2004 DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Review

Hydrogen and Natural Gas Blends; Converting Light and Heavy Duty Vehicles

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This presentation does not contain any proprietary or confidential information

Project Objectives:

To develop and demonstrate the viability of hydrogen natural gas mixtures (HCNG) as a means of providing a transition strategy to hydrogen fuel cells

- Demonstrate vehicle reliability of HCNG
- Demonstrate reduced vehicle emissions
- Develop commercial products that will utilize major advantages of HCNG

Budget

- Total Funding Since Fy'99 = 929k
- Cost Share = 370k
- Cost to DoE = 559k

- Funding in FY'04 – Currently 50k

Technical Barriers and Targets

- **Barriers**
  - Achieve equivalent power to previous fuel
    - Created by using charge dilution to achieve reduced exhaust emissions
- **Targets**
  - Meet SULEV NOx emissions for light-duty vehicles
  - Meet proposed 2007 NOx emissions for transit buses (0.02 g/hp-hr)

Approach

- Use cooled exhaust gas recirculation with the addition of a supercharger for light-duty vehicles
- Use lean burn with increased engine displacement and higher turbocharger boost pressures for heavy-duty vehicles

Project Timeline

10/1999 - 4/2002	4/2002 - 5/2003	5/2003 – 9/2004
Phase I	Phase II	Phase III

- **Phase I – Initial Development**
  - Design, build and test heavy duty bus engine
  - Design light-duty conversion to HCNG
- **Phase II – Deployment**
  - Integrate heavy duty engine into existing bus and deliver to the City of Las Vegas
  - Convert light-duty vehicle and deliver to the City of Las Vegas
- **Phase III – Expand Fleet & Develop New Bus Platform**
  - Conversion of additional light-duty vehicles
  - Development and testing of new heavy duty engine platform

Technical Accomplishments/Progress (LDV)

- Successfully developed “kit” that is user installable
- Have successfully demonstrated 50k miles of trouble free operation
- Demonstrated NOx reductions from 24 to 96%, depending on test and application

Emissions Results (LDV)

Ford F150

Fuel	Test	NMHC (g/mile)	CO (g/mile)	NOx (g/mile)
HCNG	FTP	0.018	0.251	0.084
Gasoline	FTP	0.115	1.551	0.167
CNG	FTP	0.023	0.567	0.110

HCNG Ford F150 Emissions Results

CAVTC — *CLEAN AIR VEHICLE TECHNOLOGY CENTER*

1975 Federal City Gasoline Test

Test	6224	Vehicle		Fuel	
Date	10/24/01	Control	#01NRG01	Name	30%hydrogen
Time	10:13	Model	2001 ford f-150 xlt	CWF	0.733
Cell ID	Cell 1	VIN	1FTRX17L51NB70528	OWF	0.014
Test	epa75	Engine	1fmxt05.4pfs	Spc Grv	0.609
Shift	epa75	Odometer	738	NHV	20530
Driver	Gil Rodriguez	Dyno Inertia	5,500	R-Factor	0.60
Operator	Glen Muñoz	Dyno AHP/IHP	20.8/18.4	Control #	TANK1

Ambient Conditions

Baro (inHg)	30.036	30.034	30.035
Dew Pt (F)	45.72	45.69	46.13
Dry Temp (F)	75.49	80.71	82.79
Humidity	34.732%	29.207%	27.764%
Abs (gr/lb)	45.05	45.00	45.77
NOx K Factor	0.877	0.877	0.880

Comments

30%hydrogen 70%natural gas

Tire Pressure=45 psi, Trans. Type=A-4, 40% fill=5.0
EPA fuel economy calculation used.

Phase Variables

	Begin	End	Length	Viol	Dist (mi)	Vmix(ft3)
Phase 1	10:13:19	10:21:48	509	0	3.598	2850.89
Phase 2	10:21:48	10:36:18	870.4	0	3.861	4953.96
Phase 3	10:46:19	10:54:46	507.7	0	3.590	2888.72

Bag Readings

Phase 1	HC ppmC	CO ppm	NOX ppm	% CO2	CH4ppm	NMHCppm	
Full Scale	100.00	500.00	30.00	2.00	50.00		DF
Sample Conc.	32.310	87.997	0.521	1.591	26.598	1.908	6.11
Ambient Conc.	9.302	0.000	0.072	0.054	6.823	1.503	
Net Conc.	24.532	87.997	0.461	1.546	20.892	0.652	
Grams	**1.142**	**8.269**	**0.062**	**2283.94**	**0.973**	**0.030**	
Phase 2							
Full Scale	30.00	100.00	30.00	2.00	50.00		DF
Sample Conc.	9.794	5.832	0.084	0.941	7.655	1.045	10.38
Ambient Conc.	8.905	0.000	0.075	0.053	5.950	1.294	
Net Conc.	2.479	5.832	0.016	0.894	2.278	0.000	
Grams	**0.201**	**0.952**	**0.004**	**2293.82**	**0.184**	**0.000**	
Phase 3							
Full Scale	30.00	100.00	30.00	2.00	50.00		DF
Sample Conc.	16.297	25.300	0.078	1.392	13.454	0.920	7.01
Ambient Conc.	6.263	0.000	0.073	0.054	4.438	1.190	
Net Conc.	10.927	25.300	0.016	1.346	9.649	0.000	
Grams	**0.516**	**2.409**	**0.002**	**2014.67**	**0.455**	**0.000**	

Test Results	THC	CO	NOx	CO2	CH4	NMHC	MPG
Grams/mi	0.132	0.789	0.004	593.47	0.116	0.0017	11.823

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Technical Accomplishments/Progress (HDV)

- Demonstrated proposed 2007 NOx emissions (0.02 g/hp-hr) with CTI-designed engine
- Designed, developed and manufactured cylinder heads for Daewoo 11L bus engine

Exhaust Emissions for CTI-Designed Engine

Individual Modes	NOx (g/bhp-hr)	THC (g/bhp-hr)	NMHC (g/bhp-hr)	CO (g/bhp-hr)	Weighting Factor
1800 rpm - 100% Load	0.15	3.70	0.11	0.00	0.15
- 75% Load	0.12	3.86	0.12	0.00	0.15
- 50% Load	0.09	4.86	0.15	0.00	0.15
10% Load	0.13	8.82	0.26	0.00	0.1
2800 rpm - 100% Load	0.21	3.31	0.10	0.00	0.1
- 75% Load	0.15	3.77	0.11	0.00	0.1
- 50% Load	0.10	5.75	0.17	0.00	0.1
- Idle	0.22	7.21	0.22	0.00	0.15
Weighted 8 Mode (g/bhp-hr)	0.15	5.11	0.15		
Weighted 8 Mode (g/kw-hr)	0.20	6.85	0.21		

30% Hydrogen in 8.4L CTI-Designed Engine

NOx and Efficiency Comparison

Engine Type	Efficiency	NOx (g/hp-hr)
John Deere-CNG	38.1%	10.42
CTI-HCNG	38.3%	0.15

Interactions and Collaborations

- Hess Microgen – a subsidiary of Hess Oil, cash co-funded (60k) cylinder head development for Daewoo 11L engine, in-kind cost share included 2 natural gas engines and parts, is USA distributor for NG Daewoo engines
- Gas Research Institute: Cost shared the development of CTI-designed HCNG engine (180k)
- Daewoo Heavy Industries: Technical support, engine control electronics, warranty for HCNG engines

Reviewers' Comments

- **Basing HCNG bus engine on custom made parts for racing applications not an appropriate approach**
  - Have committed to using a larger displacement engine designed for transit bus and other heavy duty transportation applications
- **The cost of converting light-duty vehicles is too high**
  - Newest design significantly reduces cost by utilizing the existing OEM computer and catalyst system

Future Plans

- **Remainder of FY 2004:**
  - Complete testing and evaluation of 11L Daewoo engine
  - Convert nine additional light-duty vehicles for the City of Las Vegas
  - Update control strategies for CTI-engined bus
- **FY 2005:**
  - Convert five City of Las Vegas buses with dedicated 11L HCNG engine
  - Convert additional light-duty vehicles for the City of Las Vegas

Safety

- **For 30% hydrogen mixtures in IC engines**
  - Treat the fuel as if natural gas
    - Use natural gas rated equipment (solenoids, etc.)
    - Use natural gas compressors
      - No deleterious effects noticed in 15 years of usage
- **For 100% hydrogen in IC engines**
  - Use only hydrogen rated equipment
  - Storage tank area vented
  - Engine compartment vented (hood louvers)
  - No safety-related incidents