2005 DOE Hydrogen Program Review Presentation

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

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Collier Technologies, Inc.

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This presentation does not contain any proprietary or confidential information

Project ID #
TVP11

Overview

Timeline

- **Project start date:**
  - July 29,2004
- **Project end date:**
  - July 29, 2005
- **Percent complete 0**

Budget

- **Total project funding**
  - DOE share
    - 149,029.00
  - Contractor share
    - 164,484.00

Barriers

- **Barriers addressed**
  - Light and Heavy Duty Vehicles

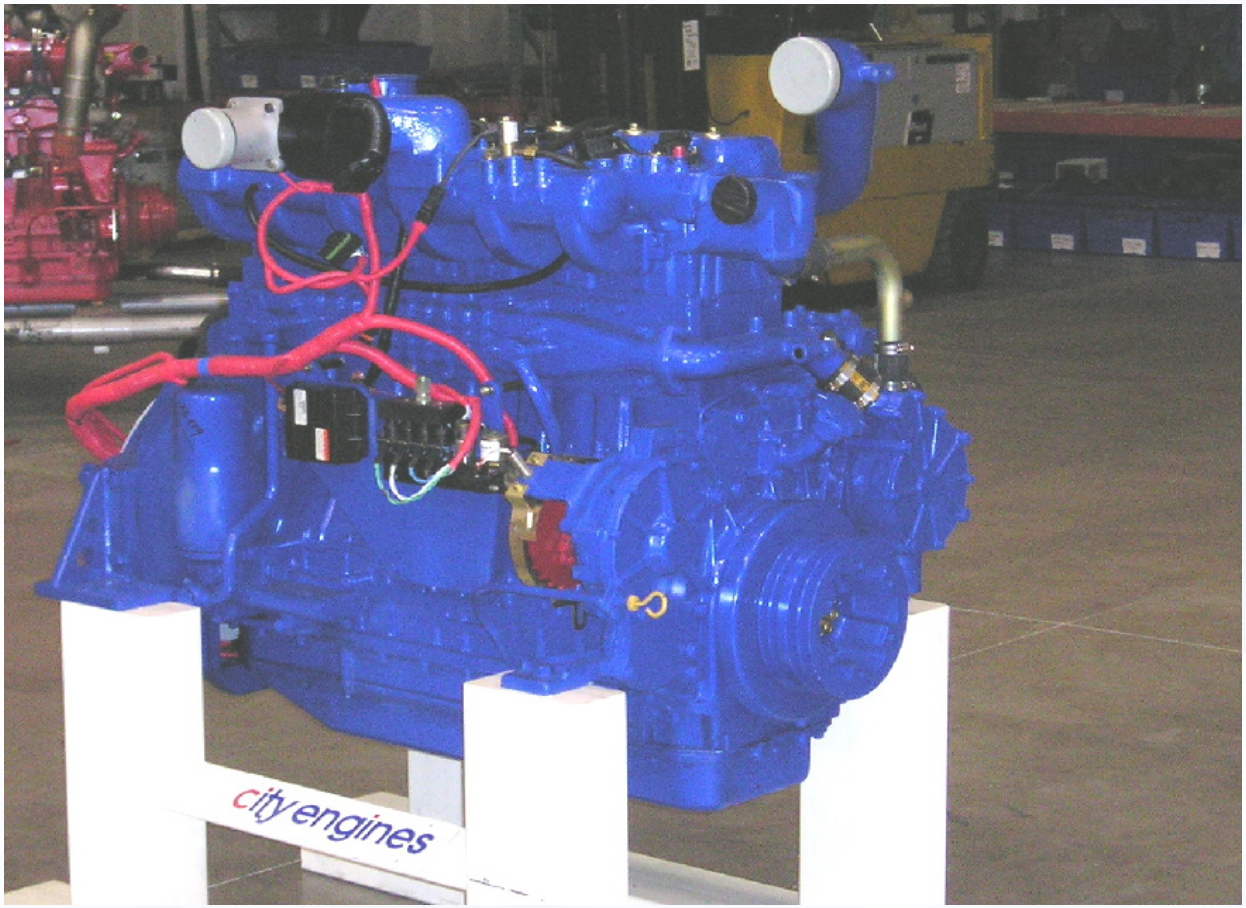
Partners

- **City of Las Vegas**
- **Daewoo Heavy Industries**

Objectives

- Development of a dedicated 30% HCNG engine for the heavy duty engine market
- NOx emissions to meet California's 2007 Urban Bus regulations of 0.2 g/hp-hr
- Utilize existing engine components to achieve equivalent power
- Develop and implement a 30% HCNG kit for light duty vehicles

Dedicated 30% HCNG engine



Approach

- 1 Approach

- Utilize empirical emissions and power data from engine testing to determine optimum intake runner sizing and discharge coefficient

Approach

- 2 Approach
- Extend the lean limit of combustion using the hydrogen portion of the fuel as the flame enhancer

Approach

- 3 Approach
- Utilize existing engine components while maintaining break specific power

Approach

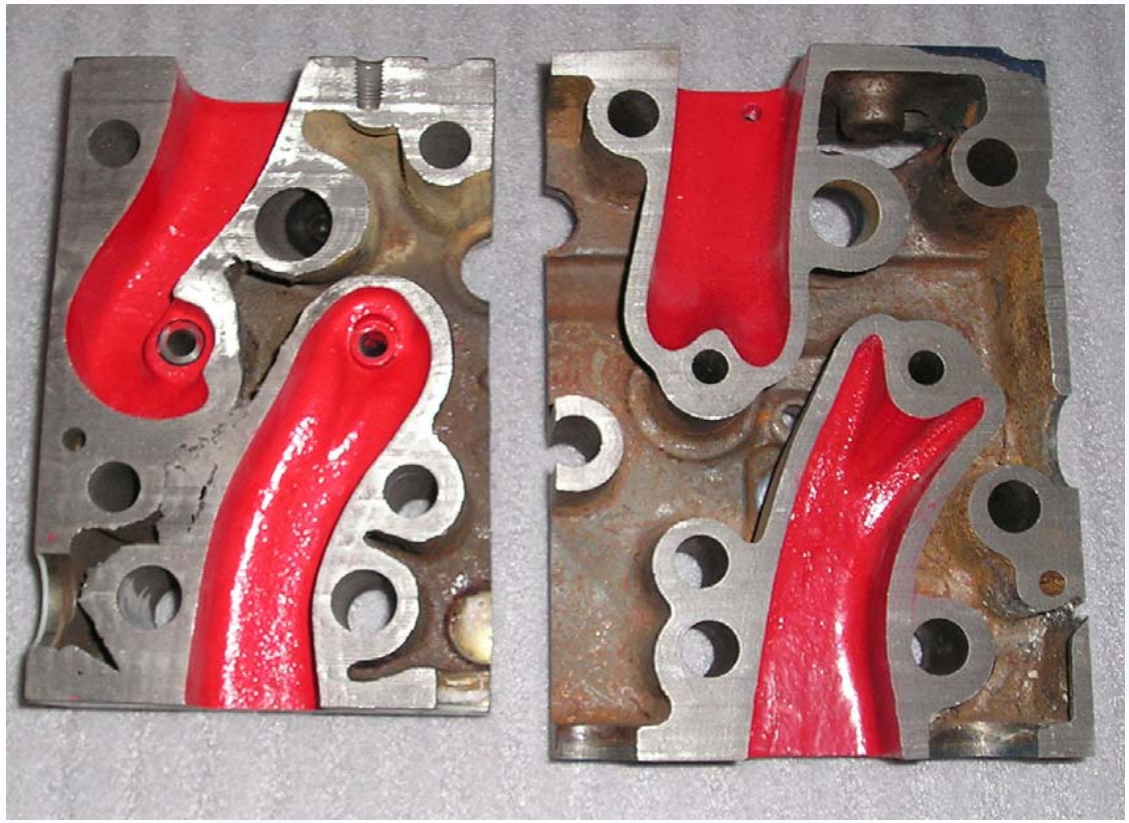
- 4 Approach
- Develop low cost engine conversion to utilize 30% HCNG fuel

Technical Accomplishments/ Progress/Results

- Complete new quiescent cylinder head design using the existing valve train components, casting and power and emissions testing
- Achieved 2007 heavy duty emissions of 0.2 g/hp-hr throughout entire operating range of engine
- All heavy duty engine design goals have been meet or exceeded
- Development phase of low cost light duty vehicle conversion kit

Technical Accomplishments/ Progress/Results
Heavy Duty Engine

High Swirl Port
Modified diesel
engine for
gaseous fuel



Quiescent Port
Designed,
Cast, machined
And Tested

Engine testing has shown the quiescent port
to produce significantly lower NOx emissions
than the high swirl port

Accomplishments Heavy Duty Engine

- Swirl Ratio as a function of BMEP, THC and NOx emissions

Head Type	RPM	Equiv. Ratio	BMEP kPa	THC (g/kW-hr)	NOx (g/kW-hr)
Quiescent	1700	0.55	703	1.6	0.07
High Swirl	1700	0.55	703	1.5	0.07
Quiescent	3000	0.55	745	1.8	0.11
High Swirl	3000	0.55	696	3.6	0.44

These data determined the intake port shape needed for our cylinder head

*Swirl is determined by the angular momentum of the incoming air
the higher the swirl the turbulence occurs

Accomplishments Heavy Duty Engine

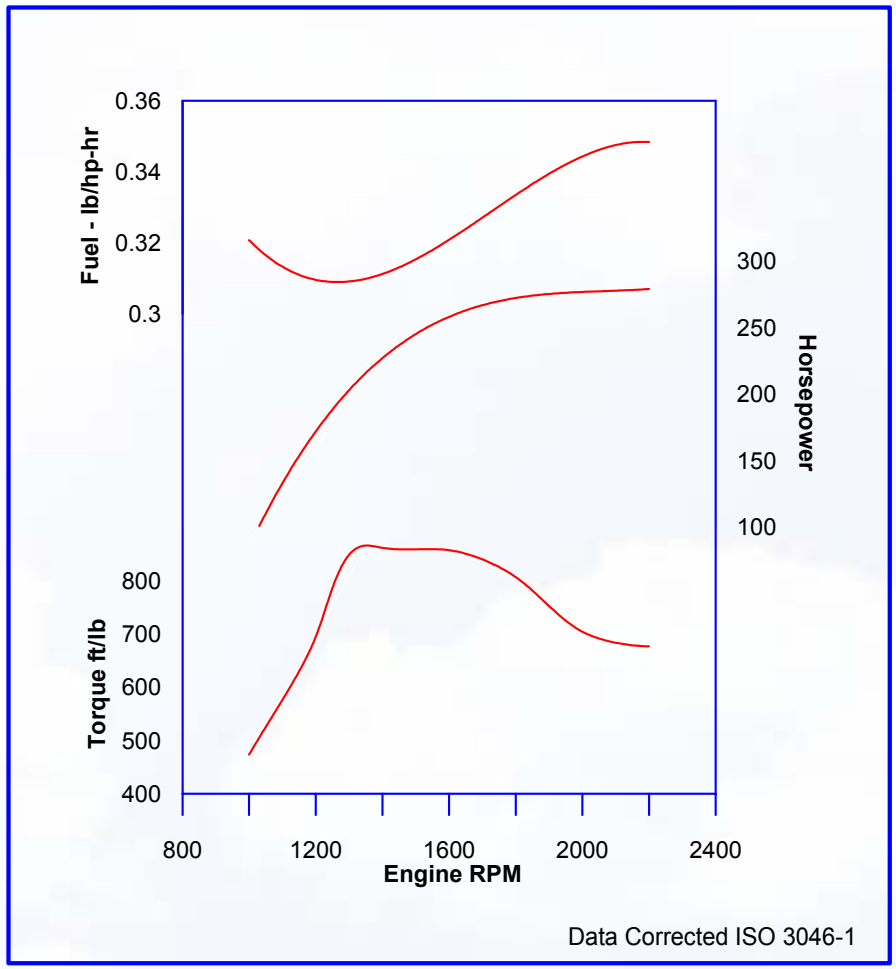
- **Fuel system development and previous testing**
  - Chart shows the significant effect of emissions on fuel mixing

System Type	RPM	Equiv Ratio	BMEP (kPa)	NO_x (g/kW-hr)
Design 1	1700	0.51	696	0.08
Design 2	1700	0.52	710	0.07
Design 1	3000	0.53	723	0.11
Design 2	3000	0.53	696	1.23

•Design 1, was a system designed by Collier Technologies, Inc.

•Design 2 was a venturi-based after market natural gas system

Accomplishments Heavy Duty Engine



Accomplishments Heavy Duty Engine

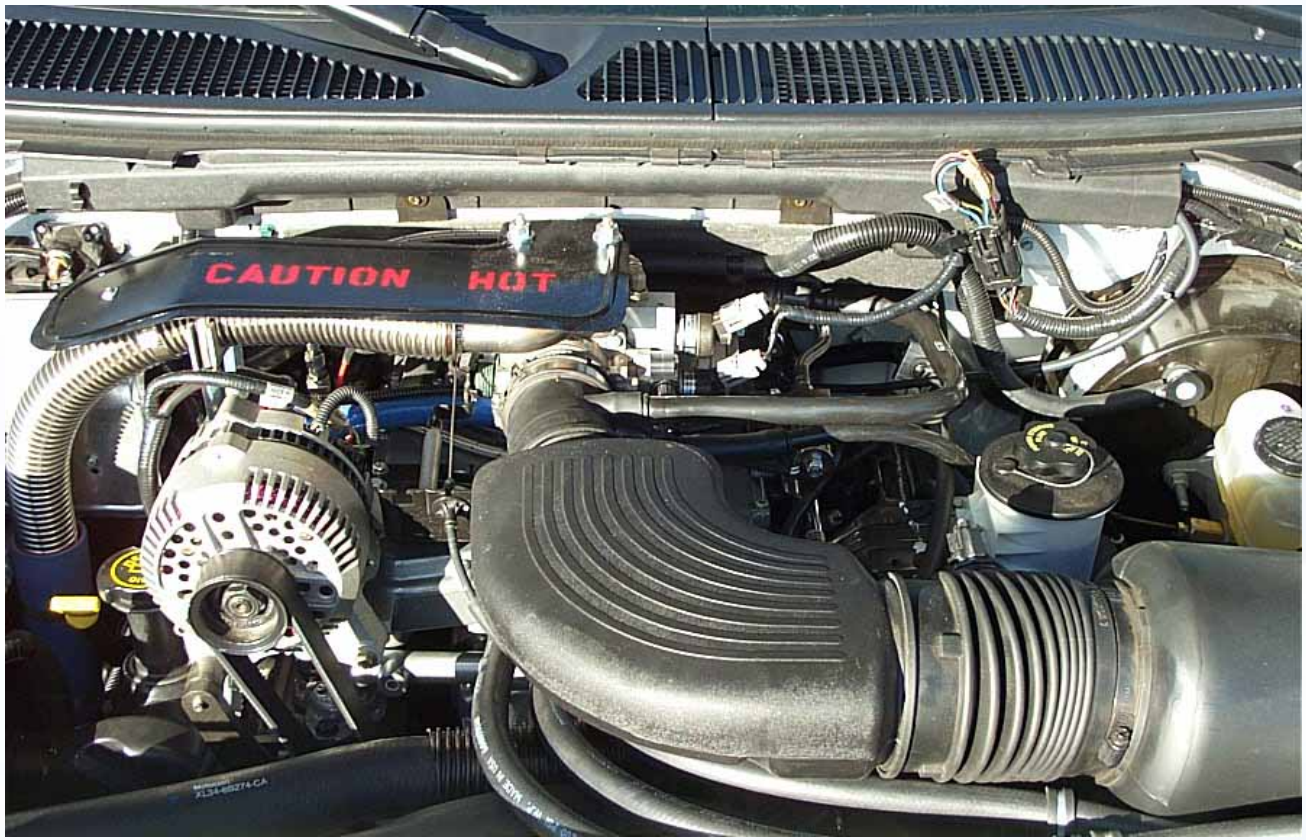
- **Design Goals and Accomplishments**
  - Developed a complete Heavy Duty 11 liter engine for operation with 30% HCNG
  - Meet or exceed pending emissions regulations
    - Emissions goal 0.2 g/hp-hr NOx
    - Accomplished 0.1 g/hp-hr NOx through entire operating range

Accomplishments Light Duty Vehicle Conversion Kit

- Developed a kit to modify an existing dedicated natural gas vehicle for operation with 30% HCNG
- Beta version in use for 4 years and 60K trouble free miles
- Successful road testing
- Continues to achieved very low emissions in FTP 75 test

Accomplishments Light Duty Vehicle Conversion Kit

- Beta version light duty kit shown below



Accomplishments Light Duty Vehicle Conversion Kit Emissions

CAVTC

CLEAN AIR VEHICLE TECHNOLOGY CENTER

1975 Federal City Gasoline Test

Test	6224	Vehicle		Fuel	
Date	10/24/01	Control #	A01NRG01	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

	HC ppmC	CO ppm	NOX ppm	% CO2	CH4ppm	NMHCppm	
Phase 1							
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**

Collier Technologies

Accomplishments Light Duty Vehicle Conversion Kit

- **Kit development will utilize the existing OEM components with minimal manufactured parts**
  - Kit components identified:
    - Supercharger, Fuel rails, Exhaust Gas Recirculation system(EGR), Condensation trap, Mechanical EGR valve and linkage

Future Work

- Commercial sales of 30% HCNG engine through newly formed OEM City Engines, Inc. in collaboration with Daewoo Heavy Industries.
- The final version of the light duty vehicle kit will be designed and documentation for installation will be compiled

Publications and Presentations

- **SAE Paper # 2005-01-0235**

EMISSION RESULTS FROM THE NEW DEVELOPMENT OF A DEDICATED HYDROGEN ENRICHED NATURAL GAS HEAVY DUTY ENGINE

Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

The most significant hazard associated with this project is the potential fire hazard during refueling operations.

Hydrogen Safety

Our approach to deal with this hazard is:

This area falls under the guidelines of Air Products and the City of Las Vegas, as they are the operators of the refueling facility