

2005 DOE H₂ Program Review

Alkaline, High Pressure Electrolysis

Project ID PD26

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Overview

■ Timeline

- Project start: April 2004
- Project end: April 2007
- 25% Complete

■ Budget

- Total funding: \$3,128,764
 - DOE share: \$1,563,882
 - TESI share: \$1,563,882
- Funding rec'd 04: \$490,000
- Funding rec'05: \$600,000
(to date)

■ Partners

- Pdc Machines Inc.
- AeroVironment Inc.
- Maryland Energy Admin.

■ Barriers & Targets addressed

(overleaf)



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Overview

- Barriers & DOE Targets addressed
 - Power conversion, Module, BOP:
 - Cost: \$0.80/gge H2
 - Efficiency: 68%
 - Compression, Storage & Dispensing:
 - Cost: \$0.77/gge H2
 - Efficiency: 94%
 - Electricity: Cost: \$2.47 /gge H2
 - O&M: Cost: \$0.71 / gge H2
 - Total:
 - Cost: \$4.75/ gge H2
 - Efficiency: 64%

Objectives

- To advance water electrolysis and develop an Electrolytic Hydrogen Generator with the following features:
 - Safe to use
 - Designed for Manufacture & Assembly
 - Deliver H₂ at 5,000 psig
 - Production capacity of 10,000 scfd
 - Low life costs
 - Reliable, low-maintenance, affordable, durable.

Approach

- Develop and produce safe, low-cost, high efficiency alkaline water electrolysis system for hydrogen production.
 - Hardware cost trade studies – sensitivity analyses
 - Detailed safety analyses
 - Benchtop system fabrication and testing at pressure
 - Efficiency optimization
 - Design for Manufacture & Assembly
 - Manufacture and demo of full scale system

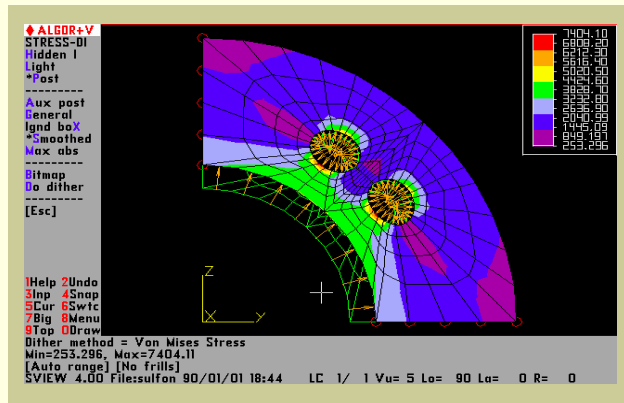


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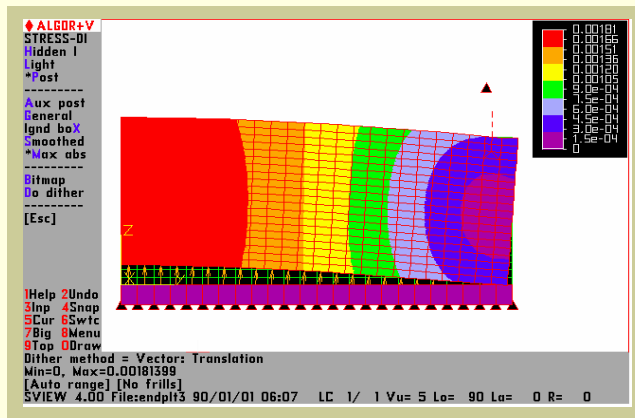
Approach

- 3 Major Components:
 - Electrolysis module & System
 - Deliverable will have 10,000 scfd capacity.
 - Currently testing benchtop version at up to 500 psi
 - May operate at up to 1500 psi if there is significant efficiency buy back.
 - DC power supply
 - Compressor to provide final compression to 5000 psi

Progress - Design



- Benchtop, Design and Engineering
- Economic studies
 - Compressor trade studies
 - Power supply design
- Safety Analyses of system
- DFMA of module

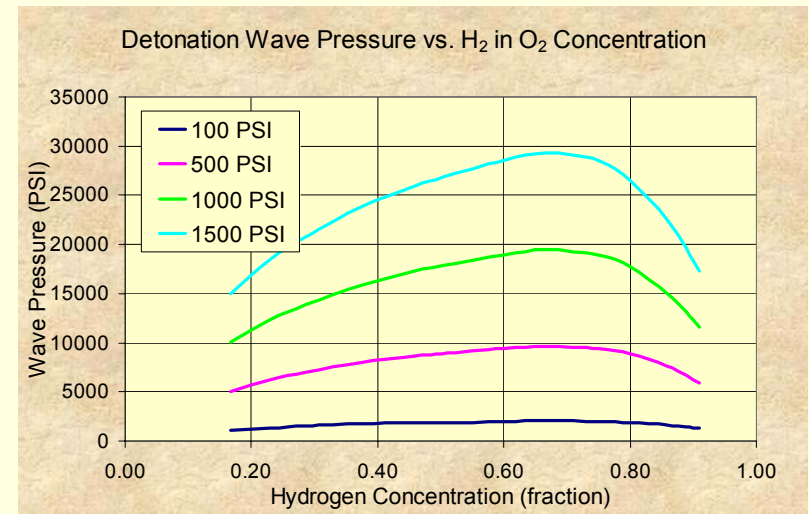
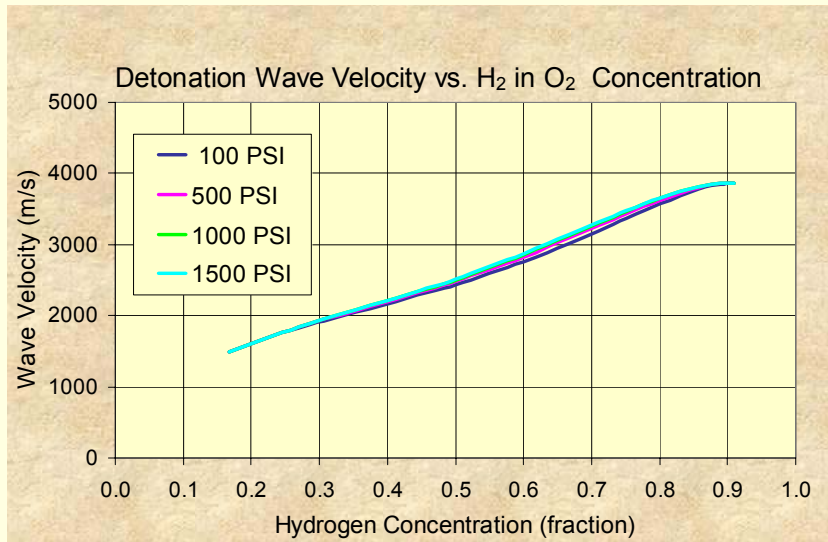


Progress – System Trade-off Studies

- Off-the-shelf component pricing shows that system costs increase significantly at $>600-800$ psi.
- Safety analyses show that hardware cost will be minimized at or below 500 psi operating pressure.
- Design studies show that one stage of the compressor can be eliminated at 500-700 psi inlet pressure.
- Initial Power Supply studies by AeroVironment have produced 4 designs for consideration in trade studies.

Progress - Safety

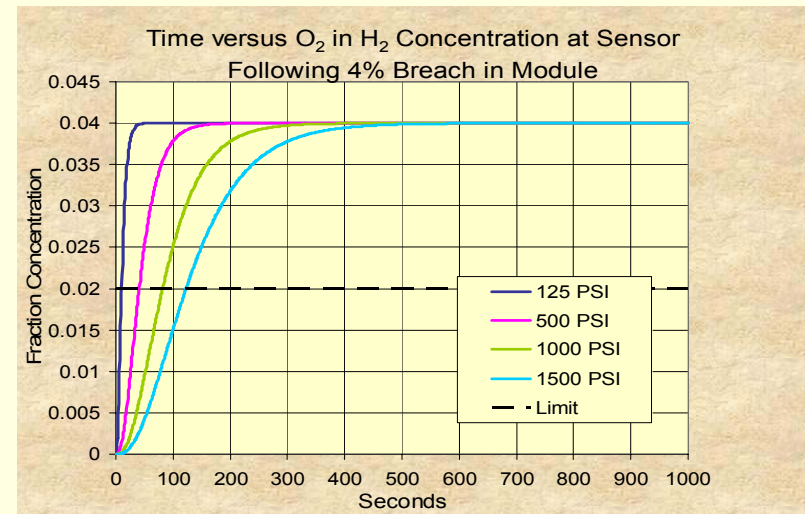
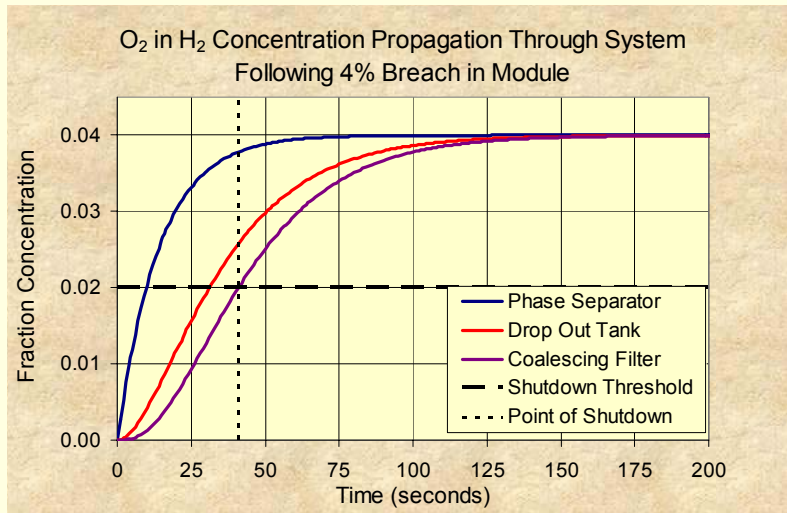
- Detonation wave velocity,
 $v = 1500 - 4000 \text{ m/s}$



- Benchtop System to operate at 500 psi

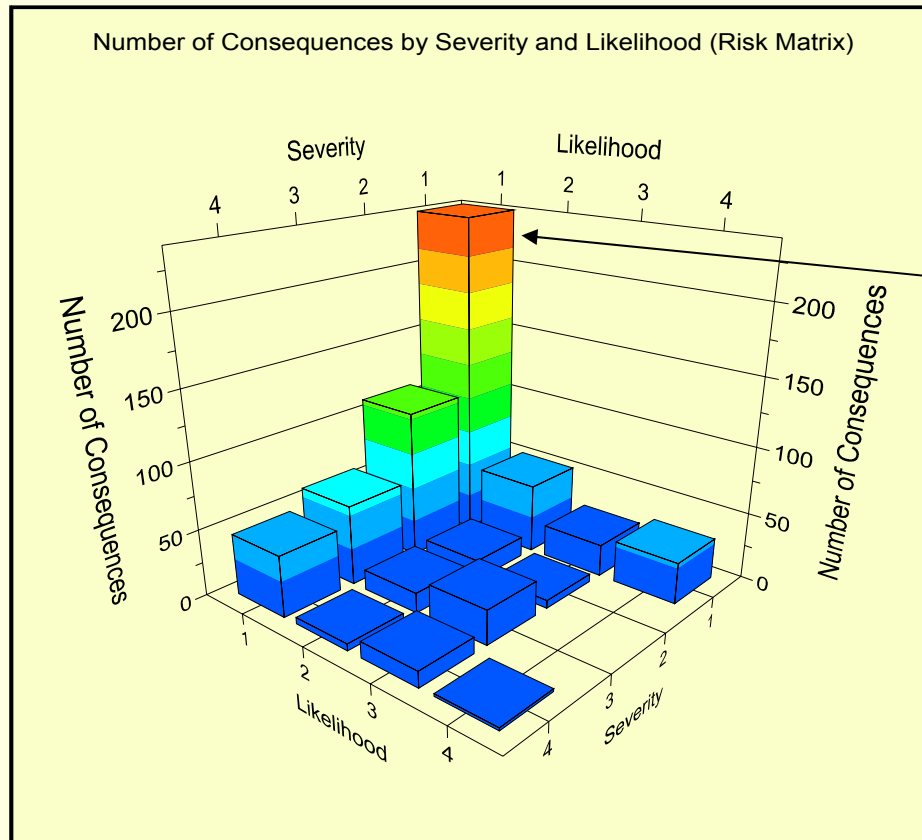
Progress - Safety

- Estimated mixture concentrations at various points in system, during emergency



- Sensor response times

Progress – HazOp Analysis



- Evaluated for no safeguards in place.
- Highest frequency events are benign.
- Safeguards reduce the highest level risks.

Progress – Pressure Control System

- Critical to reliability and safety of system
- Hardware and logic has been developed and tested
- Utilize off-the-shelf components
- Adjustable to accommodate range of operating pressures
- Ability to control H_2/O_2 ΔP within inches of H_2O

2004 Reviewers Comments

- Evaluate cost impacts of large scale production to optimize unit costs
 - DFMA is a major goal for 2005-06
- “Outside the box” ideas
 - Prototype cell mold produced that reduces cell part count by a minimum of 40%
- Supply H₂ at 10,000 psig
 - Can be achieved by a compressor swap on 5000 psig system

Future Work

- Milestones for 2005:
 - Obtain test data at elevated pressures
 - Optimize electrolysis pressure
 - Collect life data on separators
 - DFMA and deliverable design
- Milestones for 2006:
 - Complete deliverable design
 - Fabricate and test deliverable unit
 - Obtain necessary permits for demonstration site

Acknowledgements

AeroVironment Inc.

- Omo Velev, David Francis

■ Pdc Machines Inc.

- David Heim, Sy Afzal

■ Maryland Energy Administration

- Michael Li

■ Teledyne Energy Systems Inc.

- Dr. P. Borthwick, S. Cohen, M. McAlonan, M. Miller,
Y. Ngu, S. Pass, F. Robbins

Questions / Comments



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Publications and Presentations

- 2004 DOE Program Review Presentation. *Cohen, Ibrahim*, May 2004, Philadelphia, PA
- TESI High Pressure Electrolysis Progress. *Cohen, Ibrahim*, January 2005, Hunt Valley, MD (to Matt Kauffman and Pete Devlin of US-DOE)
- 2005 DOE Program Review Presentation. *Ibrahim, Cohen*, May 2005, Arlington, VA



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Hydrogen Safety

- The most significant hydrogen hazard associated with this project is:

Potential mixing of H₂ and O₂ at high pressure.

Hydrogen Safety

- Our approach to deal with this hazard is:
 - Numerical modeling, to predict, optimize sensor response.
 - Quality Assurance and leak-check of separators
 - Monitoring product gases for cross-contamination.
 - Securing gas production, should mixing occur.
 - Design of unit to contain any pressure excursions.