Idaho National Laboratory

U.S. Department of Energy FreedomCAR & Vehicle Technologies Program

Hydrogen Pilot Plant, H2ICE Vehicle Testing, & INL Alternative Energy Vehicles (Advanced Vehicle Testing Activity)

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AVTA Presentation Outline

- **Arizona Public Service's Alternative Fuel (Hydrogen) Pilot Plant Design and Operations**
- **Hydrogen internal combustion engine vehicle testing**
- **Oil bypass filter system evaluation**
- **Diesel engine idling testing**
- **INL alternative fuel infrastructure**
- **INL alternative fuel fleet**
- **WWW information**

APS Alternative Fuel (Alt-Fuel) Pilot Plant - Partners

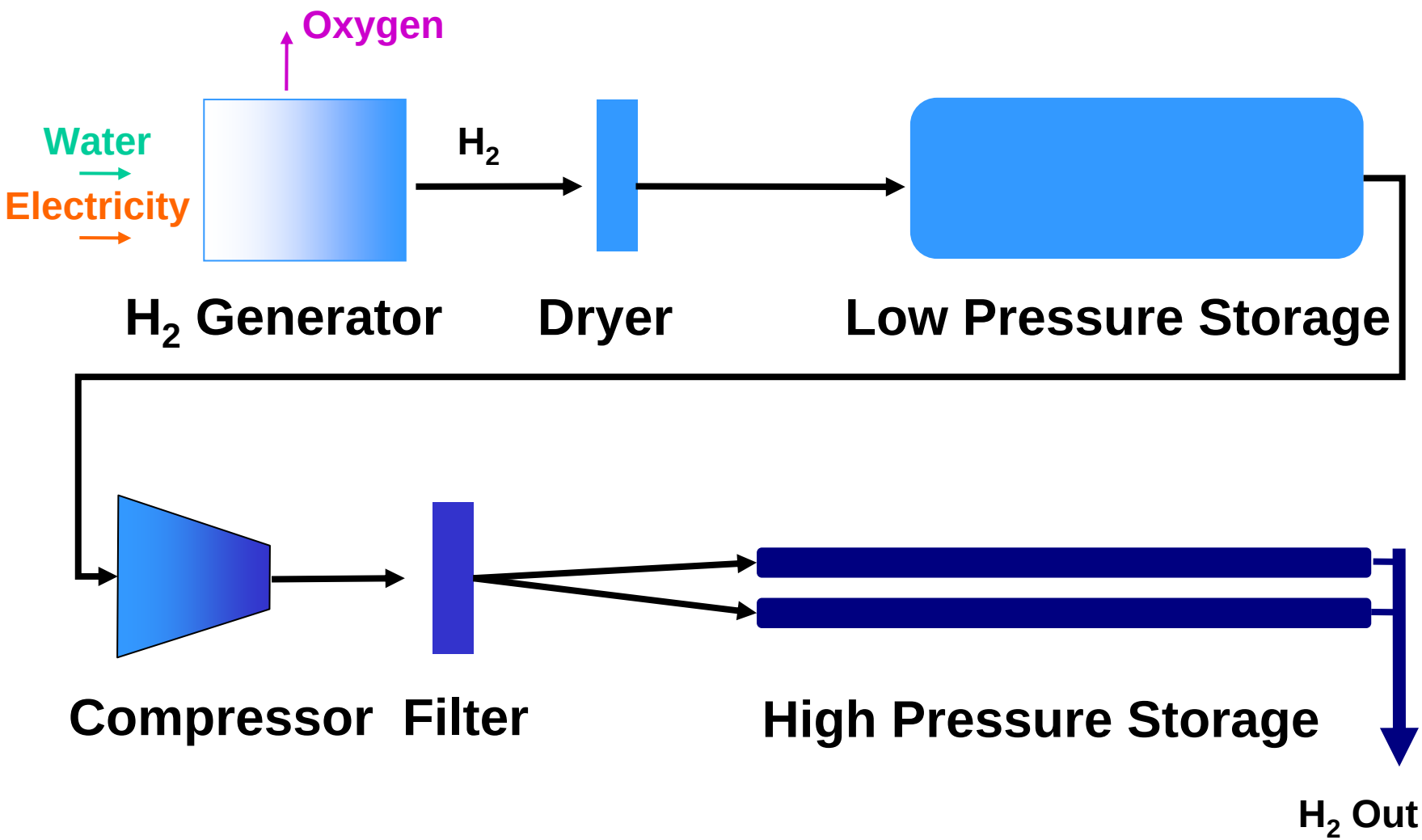
- Arizona Public Service (APS)
- Electric Transportation Applications (ETA)
- Idaho National Laboratory (INL)

- Started operations - 2002

Alt-Fuel Pilot Plant & Vehicle Testing - Objectives

- **Evaluate the safety & reliability of operating ICE vehicles on 100% hydrogen & hydrogen/compressed natural gas (H/CNG) blended fuels (15 to 50% H/CNG)**
- **Evaluate hydrogen fueling infrastructure costs**
- **Quantify hydrogen & H/CNG ICE vehicle costs, performance, & emissions**

Alt-Fuel Pilot Plant - Hydrogen Subsystem

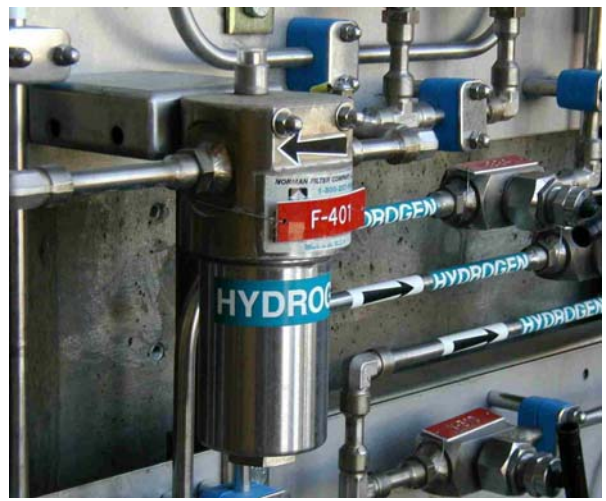


Alt-Fuel Pilot Plant – Hydrogen Subsystem

- **Proton Energy Systems' HOGEN PEM stationary fuel cell operating in reverse**
  - **300 scfh hydrogen output @ 150 psi**
  - **17 kWh per 100 scf hydrogen**
- **Hydrogen Lectrodryer**
  - **300 scfh**
  - **-80°F dew point**

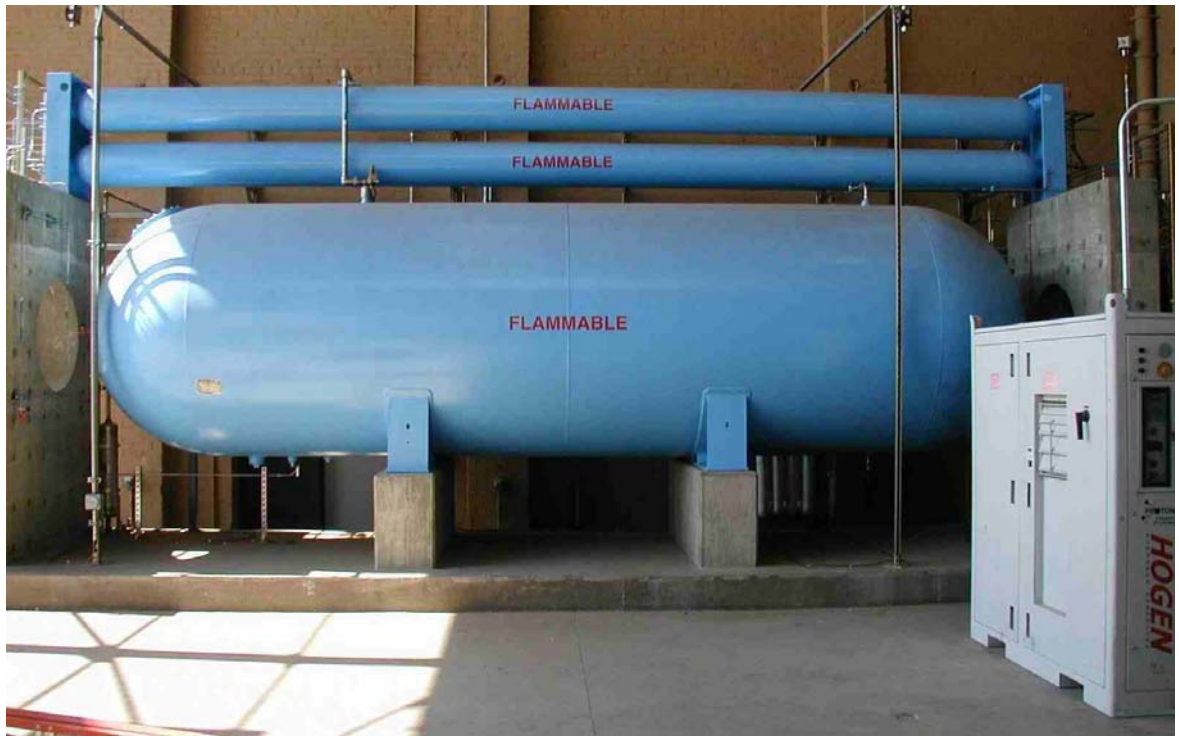
Alt-Fuel Pilot Plant – Hydrogen Subsystem

- Hydrogen compressor
  - Pressure Dynamic Consultants (Pdc Machines)
  - Oil-free triple diaphragm
  - Two-stage compression
  - 300 scfh @ 6,000 psi
- Norman hydrogen filter locations
  - High- & low-pressure storage outlets
  - Dryer inlet & outlet
  - Compressor outlets
- Hydrogen - 99.9997% purity



Alt-Fuel Pilot Plant - Hydrogen Subsystem

- **Low pressure hydrogen storage (lower tank)**
- **High pressure hydrogen storage (upper 2 tanks)**



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**
- **ASME safety relief valve rated @ 165 psi 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**
- **ASME safety relief valve rated @ 6,667 psi piped to vent stack**

Alt-Fuel Pilot Plant - Auxiliary Systems

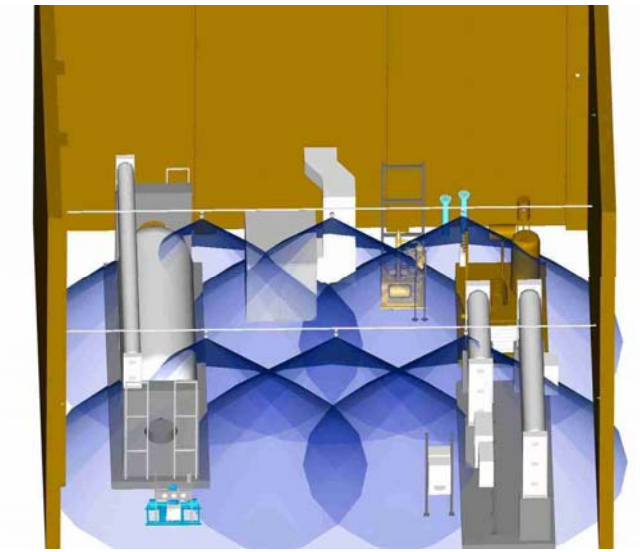
- **Water Purification - 215 gal/day, 1.0 micron exit filter**
- **Control Air - 100 cfm compressor, 90 psi**
- **Chiller - 293,000 Btu/h,**
- **Nitrogen - Air/hydrogen buffer gas - production, piping, compression & 600 scf storage. 97% purity @ 100 psi**
- **Helium - vent stack purging**
- **Vents -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

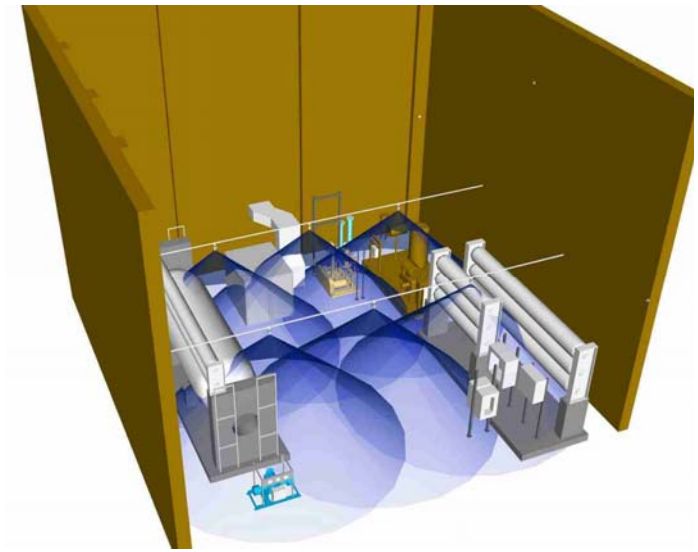
Alt-Fuel Pilot Plant - Emergency Shutdown System (EMS)

- Ultra-fast IR/UV detectors
- Combustible gas detectors
- Manual (5) & remote trips
- Vent stack temperature monitor
- Alarms, horns and strobe lights
- Vent stack fire suppression

Alt-Fuel Pilot Plant - EMS

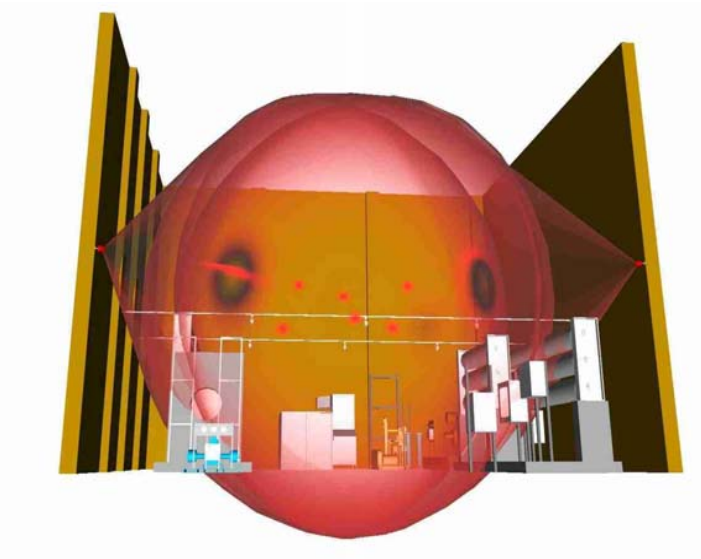
- **Six combustible gas detectors (Det-Tronics RS 8471)**
- **Monitors hydrogen & natural gas in 1% increments of lower flammability limits (LFL)**
- **Alarm condition at 25% of LFL reached**
- **Emergency shutdown when 50% of LFL reached**

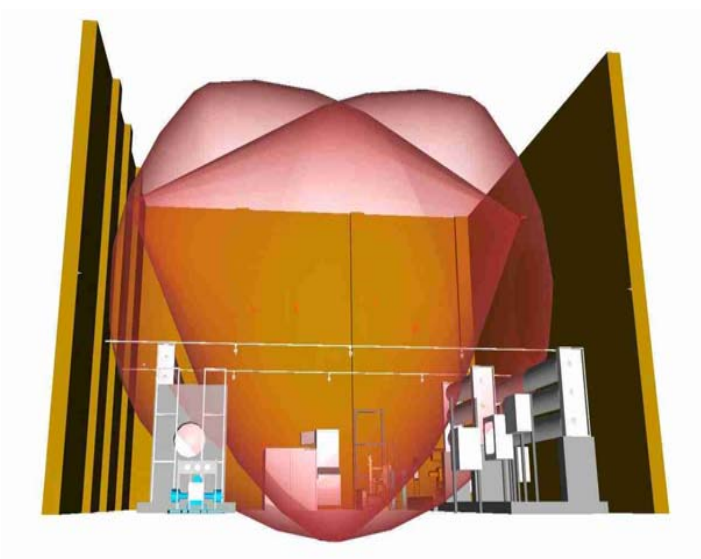




Alt-Fuel Pilot Plant - EMS

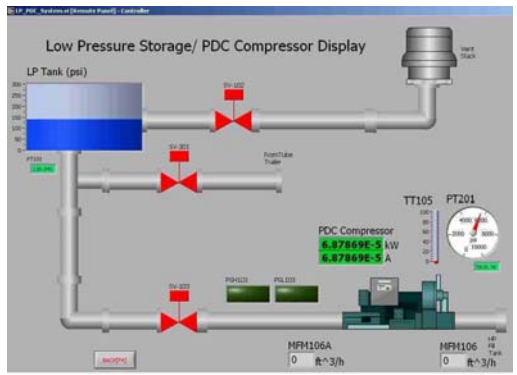
- **Two mid-level (35 feet) & four corner IR/UV flame detectors (Spectrex 20/20LB units)**
- **One detector at fuel dispenser unit**
- **If flame detected, emergency shutdown initiated within 3 milliseconds**

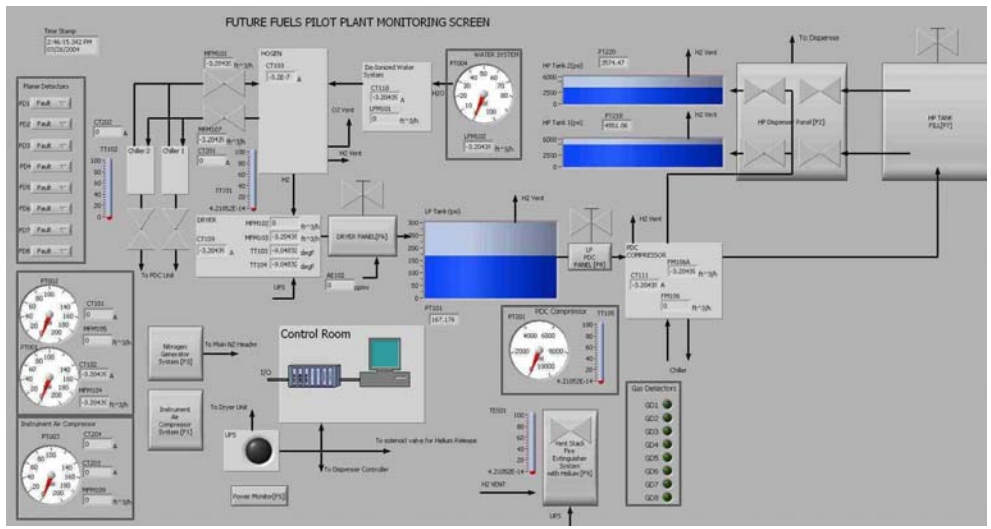




Alt-Fuel Pilot Plant - Monitoring System

- 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

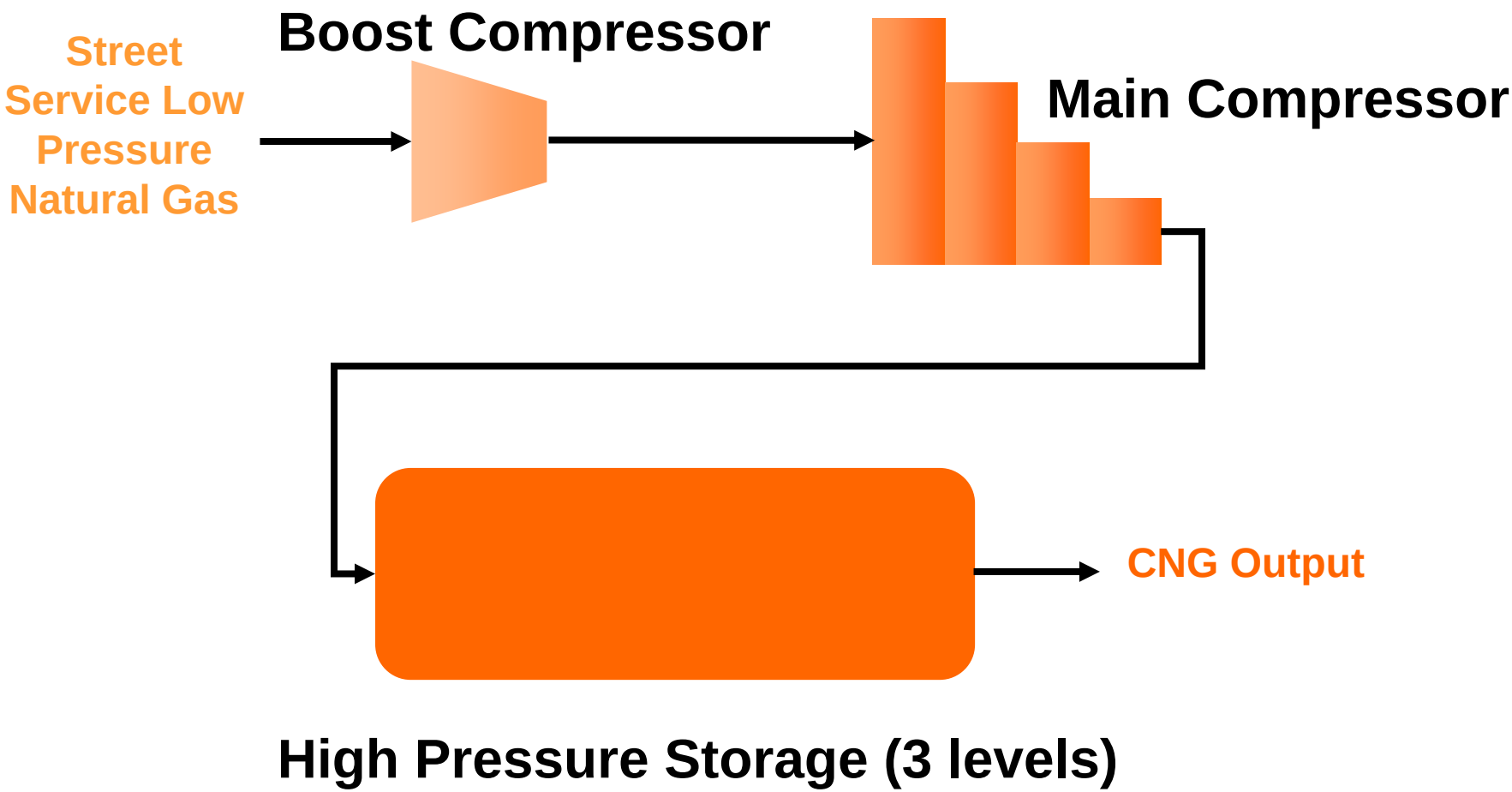




Alt-Fuel Pilot Plant - Monitoring Results

- **Better understanding component, subsystems, & plant-level efficiencies & costs**
- **Monitoring system results to date**
  - **Hydrogen kg energy costs based on historical (26% to 49%) & projected (70%) plant factors - $3.43 down to $2.39 per kg (DOE 2005 target $2.47)**
  - **Water cost per kg of hydrogen $0.10**

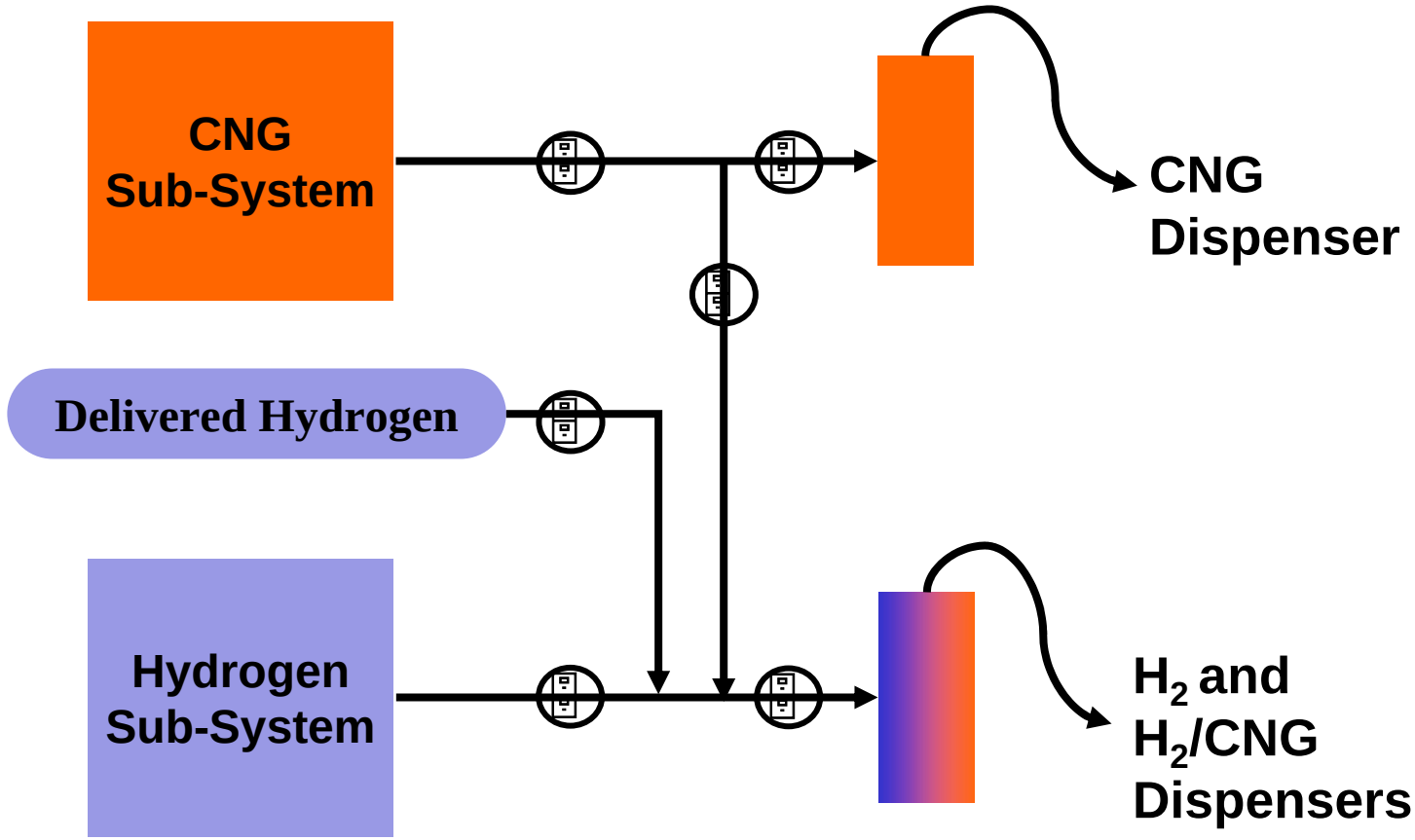
Alt-Fuel Pilot Plant - CNG Subsystem



Alt-Fuel Pilot Plant - CNG Subsystem

- CNG Boost Compressor
  - 300 scfm @ 60 psi
- CNG Main Compressor
  - 350 scfm @ 5,000 psi
- 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

Alt-Fuel Pilot Plant – Dispenser System

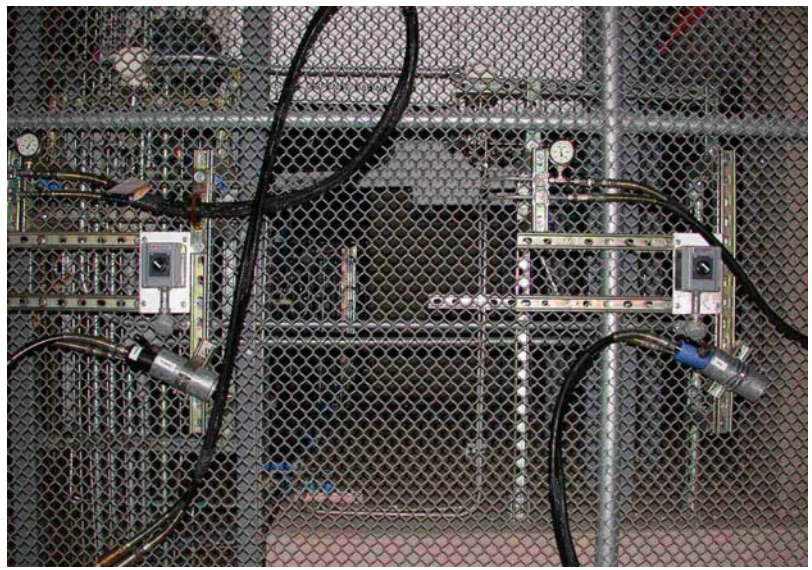


Alt-Fuel Pilot Plant - Fueling Dispensers

- **Includes metering & electronic billing interface**
- **Fully permitted for motor fuel dispensing**
- **Public access**

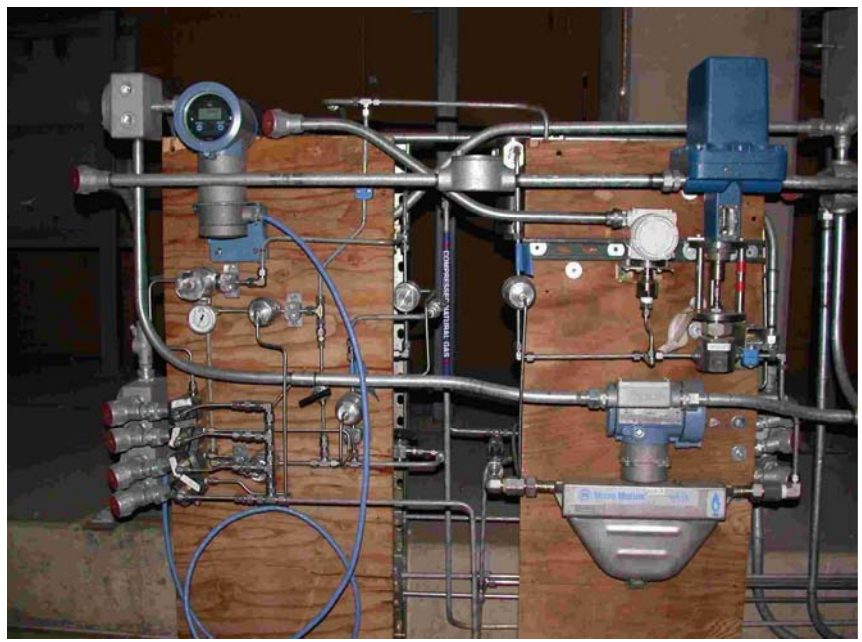
Prototype Dispenser Testing

- **Uses proportional flow control valves for hydrogen & CNG gas streams to control gas flow rates from 100 to 40,000 scfh**
- **Dispenser controller adjusts the control valves to provide real-time ratio control of blended fuels**
- **Control valves are trimmed by a digital dispenser controller using mass flow signals provided by coriolis mass flow transducers in the hydrogen & CNG gas streams**



Prototype Dispenser Testing

- **Delivers 100% hydrogen, 100% CNG, & blends of H/CNG using two independent single nozzles to AVTA test vehicles**
  - **1 Nozzle - CNG and H/CNG fuels (15, 20, 30, & 50% hydrogen - by volume) at 3,600 psi**
  - **1 Nozzle - 100% hydrogen dispensing at 5,000 psig**
- **Next step – commercial package**



Hydrogen & H/CNG ICE Vehicle Testing

- Initial ICE hydrogen & H/CNG vehicle testing
  - Ford F150 up to 30% H/CNG (continues in testing)
  - Ford F150 up to 50% H/CNG (testing complete)
  - 100% hydrogen Mercedes Benz van (operating)
  - Dodge van on 15% H/CNG (continues in testing)
- 300,000+ hydrogen & H/CNG test miles, 4,000+ successful fueling events

H/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**

5.4L 16-valve Hydrogen ICE Vehicle Testing

- **Ford 16-valve 5.4L SOHC V-8, 100% hydrogen, fuel injected, supercharged, & 1,365 lbs payload**
- **Converted by Electric Transportation Engineering Corporation (eTec)**
- **Onboard hydrogen storage**
  - **3 Dynetek tanks**
  - **Aluminum inner vessel, fiberglass wrap**
  - **3,000 psi**
  - **6.5 kilograms**

5.4L 16-valve Hydrogen ICE Vehicle Testing

- **Baseline Performance testing results**
  - **Maximum speed @ 1 mile: 81 mph & ¼ mile: 58 mph**
  - **Acceleration (0 to 50 mph): 18.1 seconds**
  - **SAE J1634 fuel economy (AC on): 14.5 miles/GGE**
  - **SAE J1634 fuel economy (AC off): 18.0 miles/GGE**
  - **45 mph constant speed fuel economy: 27.0 miles/GGE**
  - **Range 95 to 175 miles (6.5 GGE storage)**
- **Fleet testing - 2,800 miles: 17.2 miles/GGE**

5.4L 32-Valve 100% Hydrogen ICE - Status

- Engine changed to 10.5 to 1 compression, 12 pounds supercharge boost
- To be Baseline Performance and Fleet tested
- Fuel storage
  - 3 Dynetek tanks
  - Aluminum inner vessel, carbon wrap
  - 5,000 psi tanks
  - 15 kilograms

30% H/CNG F150 Performance Testing

Fuel Blend	Acceleration to 60 mph (secs.)	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

Hydrogen Test Vehicles

- **Future (Baseline) Performance testing**
  - **100% hydrogen 32-valve Ford/ETEC pickup**
  - **100% hydrogen GMC Sierra 6-passenger, 6-liter pickup modified by Roush/Power Tech/ETA**
- **Future fleet testing**
  - **32- & 16-valve 100% hydrogen pickups**
  - **Eight 100% hydrogen GMC Sierra pickups**
  - **18 H/CNG vehicles in 2 Phoenix Fleets**

Oil Bypass Filter System Evaluation

- **Goal: Examine oil bypass filter effectiveness, & demonstrate & quantify engine oil use reductions**
  - **Demonstrate oil bypass filtration systems from puraDYN & Refined Global Solutions**
  - **Demonstrate oil reduction benefits**
  - **Economic benefits analysis by vehicle & fleets**
  - **Analysis and dissemination of DOE complex-wide economic and oil-use benefits**

Oil Bypass Filter System Evaluation

- **Filters clean partial flow of oil down to 1 micron, have evaporative units, & some with additive packages**
- **Puradyn systems installed on 8 INEEL motor coach buses (Detroit Diesel series 50 & 60 engines, & 1 Caterpillar diesel engines – all 4 stroke)**
- **Puradyn filter systems installed on 6 Tahoes**
- **Refined Global Solutions (RGS) filters on 3 INL buses (Detroit Diesel series 60 engines – all 4 strokes)**

Oil Bypass Filter System Evaluation

- **Test oil quality for 28 variables - total base number, oxidation & nitration levels, contaminants (metals, water, soot, & fuel), & track makeup oil use**
- **Status – 1.1 million test miles (July 30, 2005) with 860,000 bus miles & 270,000 Tahoe miles**
- **Oil change avoidance: 90% buses (~35 quarts) & 60% Tahoes (~5 quarts)**
- **Economics good on buses**

Diesel Engine Idling Testing

- **Reduce use of 850 million gallons of diesel during idling periods**
- **Help develop accurate idling-reduction lifecycle cost analysis & system payback expectations**
- **Historical data indicates the relative composition of wear metals generated during the period directly following extended idling may be significantly different than those generated during normal engine operations**

Diesel Engine Idling Testing

- **Two INL buses (DD series 50 engines) with historical oil testing data from the Oil Bypass Study were idled 1,000 hours each**
- **Used chemical & ferrographic analysis of engine oils & oil filters to evaluate relative magnitude & differences in diesel engine wear during normal over-the-road operations & extended engine idling periods**
- **Driver logs, fueling records, & onboard data loggers used to collect: makeup oil & fuel use, idling times & percents, rpm, vehicle speeds, & overall engine profiles during operating periods & idling phases**
- **Preliminary finding: after a period of high idling, aluminum & chromium increased significantly**

INL Alternative Fuel Infrastructure

- Liquid natural gas (LNG) / compressed natural gas (CNG) station at “site”
- CNG station in Idaho Falls
- E85 (85% ethanol / 15% gasoline) station at “site”
- Adding E85 fueling in Idaho Falls
- B20 (20% biodiesel / 80% diesel) station at “site”
- Added 2nd 7.2 gge 3,600 psi CNG tanks to 36 pickups & replaced 4 gge 3,000 psi tanks on 13 Contours with 7.2 gge 3,600 psi CNG tanks

INL Alternative Fuel Fleet (318 vehicles)

- 79 B20 motor coach buses
- 7 Dedicated LNG motor coach buses
- 154 Bi-fuel light-duty CNG vehicles
- 52 Bi-fuel E85 (85% ethanol) pickups/SUVs
- 22 Bi-fuel LNG pickups
- 2 Dedicated CNG vans (injector tests Ford & Bosch)
- 2 Dedicated propane light-duty vehicles

http://avt.inl.gov

AVTA Questions?

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