2005 DOE Hydrogen Program -HYROGEN FILLING STATION-

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Project ID #
TVP8

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Start-6/12/03
- End-12/31/05
- Percent complete-35

Budget

- Total project funding
  - DOE $3,906,604
  - Share $1,546,246
- FY04: $1,720,410
- FY05: $3,732,440

Barriers

- Barriers addressed
  - Advanced Electrolysis from Renewable Sources
  - Technology Validation

Partners

- UNLV Research Foundation
- Collaborators
  - UNLV Center for Energy Research
  - Proton Energy (& Air Products)
  - Hydrogen Solar
  - Altair Nanotechnologies
  - Las Vegas Valley Water District

Objectives

- Show a path to the wide-scale utilization of hydrogen as an energy source
- Validate technology for the renewable generation of hydrogen and its utilization
- Develop advanced techniques for the electrolytic generation of hydrogen
- Bring about cost reductions to all of the above

Approach

- Develop a renewably powered hydrogen filling station that will serve as focus for a variety of advanced work
- A host organization has been incorporated that will provide vehicles for conversion to hydrogen fuel. These vehicles will utilize the system for on-site testing.
- Advanced H_2 generation processes are being developed, including high pressure electrolysis and tandem solar cells
- Student involvement viewed as important

2,000 psi PEM Electrolysis is on Pathway to Lowering H_2 Fueling Costs

5,000+ psig Electrolysis Can Eliminate Need for Compressor
2,000 psig Electrolysis Can Eliminate one Compressor Stage

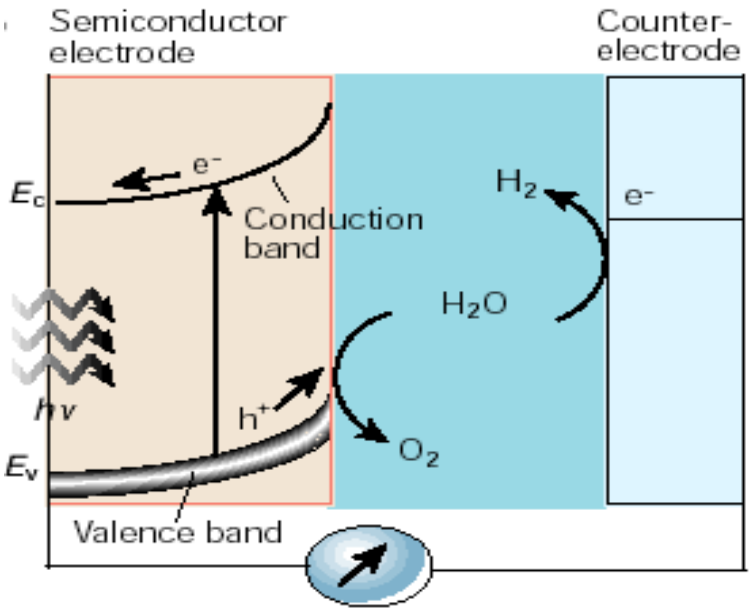
Table PES1 Technical Targets: Water Electrolysis[1]					
Characteristics		Units	2 kg/day Refueling Station Calendar Year 2010		
			Small Scale DOE Target	Estimated Actual for Mechanical Compression	Using 5,000 psi electrolysis(*)
Power Conversion	Cost	$/kg	0.12	0.12	0.12
	Energy Efficiency	% (LHV)	98	98	98
Cell Stack	Cost	$/kg	0.30	0.30	0.30
	Energy Efficiency	% (LHV)	79	79	79
Balance of Plant	Cost	$/kg	0.10	0.10	0.10
	Energy Efficiency	% (LHV)	98	98	98
Compression	Cost	$/kg	0.09	0.45	0.00
	Energy Efficiency	% (LHV)	93	85	N/A
Storage and Dispensing	Cost	$/kg	0.12	0.12	0.12
	Energy Efficiency	% (LHV)	99	99	99
Electricity	Cost	$/kg	2.80	2.87	2.80
Total	Cost	$/kg	3.80	4.18	3.71
	Energy Efficiency	% (LHV)	70	69.7	70

(*These are estimates to be confirmed when testing and data analyses are complete)

Mechanical Compression
- Capital Costs are High
- Lifetime/Durability is Low
- Efficiency is Fair-to-Good
- Only small improvements predicted in near-term

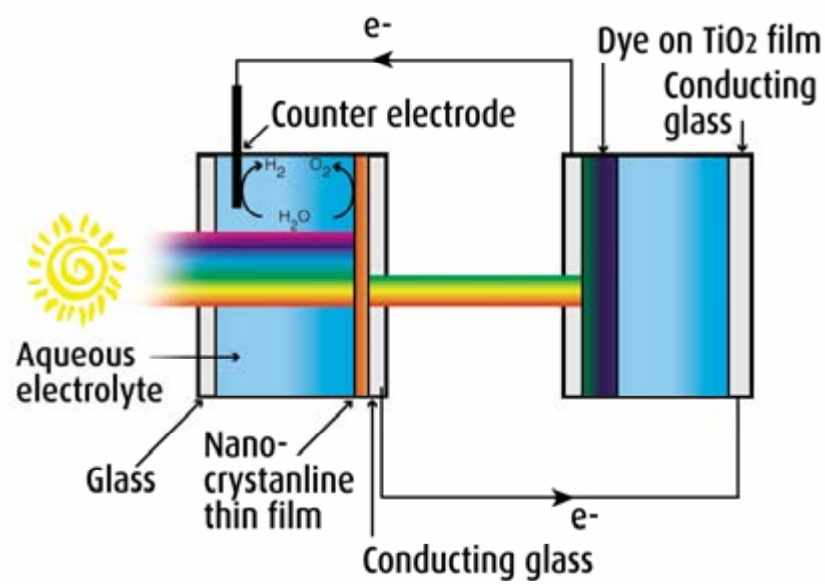
High Pressure Electrolysis
- Cost Reductions Being done (applies at Low Pressure too)
- Potential for Long Lifetime/Durability
- Potential for High Efficiency

Photo-Electrochemistry Devices



- Light photon absorbed by semi-conductor
- Energizes electron from valence band to conductance band
- Energy required is material band-gap (eV)
- Characteristic of the material

- UV light has highest energy (eV)
- Energy above band-gap triggers electron
- Electrons driven away
- Resulting “hole” used for O_2 evolution



Hydrogen Safety

1. The most significant potential hazard is a release of hydrogen due to loss of containment as a result of component failure.

<u>This poses two events of about equal severity</u>

-Potential for injury due to exposure of a high-pressure (6250 psig) gas stream or debris

-Potential for fire upon release of hydrogen

2. This potential hazard is being mitigated by the following:

-Siting per NFPA 55 requirements (incorporates NFPA 50A)

-Hydrogen storage vessels meet the ASME Boiler Pressure Vessel Code Section VIII, Division 1 requirements (Appendix 22)

-The hydrogen piping is tested per ASME B31.3 requirements

-The PEM electrolyzer meets NFPA 496

-No unclassified electrical components (ignition source) within 15 feet of hydrogen storage (motor starters are housed in explosion proof cabinets)

-Hydrogen venting per the guidelines of CGA 5.5 – Hydrogen vent systems

-Relief valves are appropriately sized and placed at locations where there is a potential for over pressurization. ASME approved relief valves used where mandated

(continued on next slide)

Hydrogen Safety (cont)

-Predominant connection types are 'medium pressure cone & thread fittings' rated to 20,000 psig

-Breakaways provided for dispensing hose

-Dispensing hose has MAWP of 7,700 psig (530 barg) & burst pressure ratio is 6:1

-Emergency stops (E-stop) available for all the units along with a remote e-stop. Pressing any one e-stop shuts down the operation of entire fueling station

The most likely accident scenario for this project comes about from operator/driver error.

-Driver inadvertently drives away with the fueling nozzle attached to vehicle

-Driver/Operator smokes near the dispensing area during vehicle fueling

The risk associated with this potential accident will be reduced by:

-Training the vehicle/fueling station operators who fuel the hydrogen-powered vehicles

-Using a dispensing system with a breakaway on the fueling hose and invoking automatic shutdown should a driver inadvertently drive away with the nozzle connected to the vehicle

-Requiring a security password to operate the fueling dispenser and requiring that the fueling nozzle interconnects be electronically verified before hydrogen fueling can commence

-Installing 'No smoking' signs near the dispenser

Technical Accomplishments/ Progress/Results

Basic filling station work

- The hydrogen filling station has been assembled, tested, and is awaiting installation at the site.
- Complete operational and monitoring plans have been developed for the system.
- Incorporation of a high-pressure electrolyzer has been laid out for pad accommodation.
- PV system for driving all has been designed.
- Work on converting two utility vehicles to hydrogen use is well underway.

Technical Accomplishments/ Progress/Results

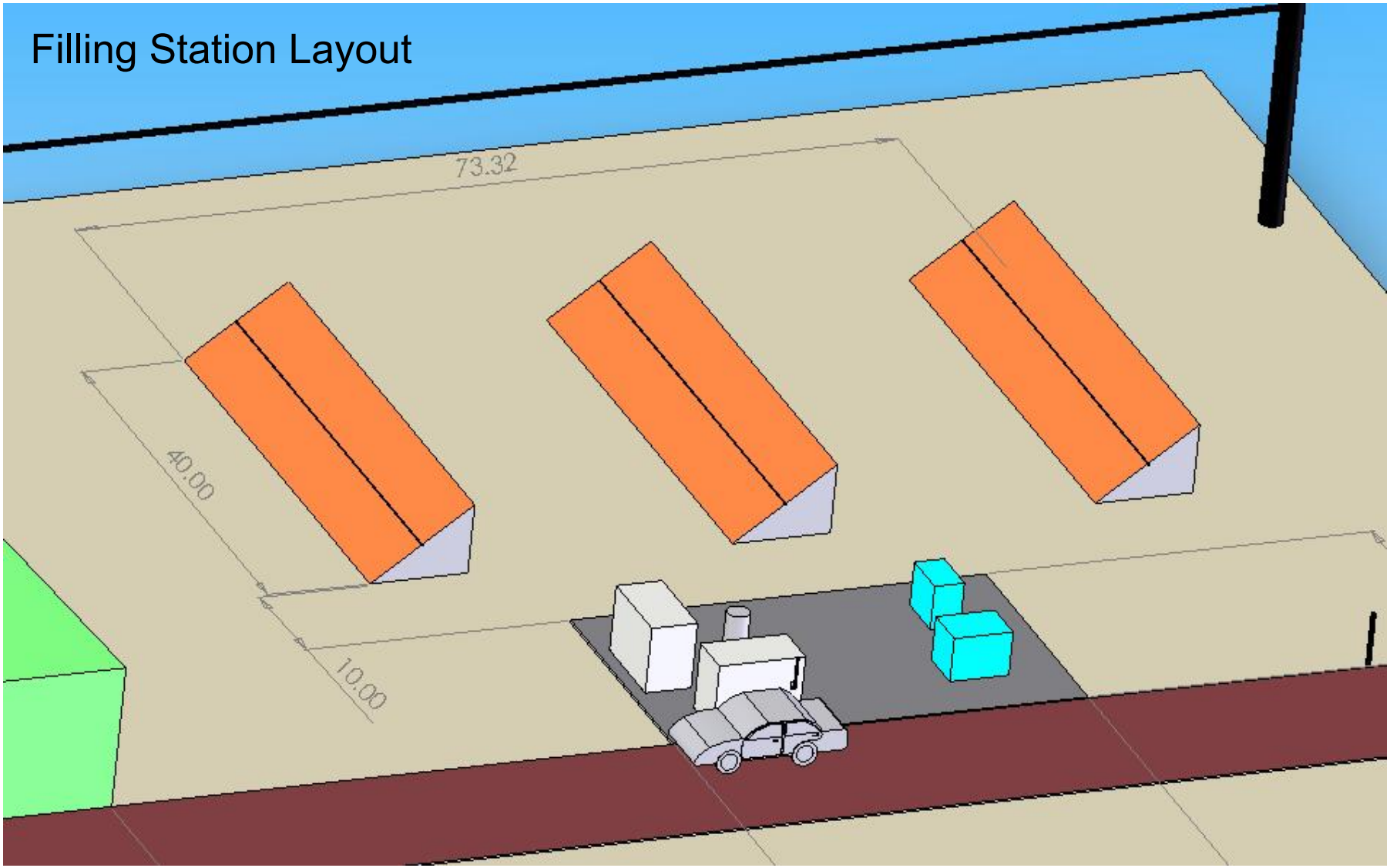
Other work (PEM Electrolysis, TC=Tandem Cell)

- (PEM) Development of a high pressure electrolyzer is underway.
- (TC) Identified materials for light harvesting capability (Fe, W, Ti) for absorbance in range 300-600nm
- (TC) Other materials identified include doped TiO_2, CdS, p-type semiconductors for direct hydrogen generation
- (TC) Identified polymer candidates and blends in low and high temperature regimes (< 300˚C polyphenylene sulphide, > 300˚C polyimide)

Technical Accomplishments/ Progress/Results

Other work (PEM Electrolysis, TC=Tandem Cell)

- (TC) Feasibility study performed for in house production of ITO/FTO coated substrates
- (TC) Initial results from CFD study for electrolyte flow and temperature control
- (TC) All equipment for material Altair characterizations has been ordered
- (TC) Nano scale photocatalyst development underway, includes glass electrode deposition at low temperature



Key: denotes PV system, denotes low pressure electrolyzer system, denotes high pressure electrolyzer system, denotes existing CNG facility

Technical Accomplishments/ Progress/Results

- Completed Design for PV-Electrolysis Fueling Station using 200 psig electrolyzer
- Hydrogen Fueling Station Installed and Tested at in-house Site (Wallingford, CT)
- Completed Design for Hydrogen Fueling System that utilizes a 2,000 psig high pressure PEM electrolyzer
- Completed Design for Integrating High Pressure PEM Electrolysis system with Low Pressure Electrolysis Fueling System from Phase I
- Fueling Station Site Plan Completed for Las Vegas Installation

Air Products Dispenser and H_2 Storage

Proton's PEM Electrolyzer, DI Water System, and Data Monitoring

Hydrogen Fueling Station Installed at Proton Energy Systems (Wallingford, CT)

Pure Electric to Fuel Cell Hybrid Electric Vehicle Conversion

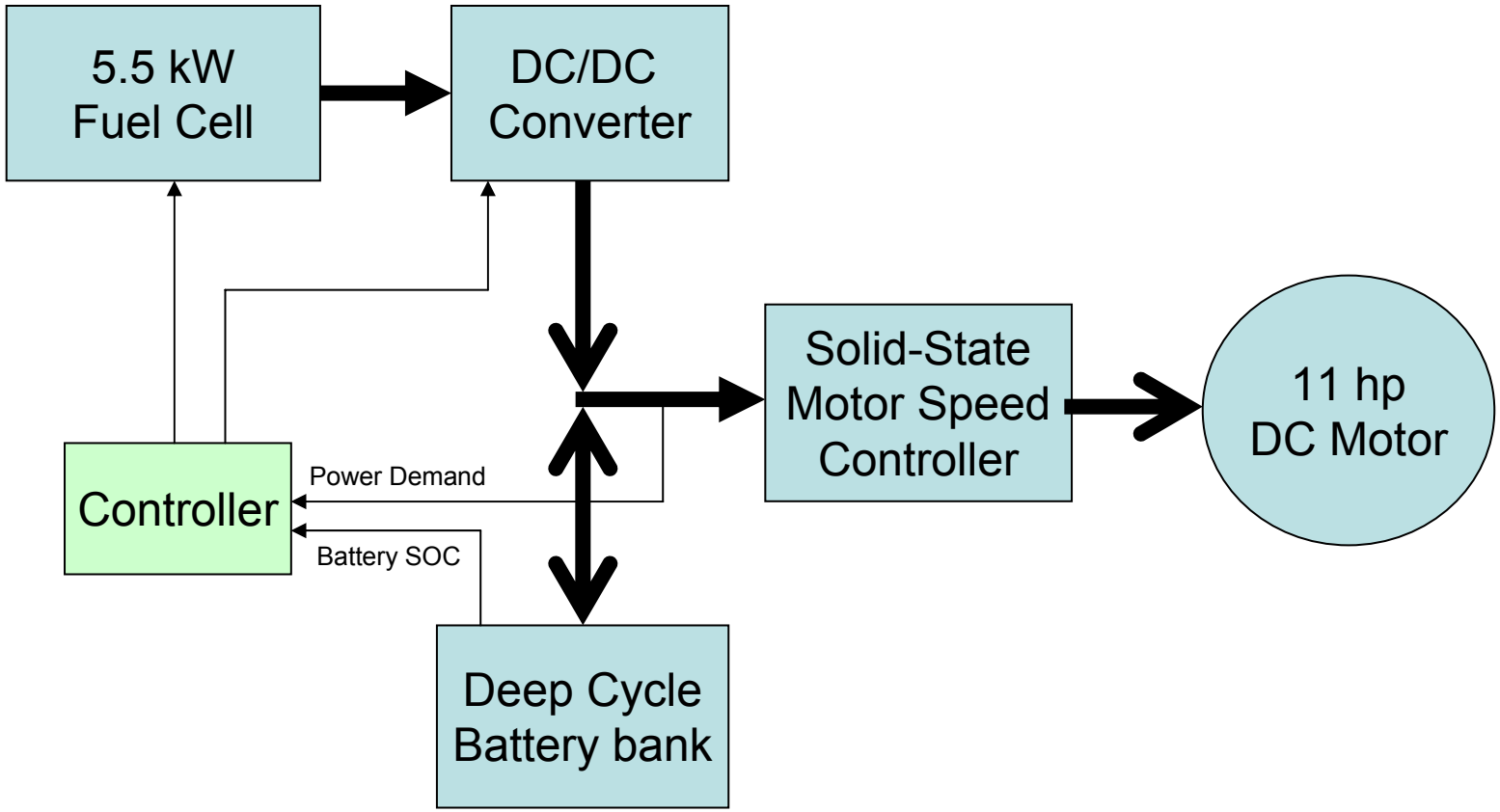
- Electrical System Specifications:
  - Twelve 6V, Deep- cycle, 244 Ah batteries
  - 72V DC motor - 11.5hp @ 4000 rpm normal duty.
  - 400amp, 72V solid-state speed controller
- Fuel Cell Specs.
  - DC power output: 2.5 kW - 5.5 kW max.
  - DC power efficiency: 51%
  - DC Voltage: 100 V @ no-load, 70 V @ full-load.
  - Size: 44x85x75 cm, Weight: 95 kg
  - External power: 300 W @ 48V for start-up.

Taylor Dunn

NUVERA FUEL CELLS

Fuel Cell Vehicle Preparation

Block Diagram--Fuel Cell Vehicle



ICE Vehicle Conversion

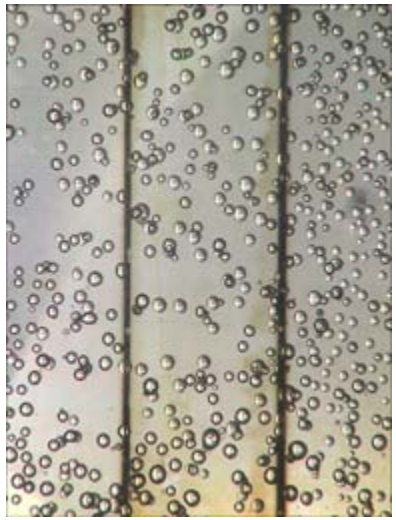
QuickTime™ and a
BMP decompressor
are needed to see this picture.

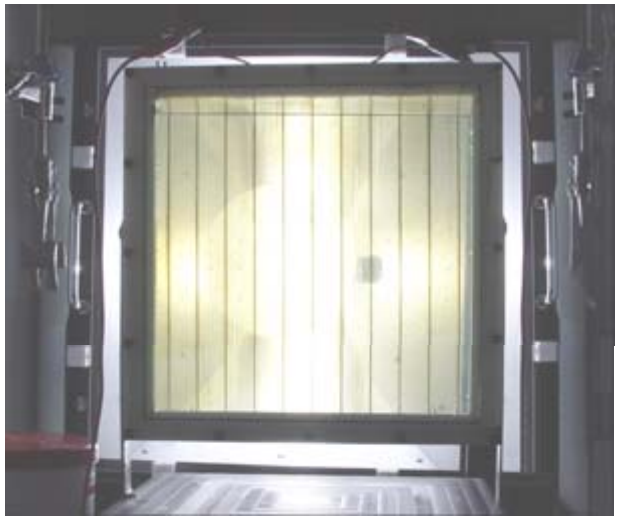
Engine being converted to direct cylinder injection of H_2

OPW
CLEANENERGY FUELING PRODUCTS

Laboratory Tandem Cell Test Units

25 cm scale

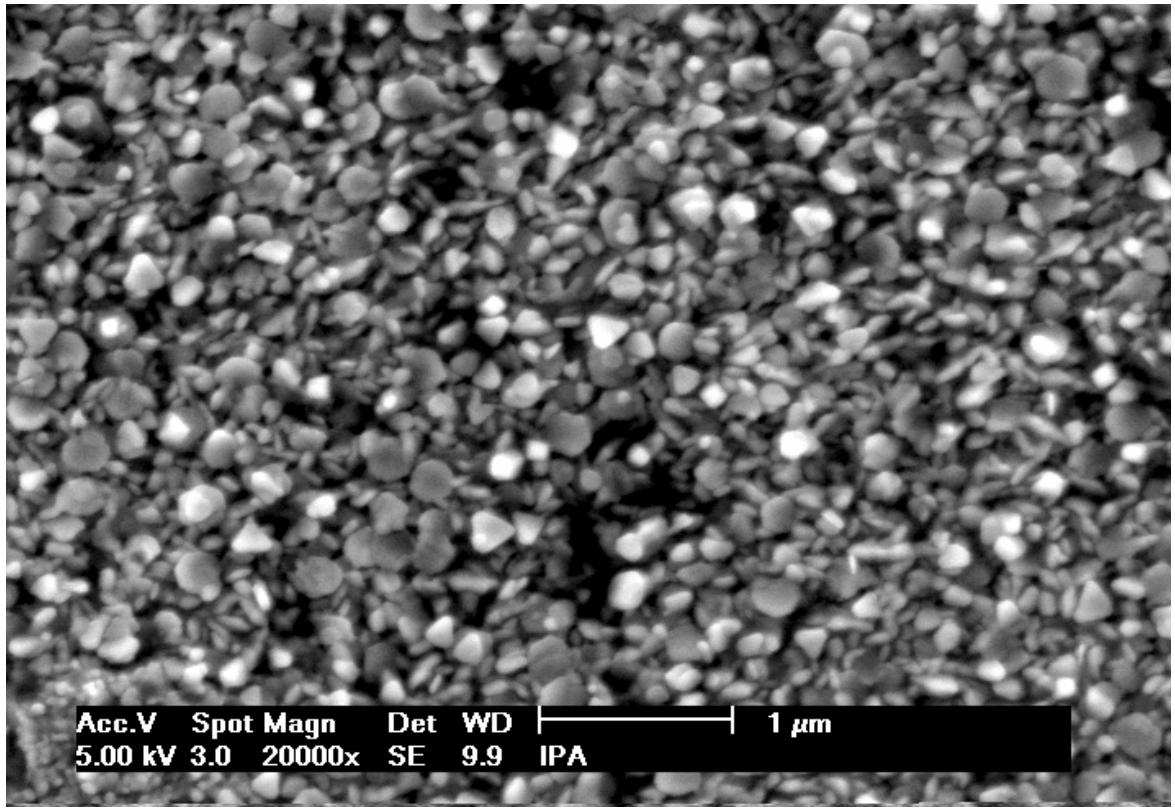




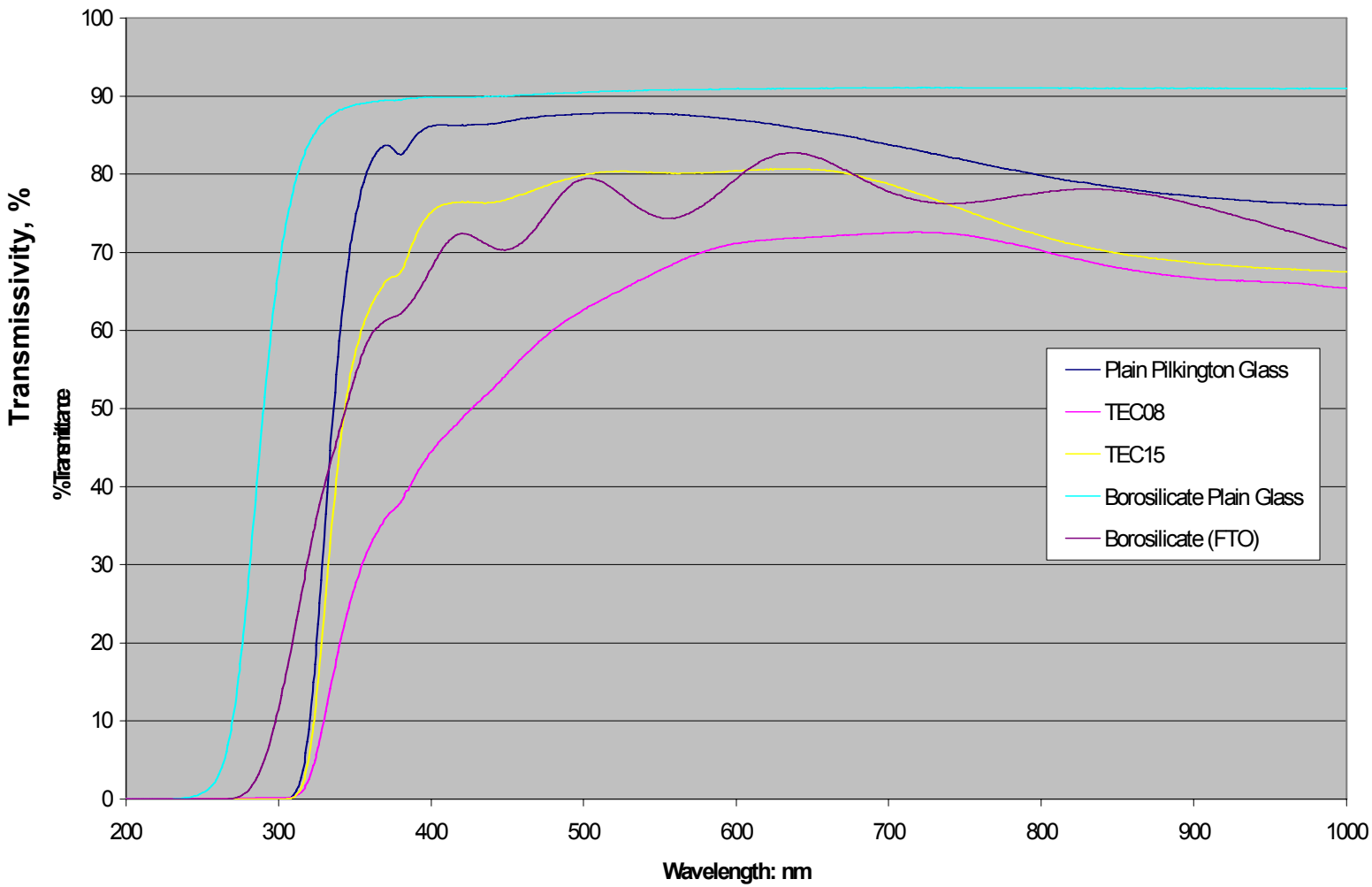
25 cm square Tandem Cell prototypes in sunlight from laboratory artificial source

Structure of Spray Pyrolyzed Films

- SEM α-Fe_2O_3 film (x 20,000)

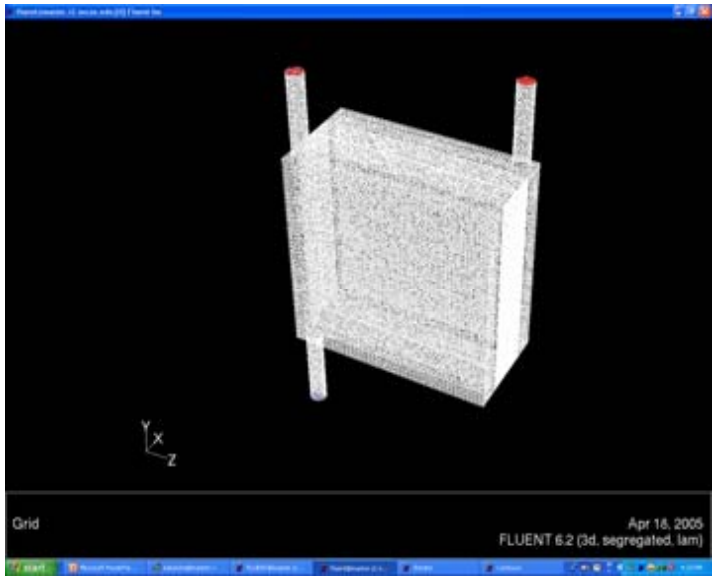


Glass Substrate UV/visible Spectra (TC)

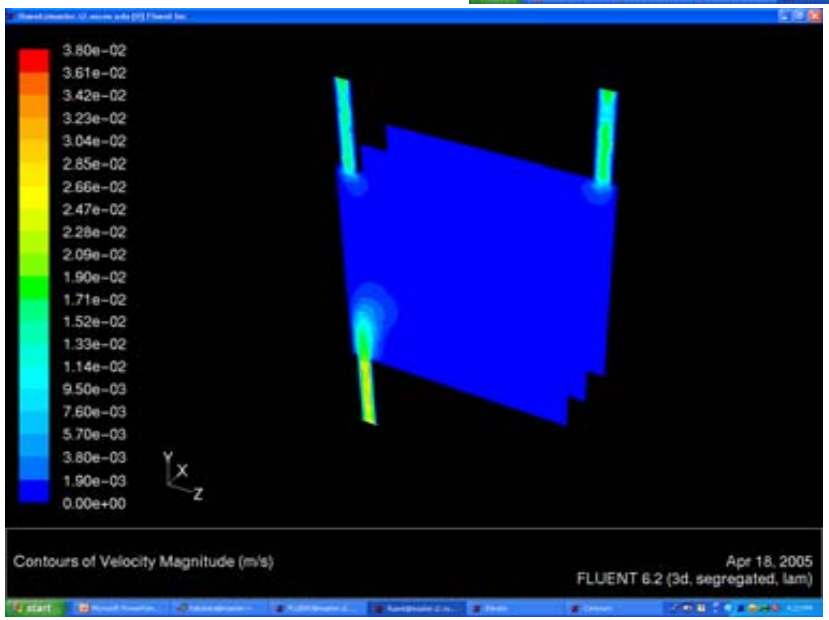


CFD Modeling of Tandem Cell Electrolyte Flow

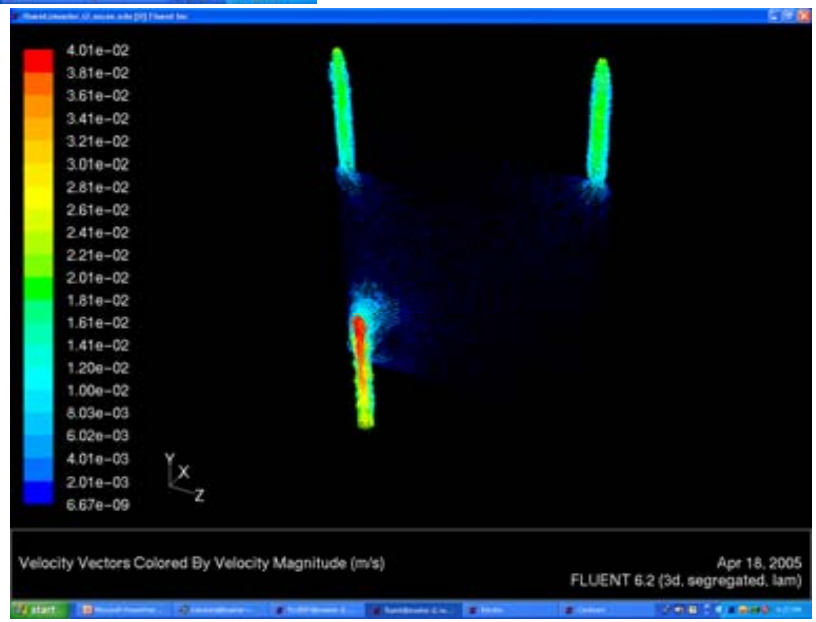
Computational Mesh



Velocity Magnitude Contours



Velocity Vectors



Responses to Previous Year Reviewers' Comments

- "Better detail desired on poster." We have attempted to do this here.
- "Three H_2 fueling stations in Nevada not communicating." Only aware of two in a 400 mile radius. We are attempting to work collaboratively with City of Las Vegas. Our concept is to use model for growing source and demand together.
- "Doesn't know the context of solar H_2." Unclear what is meant by this comment.

Future Work

FY 05

- Complete the installation of filling station by July 30
- Complete design of high pressure electrolyzer and evaluate performance.
- Complete the vehicle conversions
- Design electrolyte flow configuration in Tandem Cells

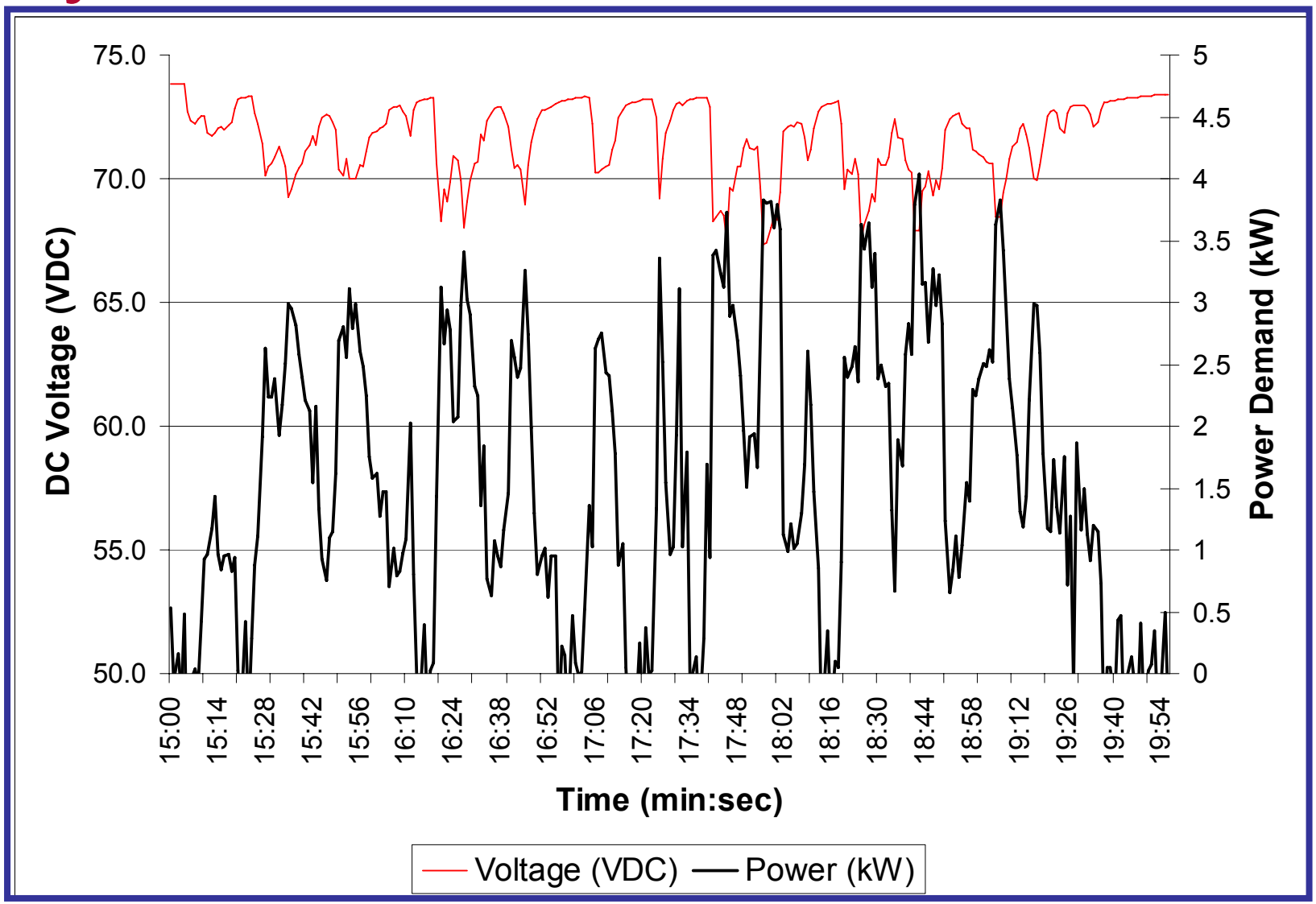
FY 06

- Monitor the general operations of the filling station and the vehicles to see how they perform compared to their design.
- Develop Tandem Cells into a market-ready product.
- Examine new concepts of using inexpensive generation and storage for applications to non-vehicular commercial applications of hydrogen.

Supplemental Slides

The following three slides are for the purposes of the reviewers only – they are not to be presented as part of your oral or poster presentation. They will be included in the hardcopies of your presentation that might be made for review purposes.

Sample of 5-Minute Driving Cycle Taylor-Dunn Vehicle



Publications and Presentations

R. Boehm, Y. Baghzouz, and T. Maloney, “A Strategy for Renewable Hydrogen Market Penetration,” 2005 International Solar Energy Conference, Orlando, Florida.

Some of the Students and Staff of the UNLV Center for Energy Research