education

Project Objectives

Overall Project

- Develop and demonstrate a low-cost, moderate-pressure PEM water electrolyzer system
  - Reduce capital costs to meet DOE targets
  - Increase electrolyzer stack efficiency
  - Demonstrate 1200 psig electrolyzer system
  - Field test electrolyzer system at NREL

Advantages of GES PEM Electrolyzer

- PEM electrolyzers have higher efficiency than alkaline systems
  - Electricity is the key cost component in electrolyzer systems
  - Present GES performance is 1.75 V at 1200 mA/cm^2
    - Stack efficiency = 71% based on LHV
  - With advanced membrane demonstrated 1.71 V at 1200 mA/cm^2
  - Alkaline systems typically >1.85 V at 300-400 mA/cm^2
- Operation at higher current density partially offsets higher cost/area of PEM electrolyzer
- GES PEM differential pressure technology produces H_2 at high pressure (up to 3000 psig to date) with O_2 production at atmospheric pressure
  - Reduces system cost and complexity
  - Improves safety - eliminates handling of high-pressure O_2
- Cost is benefited by advances in PEM fuel cell technology

Approach

- Develop lower-cost materials and fabrication methods for cell components
  - Replace high-cost metal components with other materials
  - Develop fabrication methods suitable for large-scale fabrication
  - Reduce parts count/cell
- Increase operating current density to reduce cell active area (reduce stack cost) while retaining high efficiency
  - Evaluate trade-off of efficiency vs. capital cost
  - Develop high-efficiency membrane
- System innovations to replace high-cost, high maintenance components
- Emphasize safety in design and operation

Objectives- Past Year

- Continue Development of Low-Cost Stack Components
- Continue to Decrease the Parts Count/Cell
  - Anode Side Membrane Support Structure (ASMSS)
  - Cell frames
  - Cell Separator
- Increase Operating Current Density
  - Continued development of an advanced high-efficiency, high-strength membrane
    - Provides efficiency comparable to Nafion 112, but has 10x the strength
    - Operating at higher current density reduces number of cells, thereby decreasing stack cost
- Modify stack and system for field test at NREL
  - Refurbish stack with low-cost components developed in program
  - Work with NREL to develop testing plan

Stack Cost Reduction

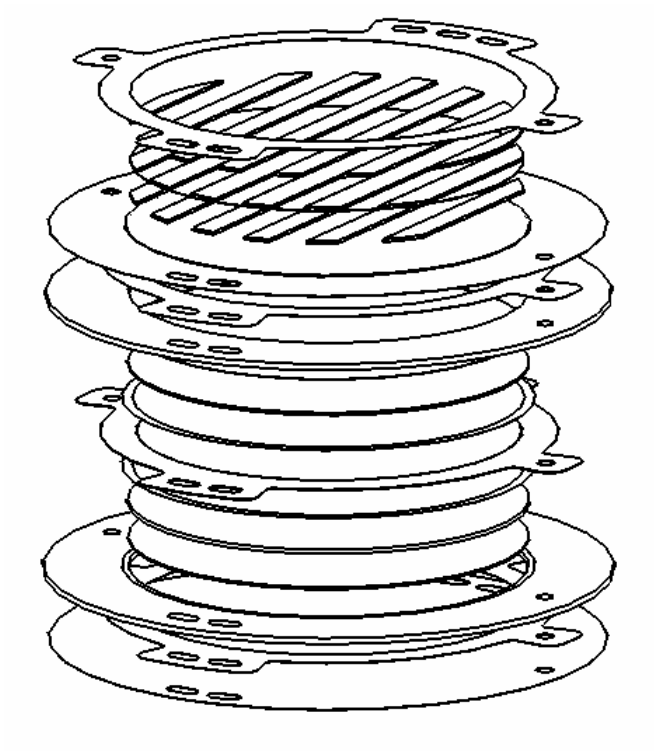
- *ASMSS*
  - Prior design consists of 9 metal parts, which are individually cut, plated, welded, cut again and assembled
  - Evaluating feasibility of using a single-piece metal part
    - Working with vendors to develop a cost-effective method for making part with acceptable tolerances
    - A single-piece part demonstrated acceptable pressure drop
    - A 160-cm^2 cell incorporating the single-piece ASMMS demonstrated stable electrolyzer performance

- *Thermoplastic Cell Frame*
  - Conducts fluids into/out of active area
  - Aids in pressure containment- highly stressed component
  - Presently these parts are molded and machined; machining accounts for 95% of part cost
  - GES is developing a low-cost fabrication method that eliminates machining
    - Enables molding of frames
- Successful development expected to reduce cell cost by 40%

- *Cell Separator*
  - Key component that must be compatible with high-pressure hydrogen on one side and oxygen at high potential on the other
  - Previous technology was a very expensive part consisting of two different valve metals
  - Evaluated several approaches for lower-cost part
    - Carbon coating on a titanium separator to reduce hydrogen embrittlement
      - Difficult to obtain an impervious, pinhole-free coating
    - Metal oxide coatings on titanium to reduce hydrogen-embrittlement
  - Short-term solution is a two-piece titanium separator
    - Projected to have lifetime of 5000 hours
    - Longer life separator needs to be developed

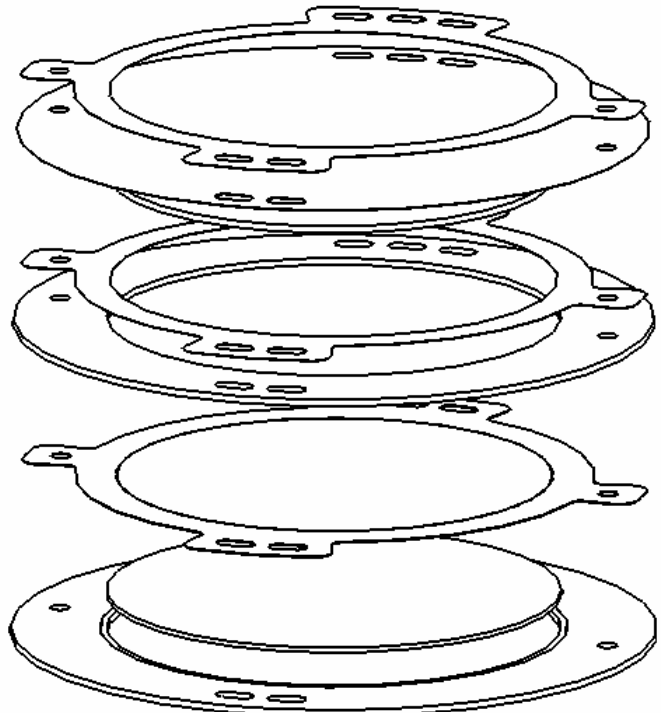
Progress in Part Count Reduction

2002



40 + Parts

Present Goal (2006)



16 Parts

Increasing Operating Current Density

- High-current-density operation reduces stack active area, and therefore stack cost
  - Thin membranes have low resistance, allowing efficient operation at high current densities
  - Drawback is poor mechanical properties, limiting operation to moderate differential pressures
- GES has reduced the thickness of the Nafion membrane used from 10 mils to 7 mils, and has demonstrated performance and short-term life of a 5 mil Nafion membrane in a short stack at 400 psid
  - However, thinner membranes operating at higher temperatures are required to achieve the DOE efficiency target
- GES is developing an advanced supported membrane structure
  - Excellent mechanical properties- suitable for high differential pressure
  - High proton conductivity- equivalent to 2 mil Nafion membrane
  - Hydrogen and oxygen permeability equivalent to N112

Supported Membrane

- Superior Mechanical Properties
  - No x-y dimensional changes upon wet/dry or freeze-thaw cycling
  - Much Stronger Resistance to tear propagation
  - Superior to PTFE based supports
    10x stronger base properties
- Ease of MEA/Stack configurations
  - Direct catalyst inking onto membranes
  - Possible to bond support structures into bipolar frame to eliminate sealing issues
- Customized MEAs
  - Provide more support at edge regions and/or at ports

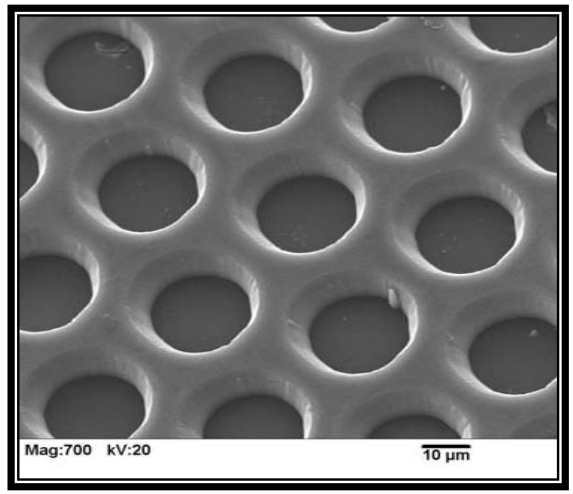


Figure 1. Scanning Electron Microscope (SEM) micrograph of the polymer membrane support structure with definable straight hole pattern

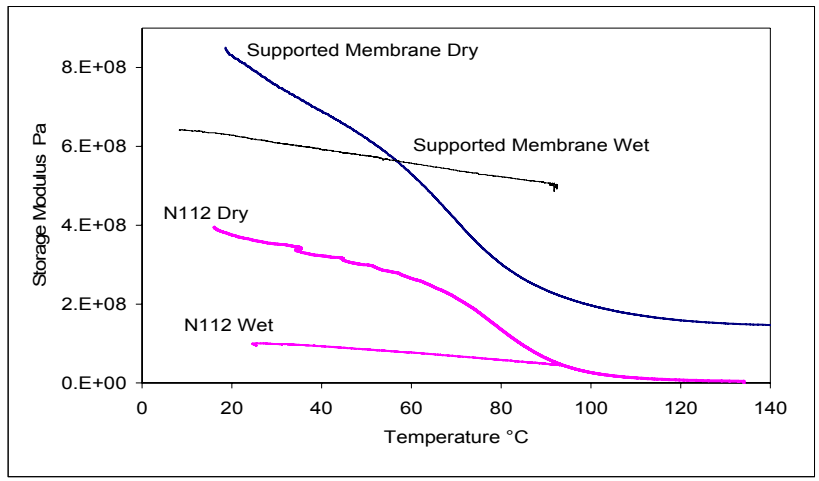
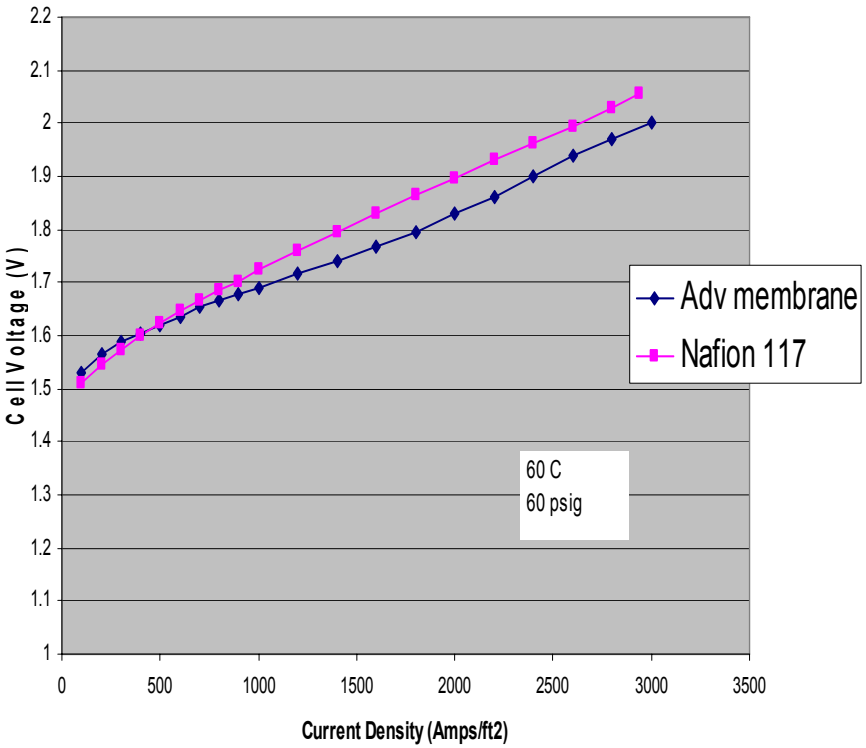
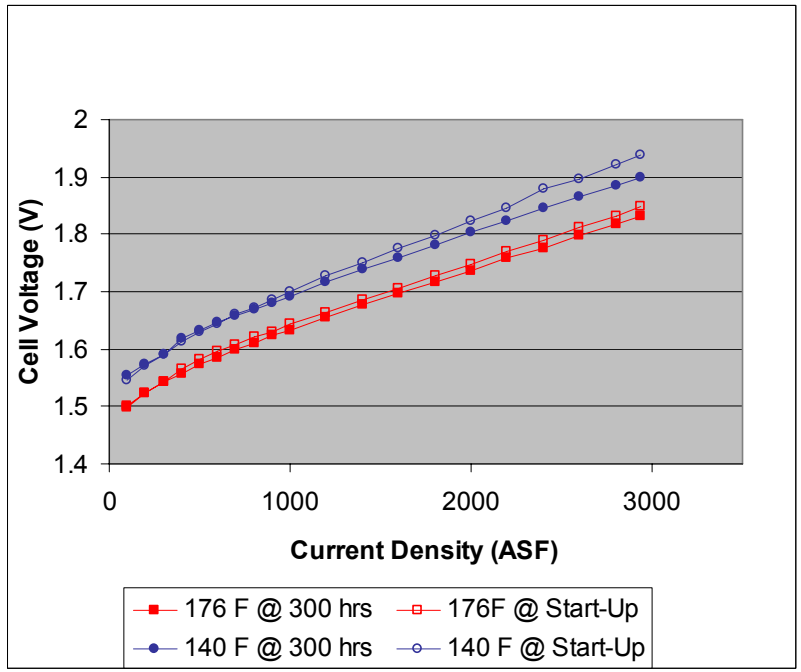


Figure 2. Dynamic Mechanical Analysis (DMA) shows the modulus of the novel supported membrane is ~10 X higher than the N112 membrane.

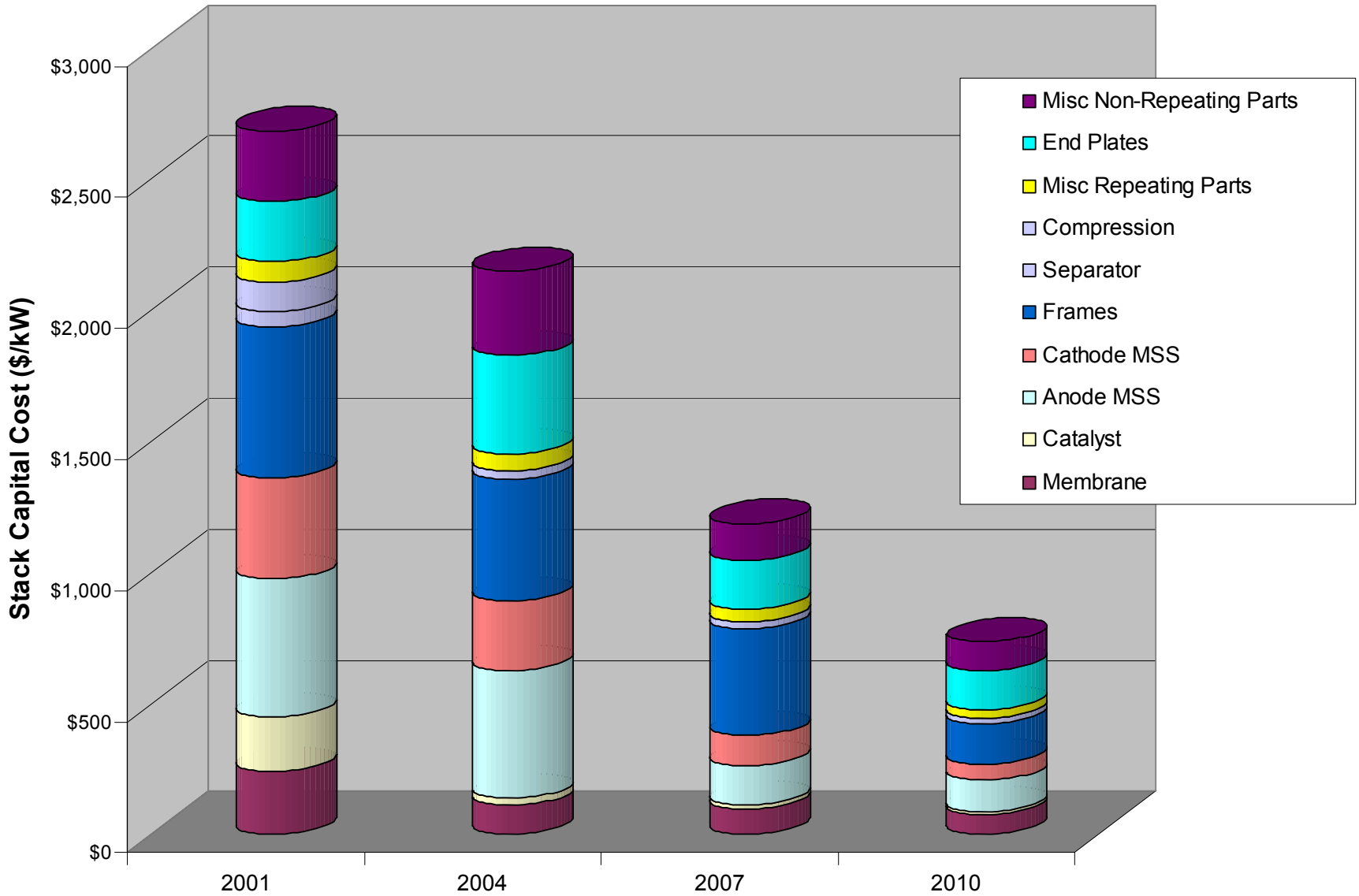
Demonstration of Advanced Membrane in 160-cm^2 cell



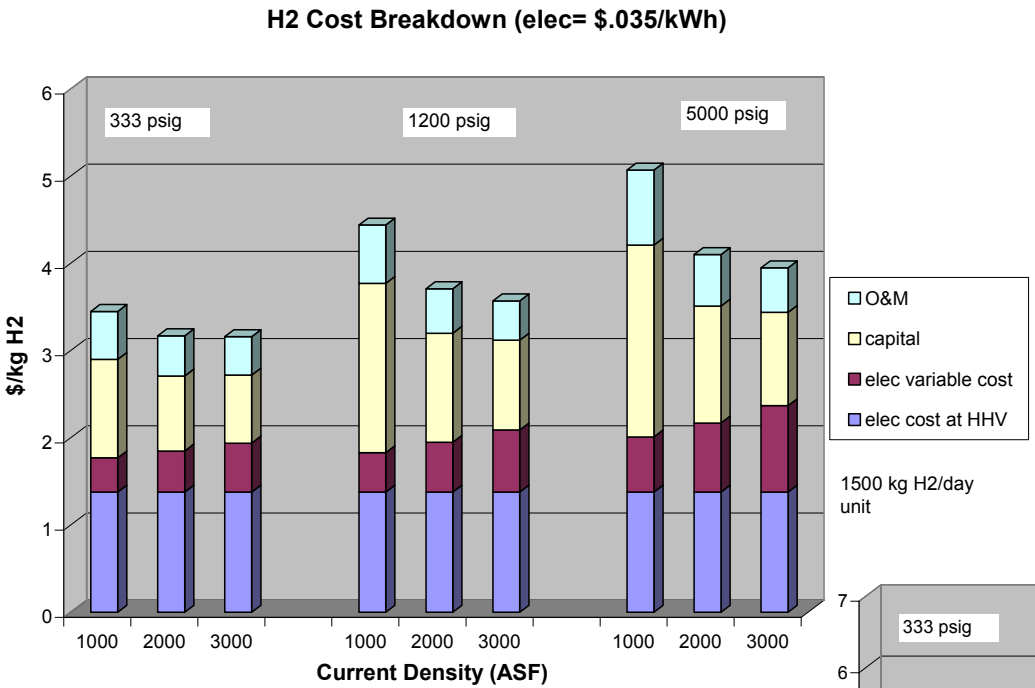


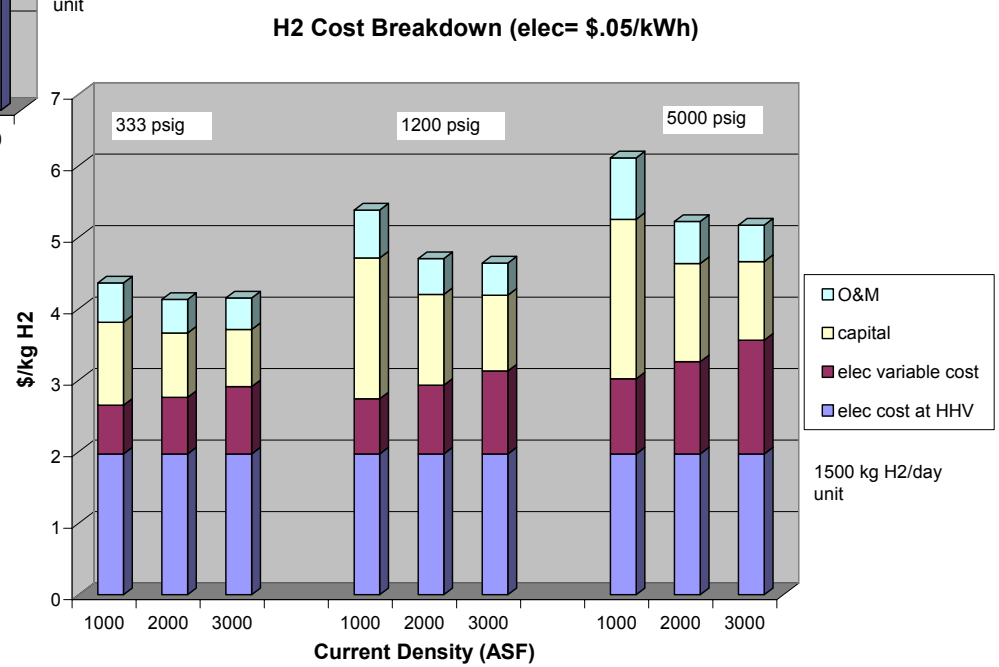
- Performance of the Advanced DSM is superior to that of Nafion 117
- DSM has demonstrated stable short-term operation
  - Membrane is expected to be highly durable; this need to be verified
  - Further development required to decrease fabrication costs

Progress in Stack Cost Reduction



H2A Model Results

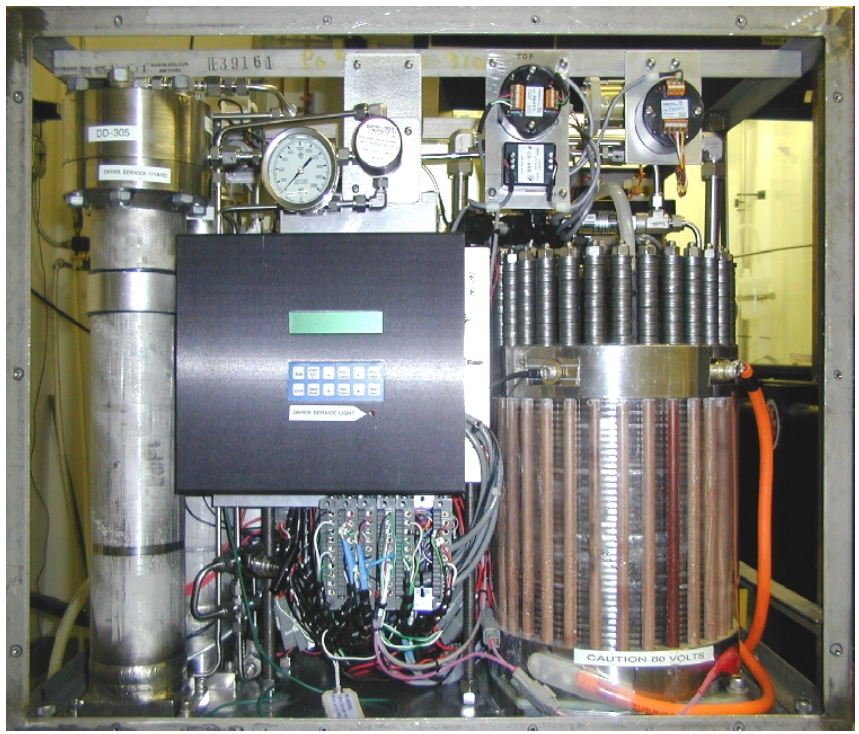




- Lowest cost H_2 at lowest pressure
- Lower cost at 2000 - 3000 mA/cm^2 (tradeoff of efficiency vs. capital cost)
- Can achieve ~$3.00/kg at 3.5¢ electricity

Demonstrate System at NREL

- System produces 0.25 kg/hr at 1200 psig
- High –performance stack
  - 28 cells
  - 12.8 kW input power
  - Incorporates the low-cost components developed in this program
- Evaluation at NREL planned for Summer 07



Future Plans

- Remainder of FY 2007
  - Conduct field test of system at NREL

Summary

- GES PEM Electrolyzer has potential to meet DOE cost and performance targets
- GES has made significant progress in stack cost reduction
- Further development of a high-strength, high efficiency membrane is recommended
  - Demonstrate reproducibility and durability
  - Decrease fabrication cost
- Development of a low-cost long-life separator is required