2005 DOE H_2 Program Review
Alkaline, High Pressure Electrolysis

Project ID PD26

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This presentation does not contain any proprietary or confidential information.

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%

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Objectives

- To advance water electrolysis and develop an Electrolytic Hydrogen Generator with the following features:
  - Safe to use
  - Designed for Manufacture & Assembly
  - Deliver H_2 at 5,000 psig
  - Production capacity of 10,000 scfd
  - Low life costs
  - Reliable, low-maintenance, affordable, durable.

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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

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

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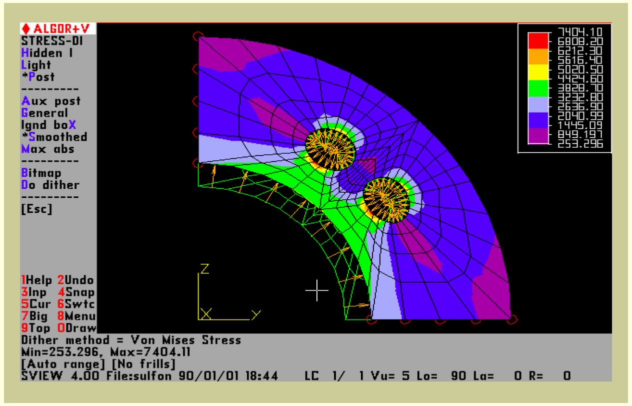
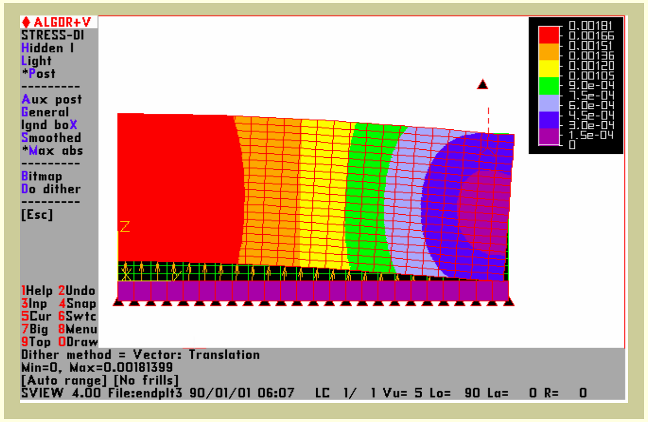
Progress - Design





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

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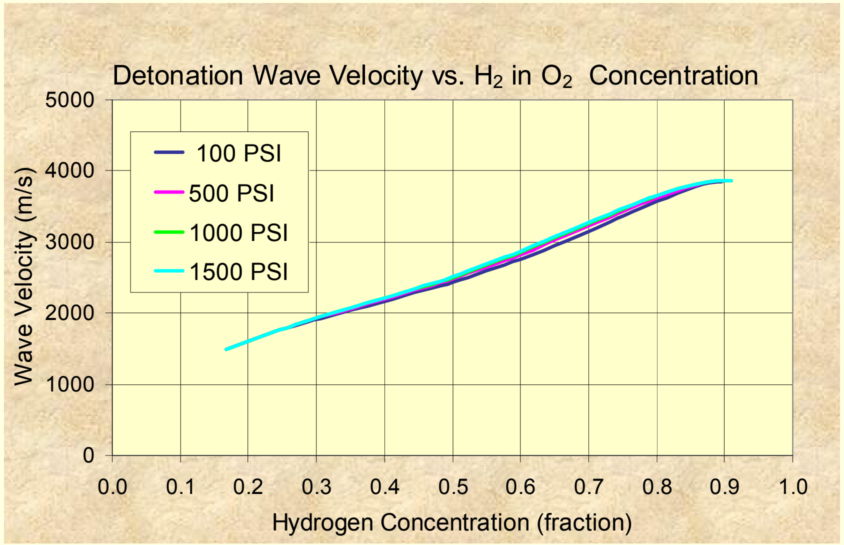
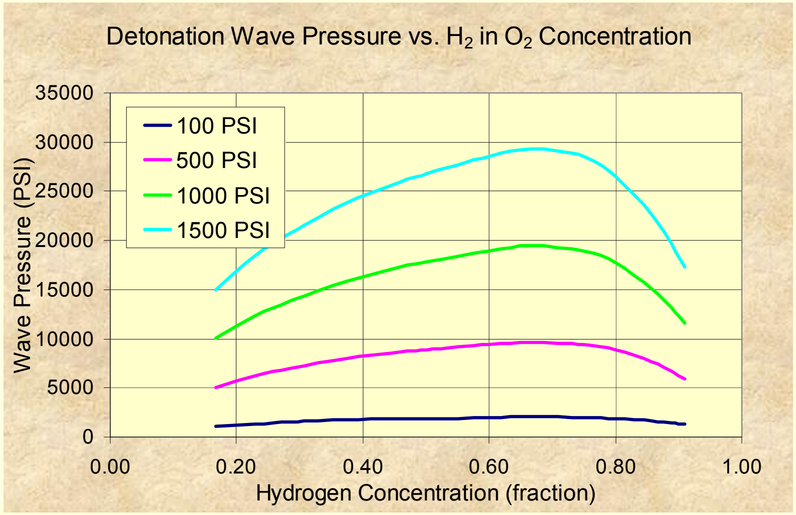
Progress – System Trade-off Studies

- 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 m/s





- Benchtop System to operate at 500 psi

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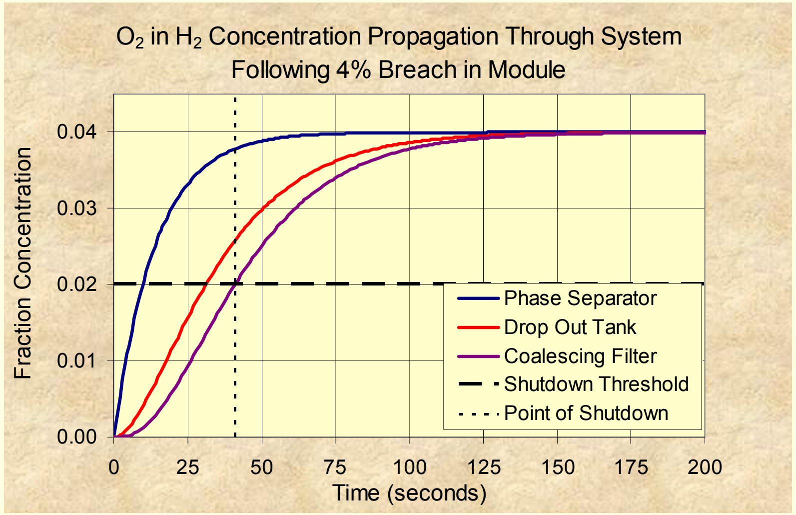
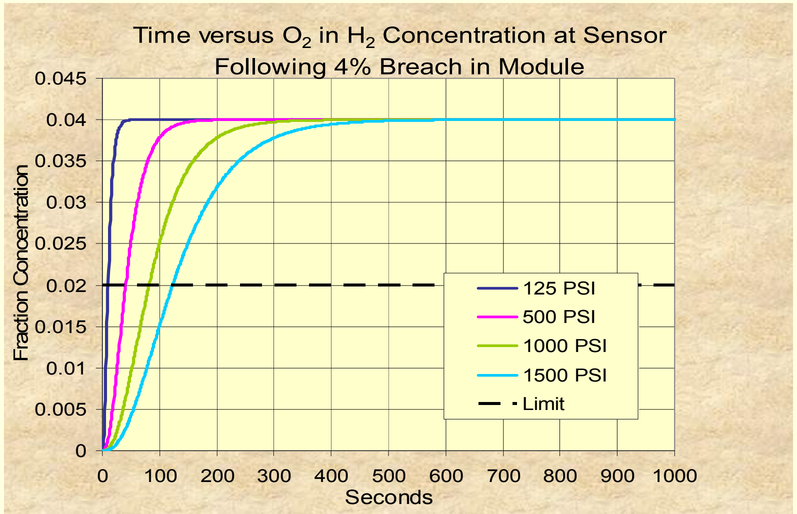
Progress - Safety

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





- Sensor response times

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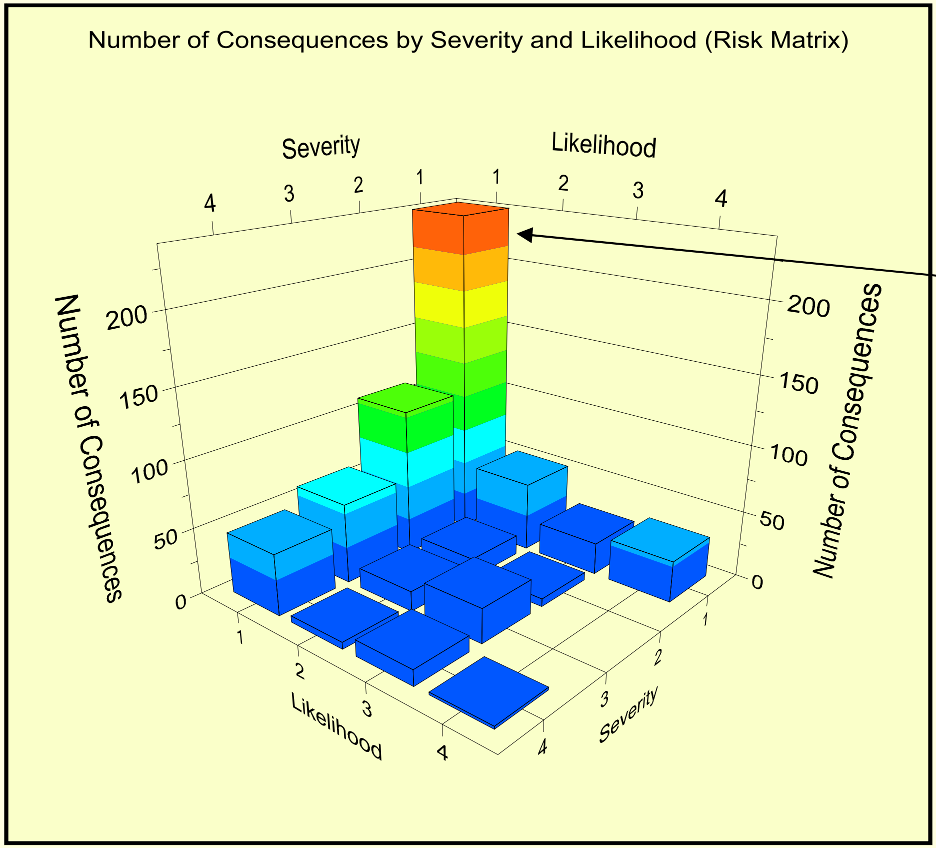
Progress – HazOp Analysis



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

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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

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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 H_2 at 10,000 psig
  - Can be achieved by a compressor swap on 5000 psig system

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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

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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

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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 H_2 and O_2 at high pressure.

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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.

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