2006 DOE H_2 Program Review
Alkaline Electrolysis

Project ID PD09

Samir Ibrahim/Joe Poindexter

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

Background

- Work stopped August 2005
  - Safety issues presented during May 2005 Review
  - Hurricane Katrina aftermath
- Work resumed April 2006
- Original goals
  - Low cost of produced H_2 by increased pressure and increased efficiency
- Goals for 2006/07
  - Low cost of produced hydrogen by increased capacity and reduced capital/manufacturing costs

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

Overview

- Timeline
  - Project start: April 2004
  - Project end: April 2007
- Partners
  - None at this time due to recent changes in primary objectives
- Budget
  - Total funding: $3,128,764
    - DOE share: $1,563,882
    - TESI share: $1,563,882
  - Expenditure ‘04: $310,900
  - Expenditure ‘05: $444,800
  - Expenditure ‘06: $2,000
- Barriers & Targets addressed

  (overleaf)

TELEDYNE ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

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%**

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

Objectives

- To advance water electrolysis and develop an Electrolytic Hydrogen Generator with the following features:
  - Low capital cost per unit produced hydrogen
  - Safe to use
  - Designed for Manufacture & Assembly
  - Increased H_2 Production capacity
  - Low life costs
  - Proven, reliable, affordable & durable.

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

Approach

- Develop and produce safe, low-cost, high efficiency alkaline water electrolysis system for hydrogen production.

  Cost-share, DOE/TES

  - Hardware cost analyses
  - Detailed safety analyses
  - Benchtop system fabrication & testing
  - Prototype system design

  TES only

  - Fabrication of prototype unit
  - Testing & Verification of prototype system

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

Approach

- 3 Major Components:
  - Electrolysis Module & System
  - Dryer / Purification System
  - DC Power Supply

Progress - Small Scale System

Small scale electrolysis system:

- Designed for 500 psig delivery pressure; MAWP of 1500 psig
- System easily configurable to run higher pressures
- Extensive safety analyses performed
- Operator safety, highest priority

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

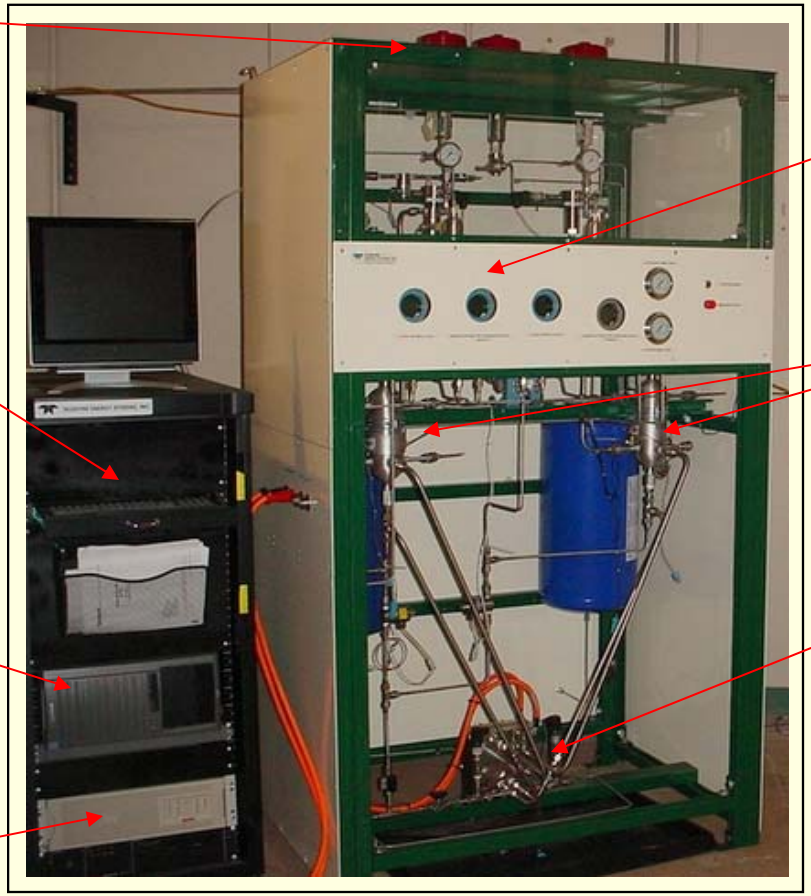
Progress – Small Scale System

PRESSURE CONTROL VALVES

ELECTRICAL HARDWARE

CONTROLS & DAQ COMPUTER

POWER SUPPLY



DELTA P TRANSMITTERS

PHASE SEPARATORS

HIGH PRESSURE ELECTROLYSIS MODULE

2005 Reviewers Comments

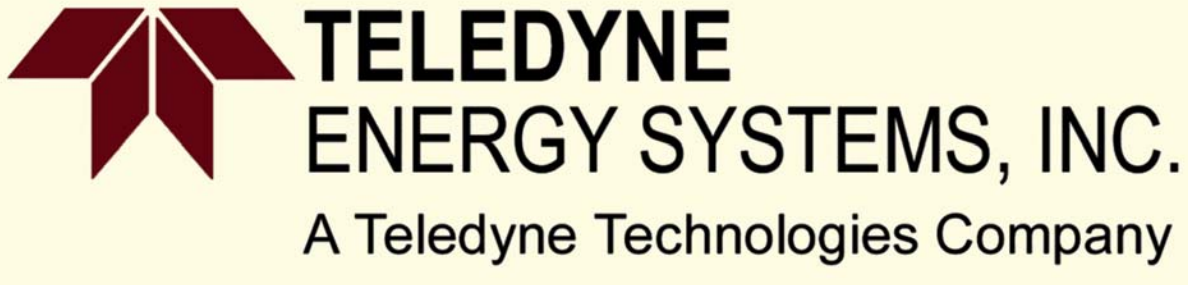
- Too much time and effort being spent on Pressure Control System
  - Pressure control critical for safe and reliable system
- Use rupture disks, pressure relief vales to raise electrolysis pressure >1000 psi
  - High pressure electrolysis adds significant cost to system, thus deviating from DOE's primary objective of low cost hydrogen

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

Future Work

- Close out original contract scope:
  - Test and verify operation of 500 psi prototype
- Achieve new contract objectives:
  - Complete design of a low cost, 150 psi alkaline generator, using DFMA
  - Fabricate prototype system
  - Test and verify lower cost, higher capacity 150 psi generator

Questions / Comments



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
- 2005 DOE Program Review Presentation. *Ibrahim, Cohen*, May 2005, Arlington, VA

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

Hydrogen Safety

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

Potential mixing of H_2 and O_2

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company

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

TELEDYNE
ENERGY SYSTEMS, INC.
A Teledyne Technologies Company