Hydrogen Internal Combustion Engine (ICE) Vehicle Testing Activities

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Idaho National Laboratory

SAE 2006 World Congress

INL Idaho National Laboratory

Presentation Outline

Background and goal

APS Alternative Fuel (Hydrogen) Pilot Plant - design and operations

Fuel dispensing and prototype dispenser

Hydrogen (H2) and HCNG (compressed natural gas) internal combustion engine (ICE) vehicle testing

WWW Information

Background

Advanced Vehicle Testing Activity (AVTA) is part of DOE's FreedomCAR and Vehicle Technologies Program

These activities are conducted by the Idaho National Laboratory (INL) and the AVTA testing partner Electric Transportation Applications (ETA)

AVTA Goal

Provide benchmark data for technology modeling, research and development programs, and help fleet managers and other vehicle purchasers make informed purchase and operations decisions

AVTA History

Full-size EVs: 40 models, 5 million miles

Neighborhood EVs: 15 models, 200k miles

Urban EVs: 3 models, 1.75 million miles

Hybrid EVs: 9 models, 1.7 million miles

H2 ICE vehicles: 18 vehicles, 300k miles

APS Alternative Fuel Pilot Plant

Station partners include Arizona Public Service (APS), ETA, DOE and INL

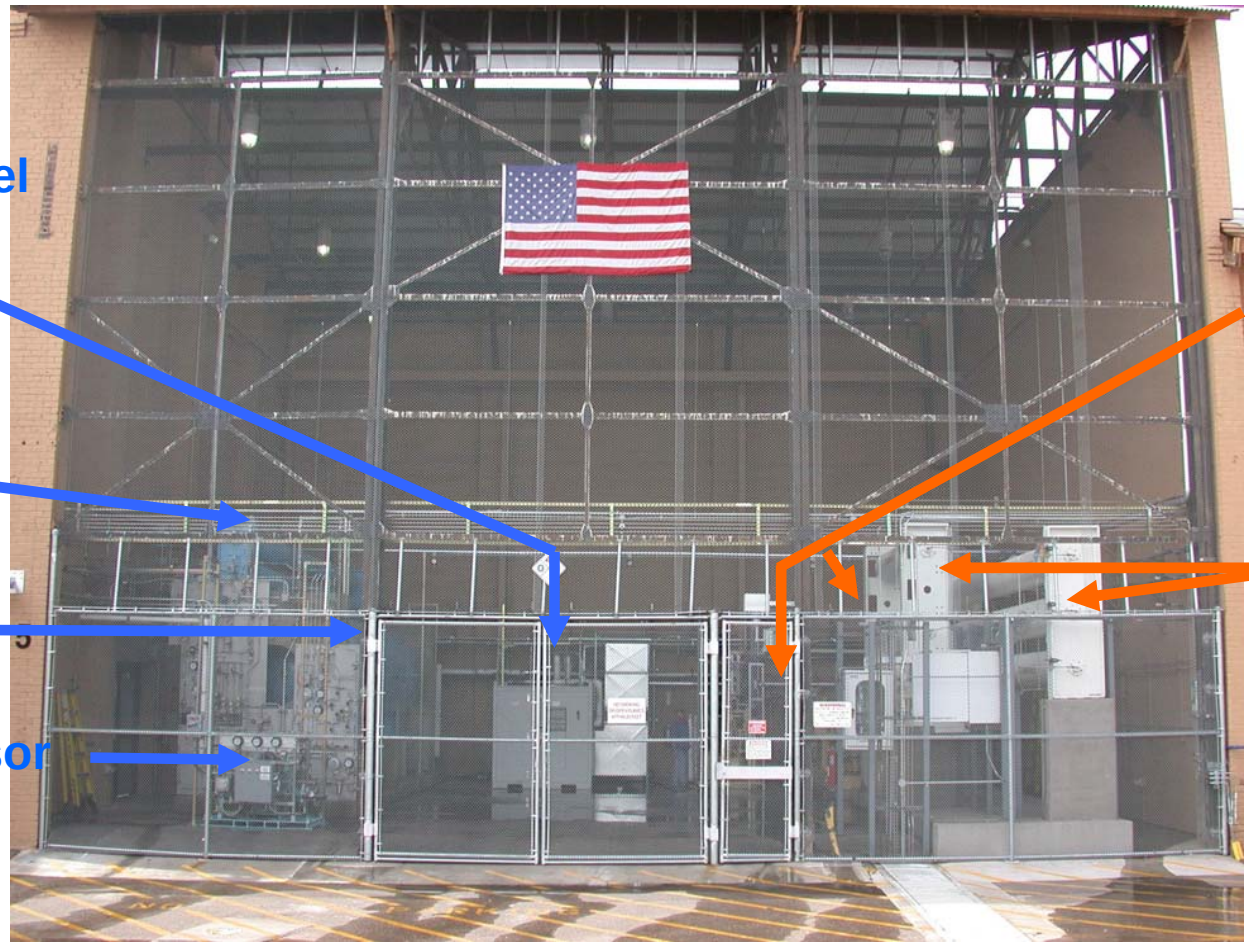
First U.S. H2 station in operation (June 2002)

Pilot Plant & Vehicle Testing Objectives

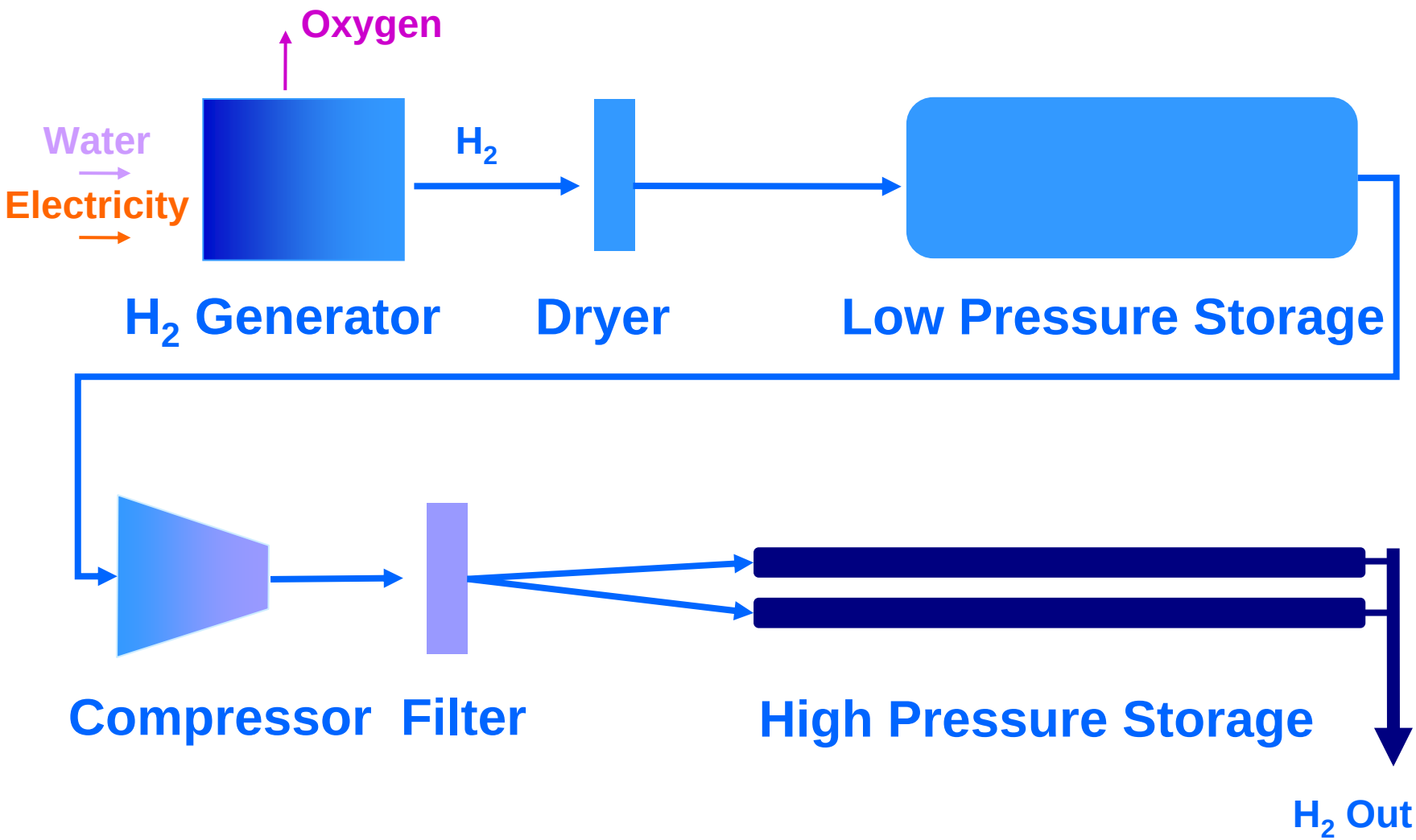
Evaluate safety and reliability of operating vehicles on 100% H2 and HCNG blended fuels (15 to 50% H2)

Evaluate fueling infrastructure and vehicle costs, performance, and emissions

Pilot Plant Layout



H2 Subsystem



Major H2 Subsystem Components

Proton Energy Systems' HOGEN PEM stationary fuel cell operating in reverse

Lectrodryer H2 dryer: -80°F

Pdc Machines H2 compressor: 6,000 psi

Norman H2 filter 8 locations

H2: 99.9997% purity

H2 Storage

Low pressure H2 storage (lower tank):
8,955 SCF @ 150 psi

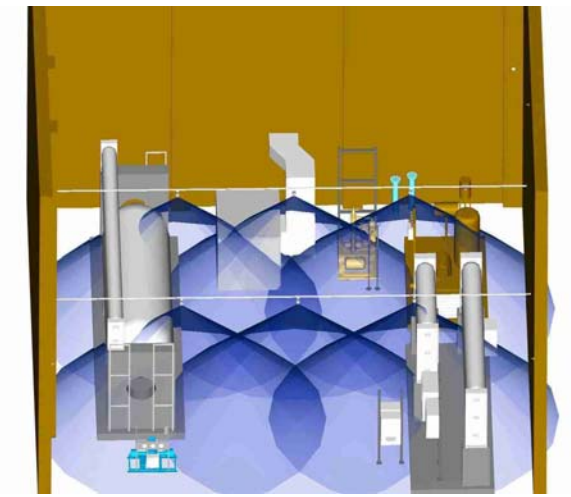
High pressure H2 storage (upper 2 tanks):
17,386 SCF @ 6,000 psi (both tanks)

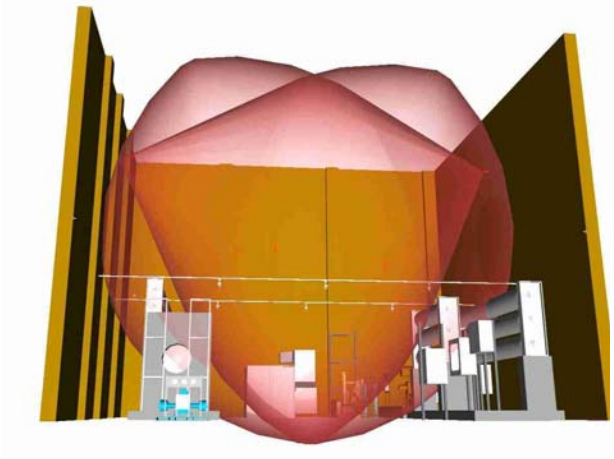
H2 Gas and Flame Detectors

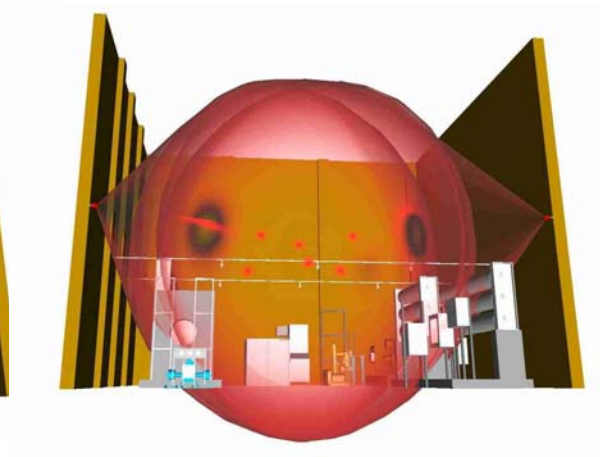
Six combustible H2 detectors

Six IR/UV flame detectors (1 more at dispensing island)

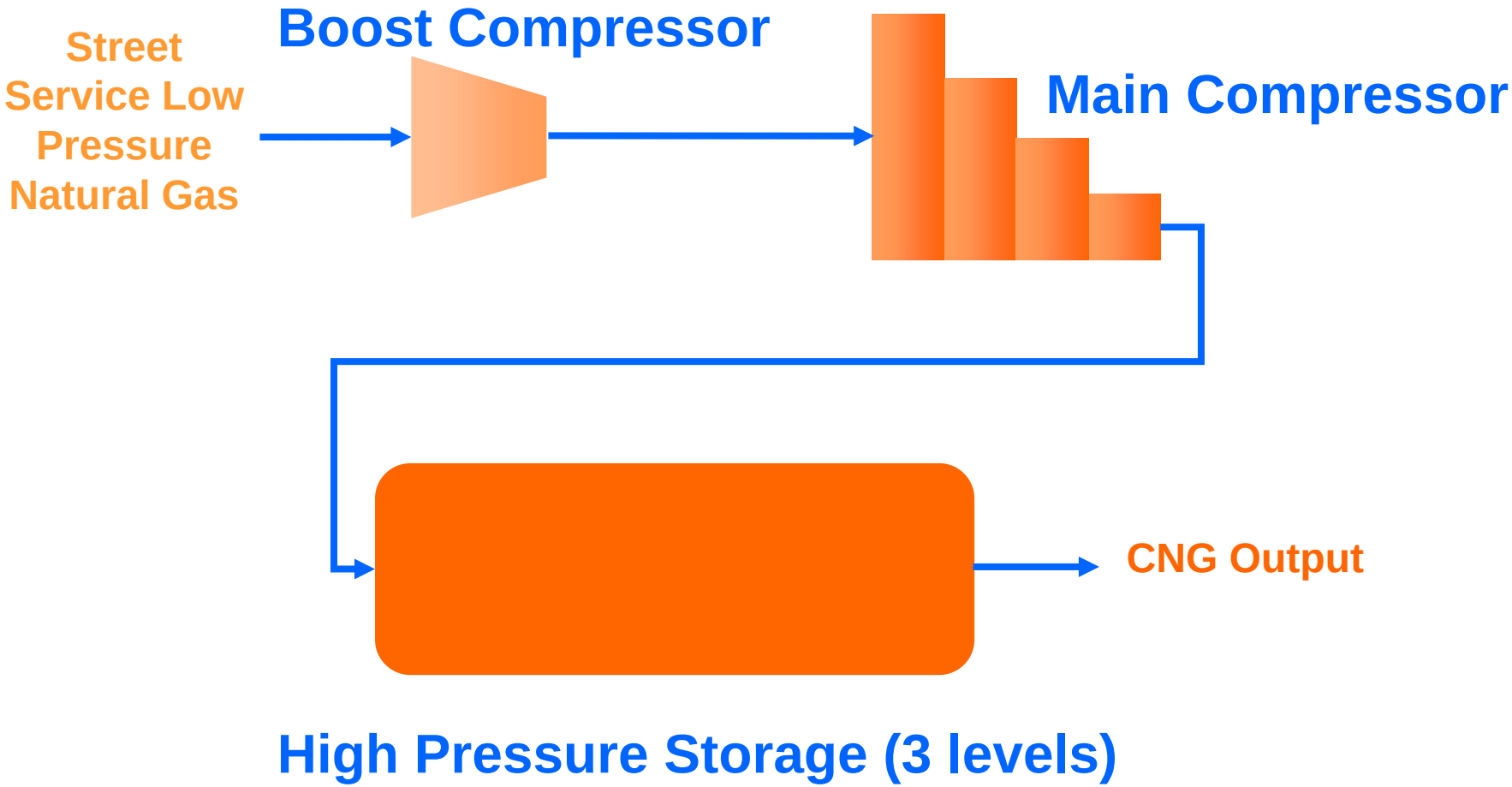
Tied to automated shutdown system







CNG Subsystem



CNG Subsystem

Boost Compressor: 60 psi

CNG Main Compressor: 5,000 psi

CNG Storage/Pressure: 6 tanks, 22,500 scf

- 3 Low: 3,600 psi
- 2 Medium: 4,500 psi
- 1 High: 5,000 psi

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H2 & HCNG Fueling Dispensers

Metering and electronic billing interface

Fully permitted for motor fuel dispensing

Public access

City of Phoenix
Fire Department

FIRE PERMIT

150 South 12th Street
Phoenix, Arizona 85034
General Information (602)262-7462

POST THIS PERMIT ON JOB SITE

Permit # F203 0200731 Issue Date 05-MAR-2002 Expires 02-MAR-2012
Permit Description FUEL DISPENSING @ 435 S. 2ND AVE.
Project 99-22738 APS
Address NOT FOUND Zoning

Description/Scope of Work: MOTOR VEHICLE FUEL DISPENSING STATION
MOTOR VEHICLE FUEL-DISPENSING STATIONS:
Operate.

PERMITEE:
APS/Pinnacle West

THIS PERMIT IS NOT TRANSFERRABLE

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Pilot Plant Monitoring

H2 kg energy costs based on historical (26% to 49%) and projected (70%) plant factors

$3.43 (26% PF) to $2.39 per kg (70% PF)

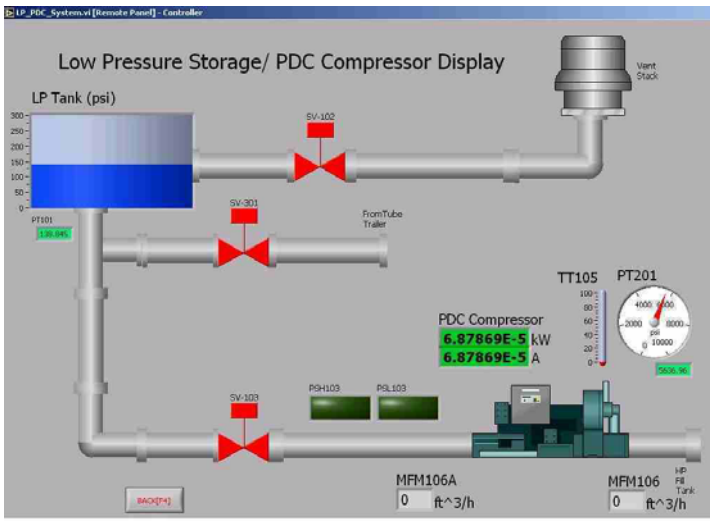
- DOE 2005 energy cost target $2.47

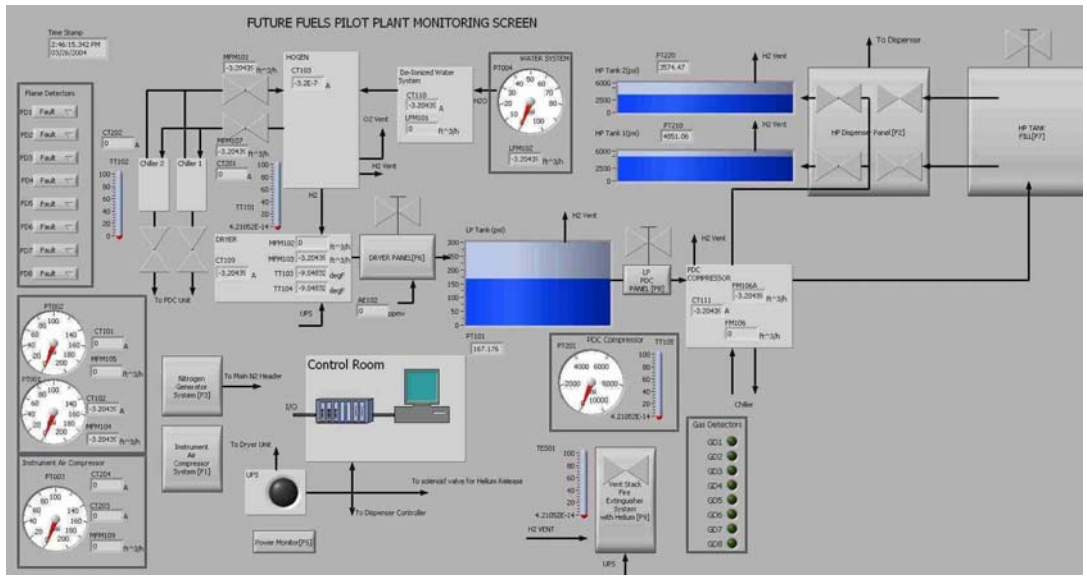
Water cost per kg of hydrogen $0.10

Pilot Plant Monitoring

6,000 fueling events

7,200 kg of H2 produced at 6,000 psi





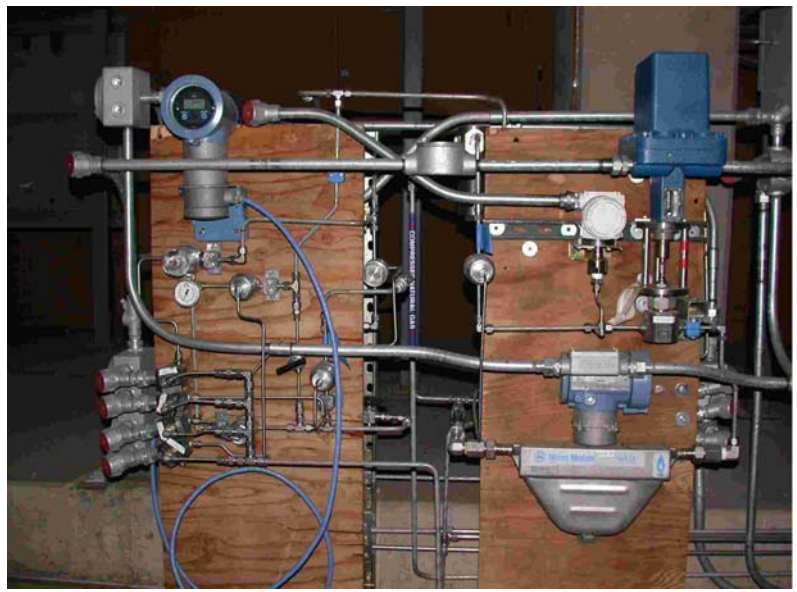
Prototype Dispenser Testing

Real-time ratio control of blended fuels

Uses 1 nozzle to deliver 100% H2 at 5,000 psig

Uses 1 nozzle for 100% CNG and blends of HCNG fuels (15, 20, 30, and 50% H2 by volume) at 3,600 psi

Brassboard design



Initial H2 & HCNG vehicle testing

Dodge van on 15% HCNG (continues)

Ford F150 up to 30% HCNG (continues)

Ford F150 up to 50% HCNG (completed)

100% H2 Mercedes Benz van (completed)

15% HCNG Dodge Van

5.2 L CNG V8 (no modifications)

71k HCNG test miles: no problems

15% HCNG, 27k data miles: 15.5 miles/GGE

Percentage change in 15% HCNG emissions compared to 100% CNG	
Total hydrocarbons	-34.7%
Carbon monoxide	-55.4%
Oxides of nitrogen	+92.1%
Carbon dioxide	-11.3%

30% HCNG F150

5.4 L V8 CNG engine, added supercharger, ignition mods & exhaust gas recirculator

54k 30% HCNG miles: 17.5 miles/GGE

Fuel Blend	0 to 60 mph (secs.)	Miles/GGE	Range (miles)
CNG	10.10	23.3	122
15% HCNG	10.97	22.6	110
30% HCNG	12.68	23.5	102

30% HCNG F150 Emissions

Fuel Type	Percentage Change in Emissions Testing					
	NMHC	CH_4	HC	CO	NO_X	CO_2
Gasoline	Base	Base	Base	Base	Base	Base
CNG	-80	+967	+35	-63	-34	-24
15% HCNG	-78	+1000	+40	-70	-26	-27
30% HCNG	-89	+1050	+37	-73	-25	-28

NMHC=Non-Methane Hydrocarbons
HC=Total Hydrocarbons
NOx=Oxides of Nitrogen
CH_4=Methane
CO=Carbon Monoxide
CO_2=Carbon Dioxide

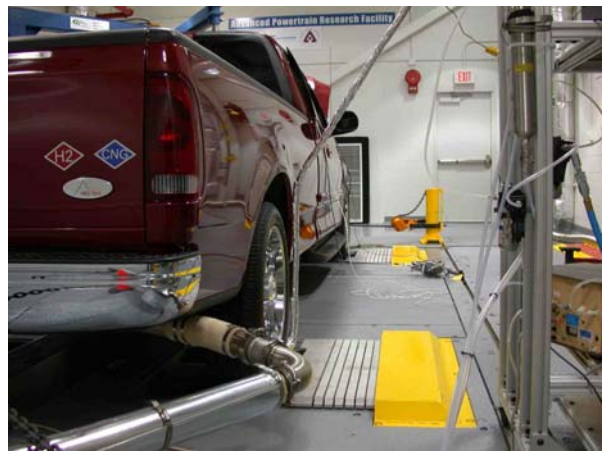
50% HCNG F150

Modifications: SVO heads, supercharger, exhaust intercooler, ignition system, and exhaust gas recirculator

Three 3,600 psi tanks with 3 kg H2 storage

Percent reduction in emissions (HCNG versus gasoline-fueled F-150)

HC	CO	NO_X	CO_2
-3.5%	-43.3%	-97.0%	-16.7%



HCNG ICE Vehicle Testing

APS meter reader fleet 12 Bifuel vehicles

- 1,600 fueling events, 190k miles using 10,600 GGE of 15% HCNG

Public Fleet - private Bifuel conversions

- 350 fueling events, 36k miles (estimated), 1,800 GGE of HCNG blends (mostly 15%)

5.4L 16-valve 100% H2 ICE Pickup

5.4L V-8, 100% H2, 16-valve pickup, converted by ETEC

5 speed manual, supercharged (3 psi boost), H2 fuel injectors, and air-to-water intercooler

Hardened valves and seats, and forged pistons with 12:1 compression

Motec fuel and spark controllers

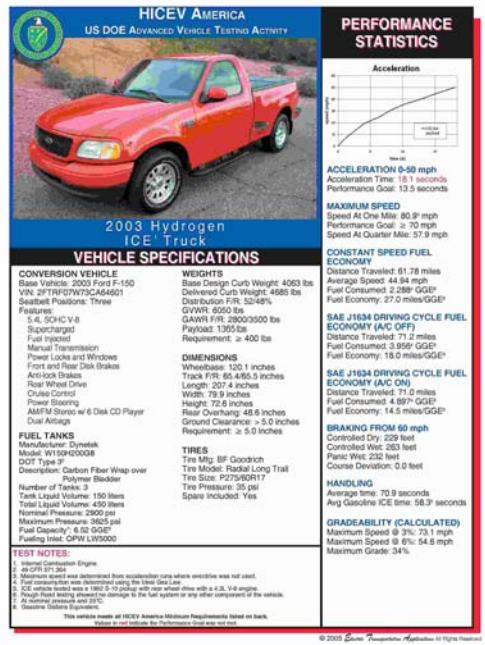
Lean-burn mode

5.4L 16-valve 100% H2 ICE Pickup

6.5 kg onboard H2 storage

3 Dynetek tanks (aluminum vessel and fiberglass wrap) @ 3,000 psi

1,365 lbs payload



5.4L 16-valve 100% H2 ICE Pickup

Max speed 1 mile: 81 mph ¼ mile: 58 mph

Acceleration (0 to 50 mph): 18.1 seconds

SAE J1634 (AC on): 14.5 miles/GGE

SAE J1634 (AC off): 18.0 miles/GGE

45 mph constant speed: 27.0 miles/GGE

Range - 95 to 175 miles (14.5 to 27 mi/GGE)

Fleet testing (3.5k miles) results: 17.0 miles/GGE = 110 miles range

5.4L 32-valve 100% H2 ICE Pickup

5.4L V-8, 100% H2 32-valve pickup, converted by ETEC

Automatic transmission, H2 fuel injectors, 12 lbs supercharger boost, and air-to-air intercooler

Hardened valves and seats, and forged pistons with 11.5:1 compression

Motec fuel and spark controllers

Lean-burn mode

5.4L 32-valve 100% H2 ICE Pickup

15.3 kg onboard H2 storage

3 Dynetek tanks @ 5,000 psi

Fleet testing (7.5k miles): 15.3 miles/GGE and 230 miles range

To be baseline performance tested

6L V-8 100% H2 ICE Pickup

Base vehicle: Chevrolet 1500HD crew cab (4 door) with 6L V8 CNG engine

Converted by ETEC/Roush

4-speed automatic, supercharger, electronic port fuel injection, liquid-to-air intercooler

Integration of powertrain control module and development of H2 lean-burn control strategies

6L V-8 100% H2 ICE Pickup

- Implementation of J1850 communications to maintain seamless integration with existing OEM equipment
- 10.5 kg onboard H2 storage @ 5,000 psi
- 180 Horsepower and 260 lb-ft torque
- Anticipated 15 miles/GGE = 155 miles range

6L V-8 100% H2 ICE Pickup

- Targeted to meet NOx requirements for 2007 Tier II, Bin 7 standards
- HC<10 ppm and NOx<25 ppm on engine dynamometer
- Nine vehicles being produced in 1st run
- To be baseline performance tested
- Track 8 unit fleet in Vancouver

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Acknowledgement

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Vehicle Systems Team Leader, Tien Duong

Project Leader and VSATT Lead, Lee Slezak

http://avt.inl.gov