



# **U.S. Department of Energy - FreedomCAR & Vehicle Technologies Program**

## **Hydrogen Fuel Pilot Plant and Hydrogen ICE Vehicle Testing**

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***2004 Fuel Cell Seminar – San Antonio  
Session 5B - Hydrogen***

# Advanced Vehicle Testing Activity (AVTA)- Background

- **AVTA part of DOE's FreedomCAR and Vehicle Technologies Program**
- **AVTA Goal - Benchmark & validate the performance of light-, medium-, & heavy-duty vehicles that feature one or more advanced technologies, including:**
  - **ICE's burning advanced fuels, such as 100% hydrogen and hydrogen/CNG-blended fuels**
  - **Hybrid electric, pure electric, & hydraulic drive systems**
  - **Advanced batteries & engines**
  - **Advanced climate control, power electronic, & other ancillary systems**

# **APS Alternative Fuel (Alt-Fuel) Pilot Plant & Vehicle Testing - Partners**

- **Electric Transportation Applications (ETA)**
- **Arizona Public Service (APS)**
- **DOE's AVTA**
- **Idaho National Engineering and Environmental Laboratory (INEEL) – manages these activities for the AVTA**

# APS Alt-Fuel Pilot Plant & Vehicle Testing - Objectives

- Evaluate the safety & reliability of operating ICE vehicles on hydrogen & H/CNG blended fuels
- Evaluate hydrogen fueling infrastructure costs
- Quantify hydrogen & H/CNG ICE vehicle costs, performance, & emissions



# APS Alt-Fuel Pilot Plant - Layout

Hydrogen Fuel Cell

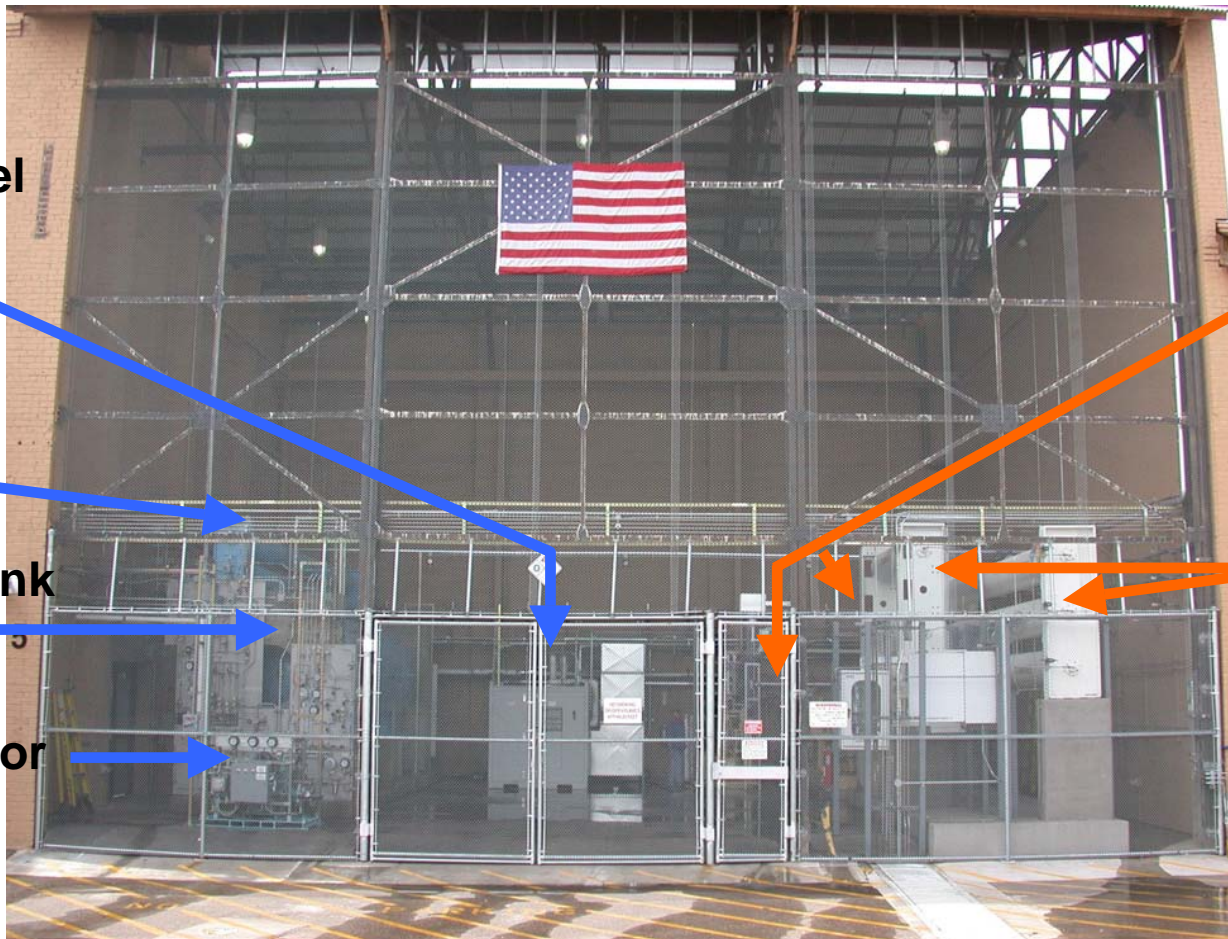
2 H2 High psi tanks

H2 Low psi tank

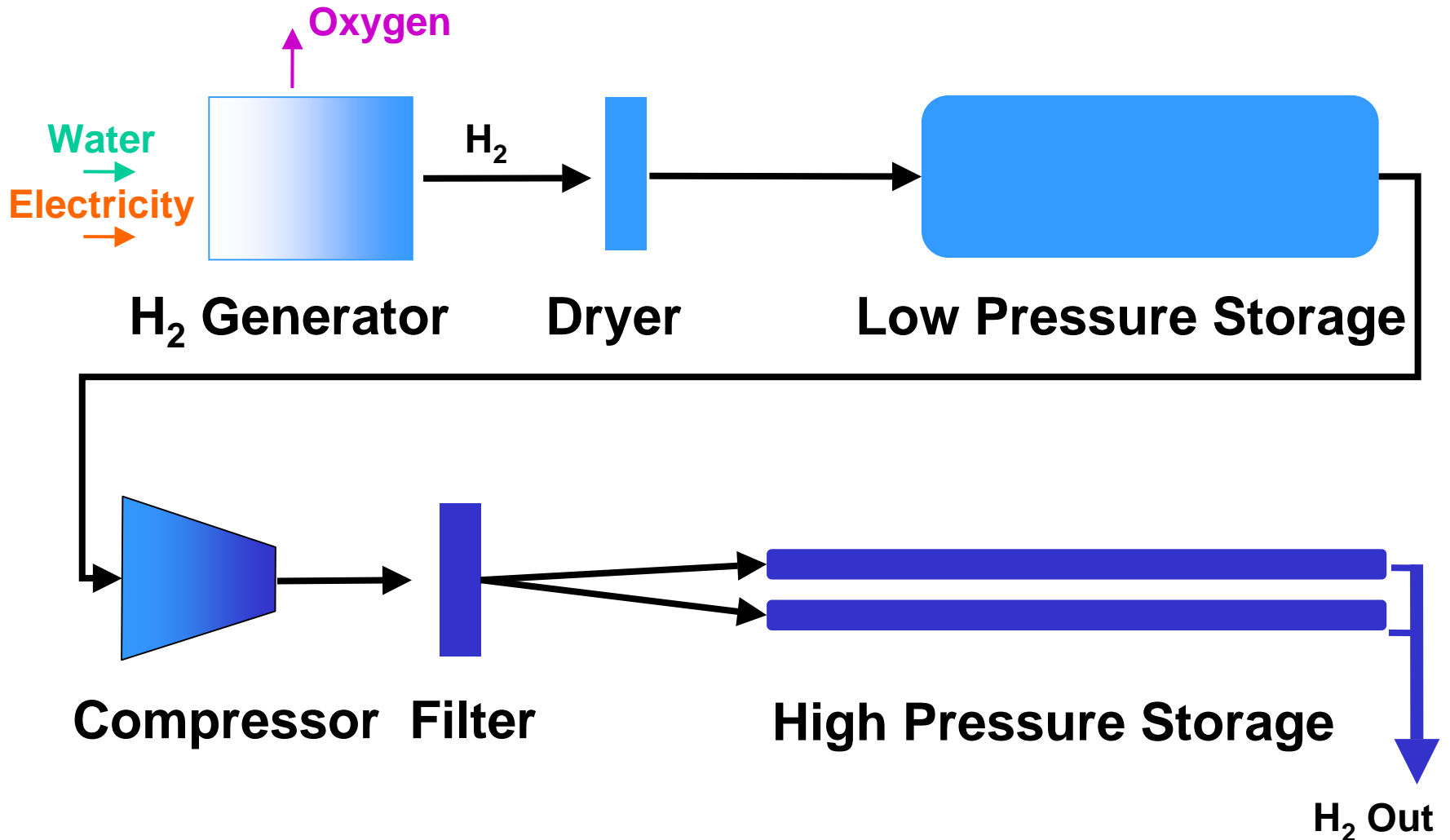
H2 Compressor

2 CNG Compressors

6 CNG Tanks  
3 psi levels



# APS Alt-Fuel Pilot Plant - Hydrogen System



# APS Alt-Fuel Pilot Plant – Hydrogen System

- Proton Energy Systems' HOGEN PEM stationary fuel cell operating in reverse
  - Model – HOGEN 300
  - 20 cells
  - Uses 57 kW, 480 V, 150 A, 3 phase
  - 300 SCFH hydrogen output @ 150 psi
  - 17 kWh per 100 SCF hydrogen
- Hydrogen dryer
  - Lectrodryer model GAS-B12
  - 300 SCFH
  - -80°F dew point
  - 120-V



# APS Alt-Fuel Pilot Plant – Hydrogen System

- **Hydrogen compressor**
  - Pressure Dynamic Consultants - Pdc Machines
  - Model: Pdc-4
  - 5 hp, 480 V, 10 A, 3 phase
  - Oil-free triple diaphragm
  - Two-stage compression
  - 300 SCFH @ 6,100 psi
- **Norman hydrogen filter locations**
  - High- & low-pressure storage outlets
  - Dryer inlet & outlet
  - Compressor outlets
- **Hydrogen - 99.9997% purity**





# APS Alt-Fuel Pilot Plant - Hydrogen System

- Low pressure hydrogen storage (lower tank)
  - 8,955 SCF @ 150 psi
- High pressure hydrogen storage (upper 2 tanks)
  - 17,386 SCF @ 6,000 psi



# Low Pressure Hydrogen Storage Tank

- **8,955 SCF @ 150 psi**
- **Rated for 250 psi @ 125°F**
- **Carbon steel, 6 ft. 11 in. inside diameter, 19 ft. long**
- **Water volume of 6,565 gal.**
- **Manufactured by Trinity Industries under ASME Pressure Vessel Code, Section VIII, Division 22**
- **ASME safety relief valve rated @ 165°F piped to vent stack**

# High Pressure Hydrogen Storage Tanks

- **17,386 SCF @ 6,000 psi (total both tanks)**
- **Rated for 6,667 psi @ 200°F**
- **Seamless horizontal carbon steel, 16 in. outside diameter, 28 ft. long**
- **Water volume of 405 gal. (total both tanks)**
- **Manufactured by CP Industries under 1998 ASME Pressure Vessel Code, Section VIII, Division 1, Addendum 1999, Appendix 22 (SF3)**
- **ASME safety relief valve rated @ 6,667°F piped to vent stack**

# APS Alt-Fuel Pilot Plant - Auxiliary Systems

- **Water Purification - 215 gal/day, 1.0- $\mu$  exit filter**
- **Control Air - 100 cfm compressor, 90 psi**
- **Chiller - 293,000 Btu/h,**
- **Nitrogen - Air/hydrogen buffer gas - production, piping, compression & 600 scf storage. 97% purity @ 100 psi**
- **Vacuum - portable pump used to reduce purge cycles**
- **Helium - vent stack purging**
- **Vents - fabricated from 0.5 in. 304 stainless steel tubing, 3 in. schedule 40 stainless steel pipe**

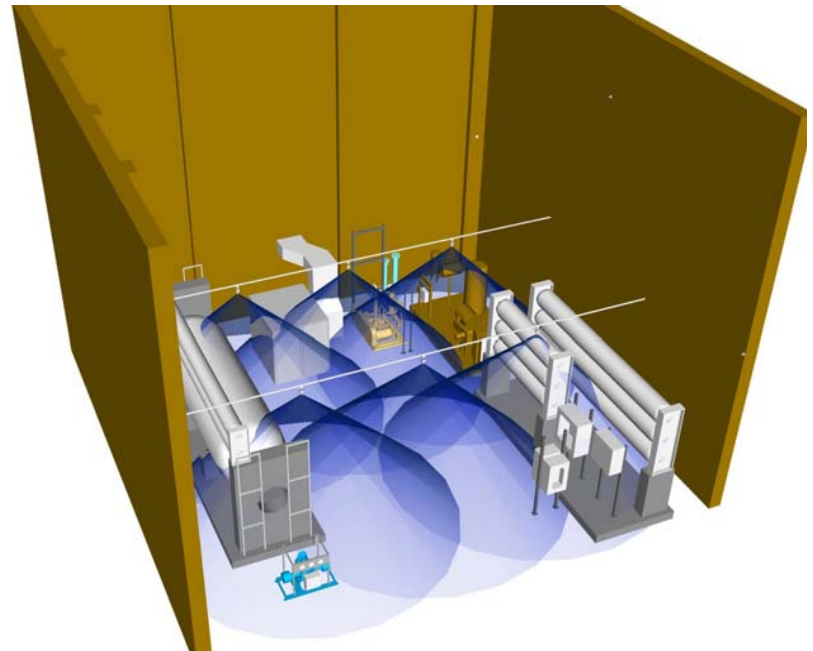
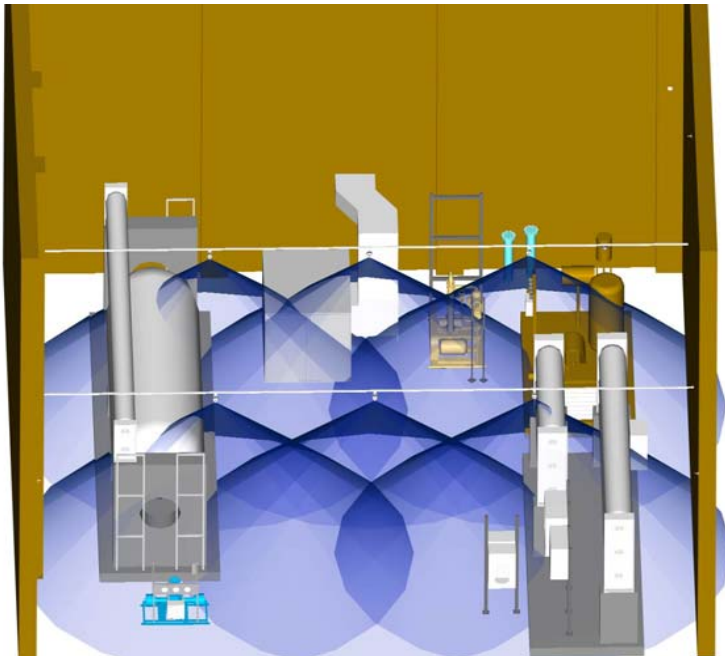
# APS Alt-Fuel Pilot Plant - Auxiliary Systems

- **Emergency Shutdown System (EMS)**
  - Ultra-fast IR/UV detectors
  - Combustible gas detectors
  - Manual (5) and remote trips
  - Vent stack temperature monitor
  - Alarms horns and strobe lights
  - Vent stack fire suppression



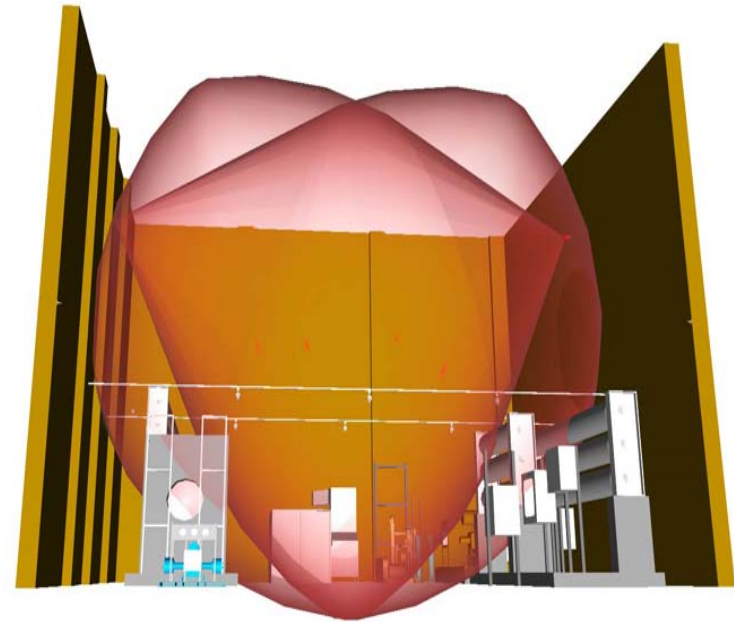
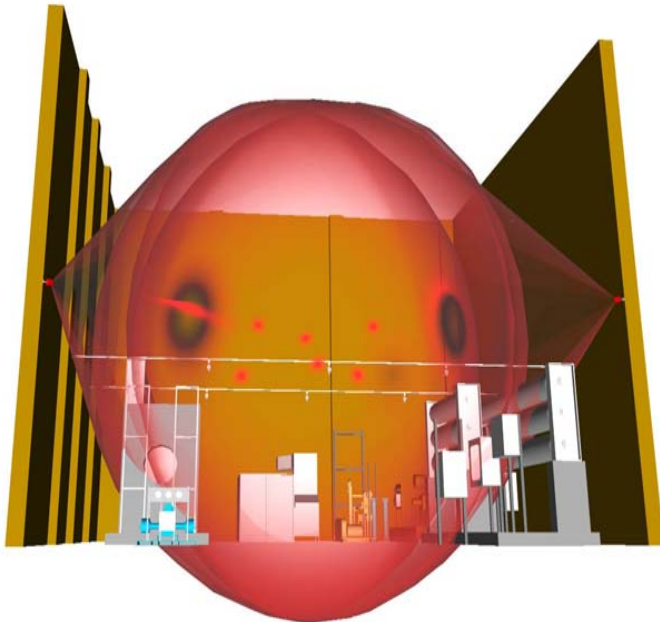
# APS Alt-Fuel Pilot Plant - EMS

- **Six combustible gas detectors (Det-Tronics RS 8471)**
- **Monitors hydrogen & natural gas in 1% increments of lower flammability limits (LFL)**
- **Alarm condition @ 25% of LFL reached**
- **Emergency shutdown when 50% of LFL reached**



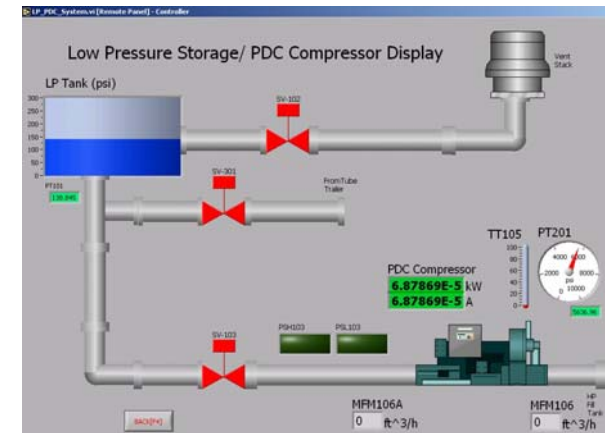
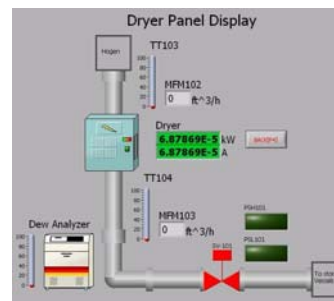
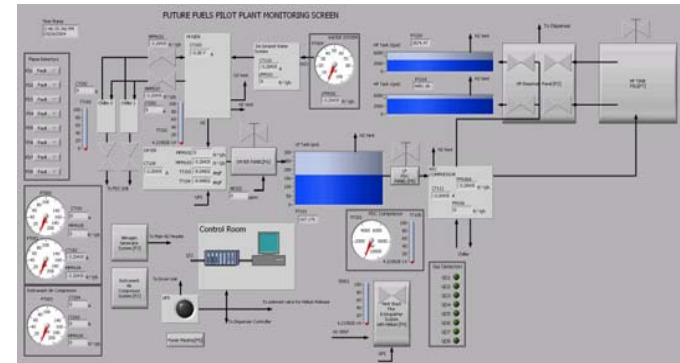
# APS Alt-Fuel Pilot Plant - EMS

- Two mid-level (35 feet) & four corner IR/UV flame detectors (Spectrex 20/20LB units)
- 1 @ fuel dispenser unit
- If flame detected, emergency shutdown initiated within 3 milliseconds



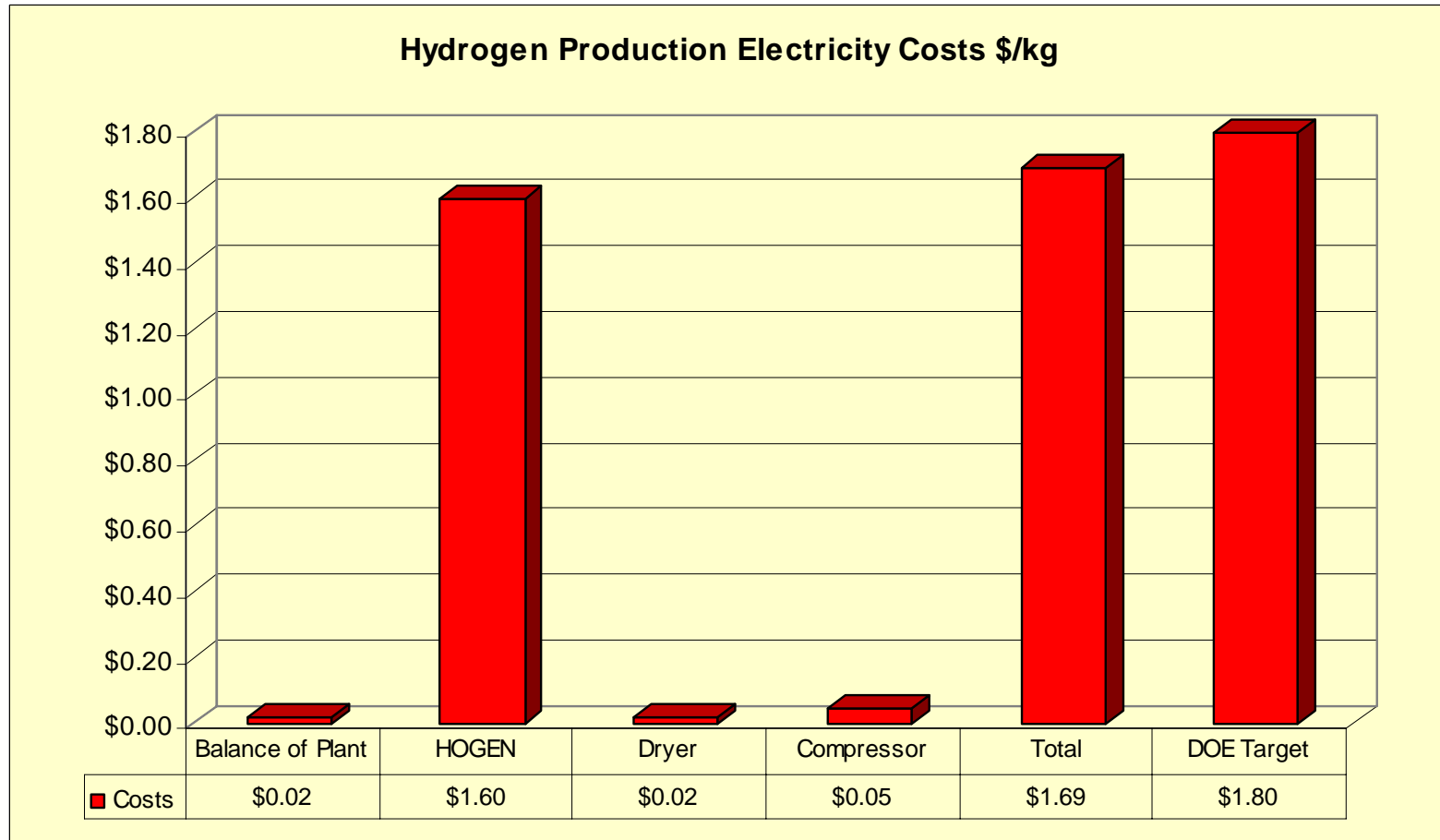
# APS Alt-Fuel Pilot Plant - Monitoring System

- Real-time station & component monitoring @ 50 monitoring nodes (100 @ completion)
- Fuel quantities collected and costs calculated for pure hydrogen and H/CNG blended fuels
- Electric powered equipment
  - Voltages & currents
- Select process temperatures
- Major process parameters
  - Pressures & flows
- LabVIEW-based custom system



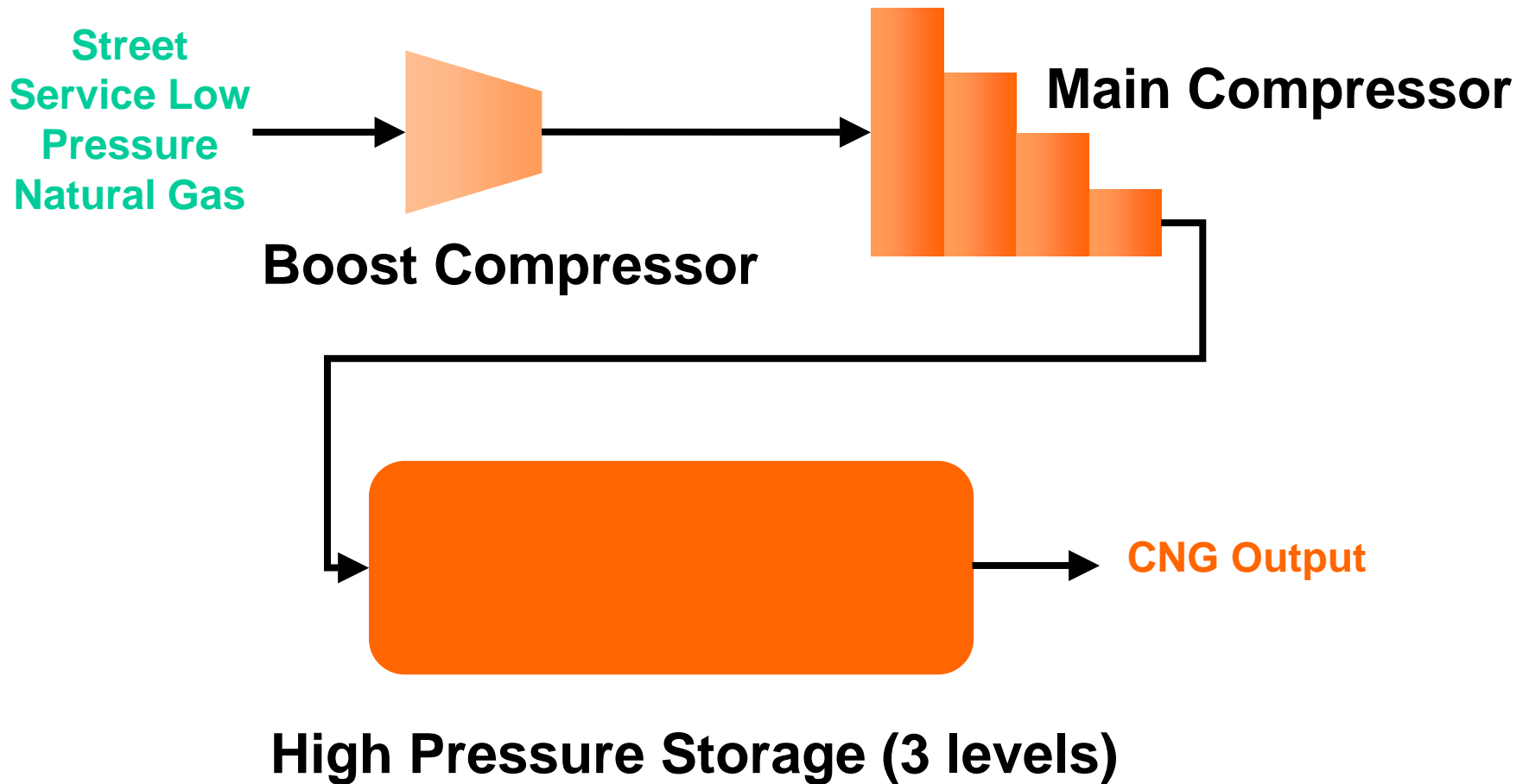


# APS Alt-Fuel Pilot Plant – Monitoring System



**DOE 2005 Electricity Target (\$1.80) for a refueling station producing 250 kg/day. APS Hydrogen Production Electricity Cost based on APS published commercial/industry rate of \$0.02/kWh for 5 MW & larger.**

# APS Alt-Fuel Pilot Plant - CNG System

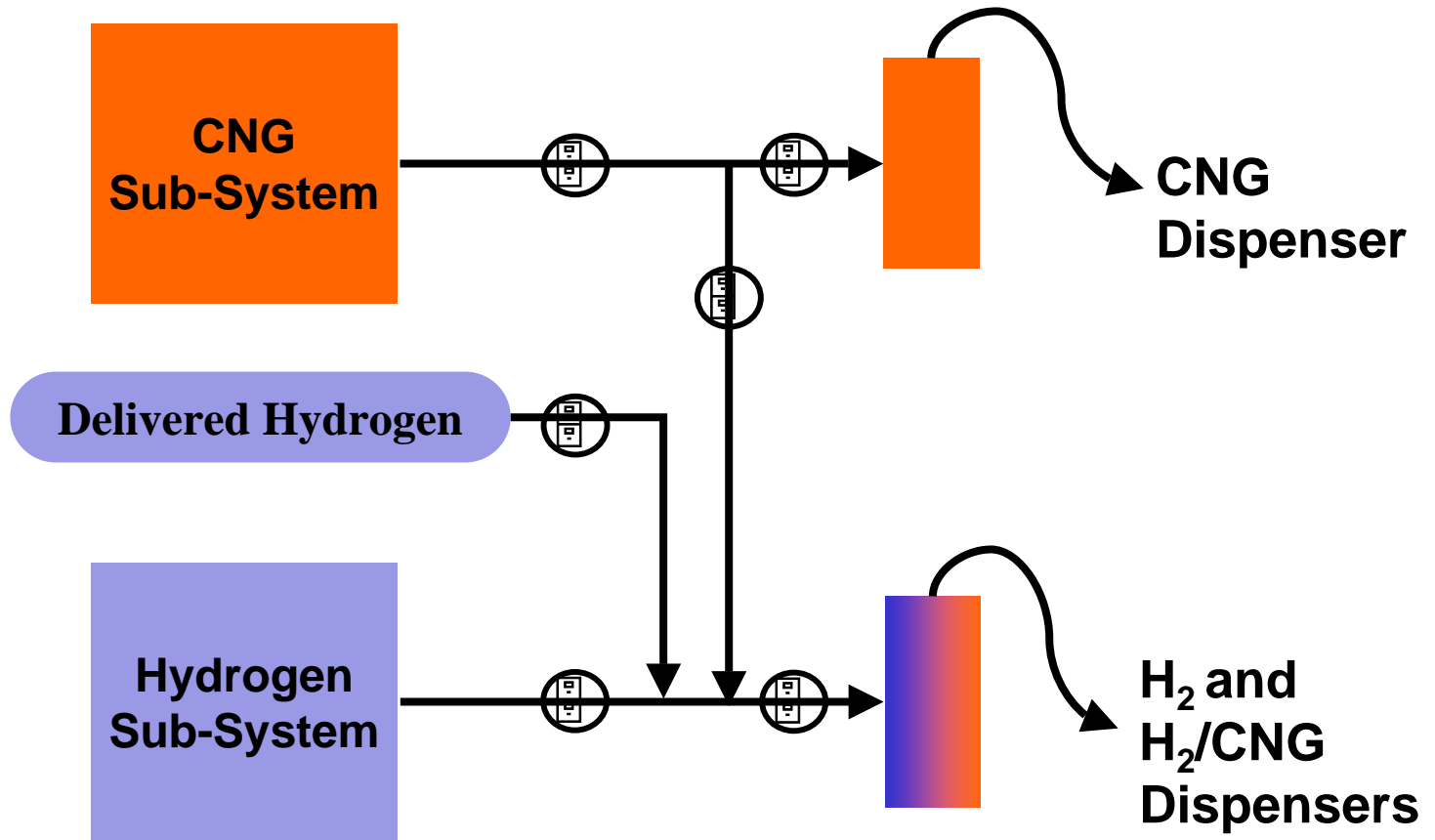


# APS Alt-Fuel Pilot Plant - CNG System

- **CNG Boost Compressor**
  - Hy-Bon model AC-8DB
  - 300 SCFM @ 60 psi
- **CNG Main Compressor**
  - Gemini model HPSS-4
  - 350 SCFM @ 5,000 psi
  - Multi-Stage Piston
- **CNG Storage/Pressure – 6 tanks**
  - 3 Low: 11,079 SCF @ 3,600 psi
  - 2 Medium 5,711 SCF @ 4,500 psi
  - 1 High: 5,711 SCF @ 5,000 psi
  - Manufacturer: CP Industries



# APS Alt-Fuel Pilot Plant – Dispenser System



# APS Alt-Fuel Pilot Plant - Fueling Dispensers

- Dispense pure hydrogen, pure CNG fuel, or H/CNG
- Fueling Technologies Inc. - 2 fuel dispensers
- 1 Dual dispenser: 2 nozzles, 1 hydrogen (5,000 psi) and 1 H/CNG blended fuels (3,600 psi)
  - WEH (Germany) nozzle and hose assemblies
- 1 Dual dispenser: both nozzles CNG (3,600 psi)
  - Furon/Synflex process/vent hoses
  - Shurex NCV1 nozzle



# APS Alt-Fuel Pilot Plant - Fueling Dispensers

- Includes metering and electronic billing Interface
- Permitted for motor fuel dispensing



# APS Alt-Fuel Pilot Plant - Future Testing

- **New Generation Hydrogen Production Unit**
  - Proton PEM HOGEN 228
  - 228 scfh @ 218 psi
  - 34 cells/stack, 3 parallel stacks
- **New High Pressure Compressor**
  - PDC 4 frame
  - Oil-free triple diaphragm
  - Two-stage compression
  - 30 hp, 480 V, 3 phase
  - 1,250 SCFH @ 6,000 psi



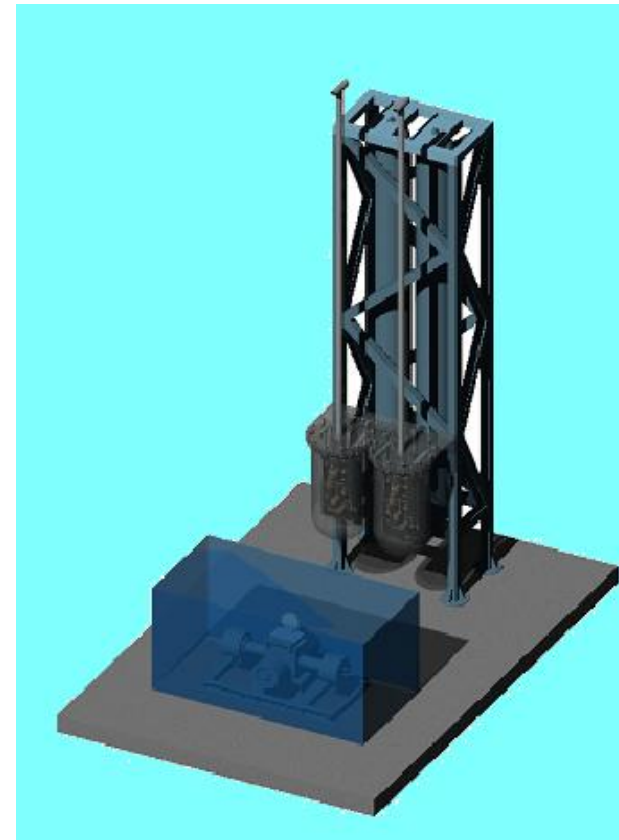
# Next Generation Station Design

- **Driven by commercial fueling station design requirements**
  - **Reduced setbacks to allow siting on a commercial corner**
  - **Reduced operator training to allow operation by service station personnel or vehicle operators**
  - **Reduced hazards to minimize the maximum potential accident**
  - **Multiple layers of safety to significantly reduce operating risk**



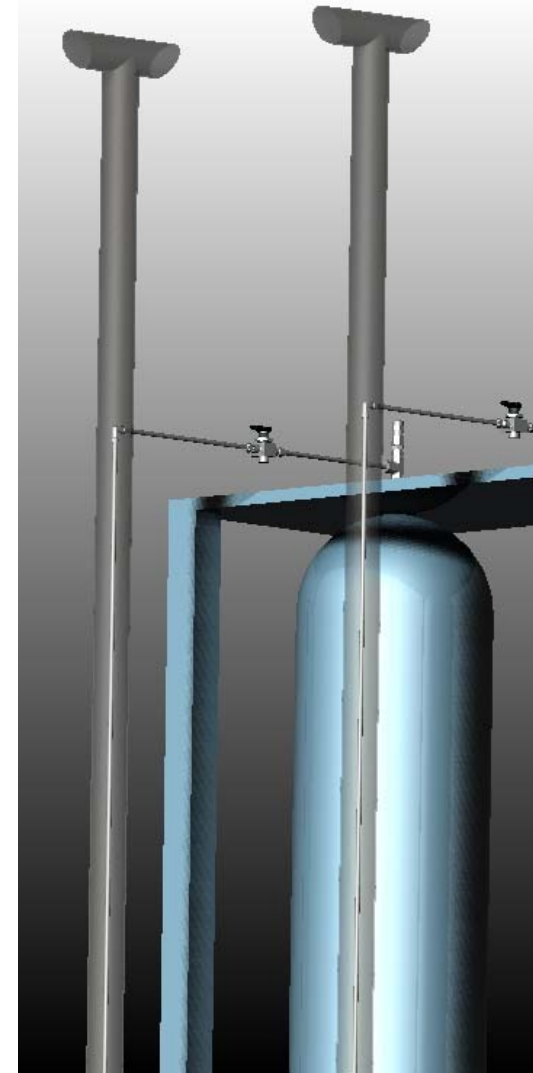
# Next Generation Station Design

- **Coaxial Containment System™**
- **Expandable modular design**
- **Envelopes most severe environmental conditions**
- **Exhaustive safety analysis to support permitting**
- **Zero setback requirements for flexible siting**
- **Shop assembled skid design**
  - **Assembly by ASME shop**
  - **Field welding minimized**



# Next Generation Station Design - Coaxial Containment System™

- **Double wall piping system**
  - Shields process piping within a pressure containing pipe
  - Contains pressure waves resulting from any gas ignitions
  - Redirects any detonations to benign location
  - Allows inerting of annulus to prevent gas ignition
  - Eliminates need for blast setback
  - Protects process pipe from vandalism



# Hydrogen & H/CNG ICE Vehicle Testing

- Initial ICE hydrogen & H/CNG vehicle testing
  - Ford F150 up to 30% H/CNG (continues testing)
  - Ford F150 up to 50% H/CNG
  - 100% hydrogen Mercedes Benz van (operating)
  - Dodge van on 15% H/CNG (continues testing)



# Hydrogen/CNG ICE Vehicle Testing

- **Ongoing hydrogen & H/CNG ICE vehicle testing**
  - **8 APS fleet vehicles on 15% H/CNG - S-10s, Sierra pickups, Blazers, Dodge Ram van**
  - **16+ City of Phoenix (including Phoenix Fire Department) fleet vehicles on 15% H/CNG**
  - **Ford F150 30% H/CNG (tested @ 100% CNG, 15%H/CNG, and 30% H/CNG)**



# Hydrogen/CNG ICE Vehicle Testing

- Ongoing hydrogen ICE vehicle testing (cont'd)
  - Ford F150 - 100% hydrogen, 5.6 liter, 32 valve
  - Ford F150 – 100% hydrogen, 5.4 liter 16 valve
  - Adding F150 100% hydrogen, 5.4 liter 24 valve engine
  - Baseline, fleet & emissions testing
  - 250,000+ hydrogen test miles, 3,000+ successful fueling events



# Hydrogen Vehicle Fuel Storage

- **100% Hydrogen, 32 Valve, F150**
  - 100% hydrogen Dynetek tanks
  - aluminum inner vessel, carbon wrap
  - 5,000 psi tanks
  - 15 kilograms



# Hydrogen Vehicle Fuel Storage

- **100% Hydrogen, 16 Valve, F150**
  - 100% hydrogen Dynetek tanks
  - aluminum inner vessel, fiberglass wrap
  - 3,000 psi
  - 6 kilograms



# 30% H/CNG F150 Performance Testing

Fuel Blend	Time to 60 mph (seconds)	Fuel Economy (miles/gge)	Range (miles)
CNG	10.10	23.3	122
15% H/CNG	10.97	22.6	110
30% H/CNG	12.68	23.5	102





# 50% H/CNG F150 Emissions Testing

	Ave. FTP	Ave. Hwy	ULEV	SULEV
CO (g/mi)	0.864	0.097	1.93	1.0
CO <sub>2</sub> (g/mi)	373.85	248.24		
THC (g/mi)	0.062	0.0097		
NO <sub>x</sub> (g/mi)	0.033	0.017	0.06	0.02
MPG	14.28	21.57		
PM (g/mi)	0.0003	0.0006		



**Hydrogen Station Report, vehicle reports, this presentation, and the online hydrogen monitoring system are all available via:**

**<http://avt.inel.gov>**

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