V.E.2 Hydrogen and Natural Gas Blends – Converting Light and Heavy Duty Vehicles

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Objective

To develop and demonstrate the viability of hydrogen compressed 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.

Technical Barriers

This project addresses the following technical barrier from the Technology Validation section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- A. Vehicles

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.

Accomplishments

- Successfully developed "kit" that is user installable.
- Successfully demonstrated 50k miles of trouble free operation.
- Demonstrated NO_x reductions from 24 to 96%, depending on test and application.

Future Directions

- Convert nine additional light-duty vehicles for the City of Las Vegas.
- Update control strategies for bus using engine modified by Collier Technologies, Inc. (CTI).

Introduction

One of the major mechanisms for reducing NO_x emissions in internal combustion engines is charge dilution. The most common charge dilution techniques are lean burn (excess air) and exhaust gas recirculation (EGR, adding exhaust gases to the intake air). The problem encountered using conventional fuels is that the engine can experience incomplete combustion (misfire) before significant

NO_x reductions are achieved. Adding hydrogen to the fuel extends the amount of charge dilution that can be achieved while still maintaining efficient combustion. Merely adding hydrogen to any fuel does not reduce emissions. In fact, all other things being equal, hydrogen addition to the fuel actually increases NO_x emissions. The question then becomes, does hydrogen addition extend the amount of charge dilution enough to actually reduce NO_x relative to the baseline fuel? Previous work has shown that 20% hydrogen, by volume, in natural gas can reduce NO_x emissions by about one-half while 30% hydrogen and above can reduce NO_x emissions up to 98%.

Approach

CTI has developed a "conversion kit" for light-duty vehicles to operate at lower emissions using a mixture of 30% hydrogen and 70% natural gas. This kit incorporates an innovative EGR system for charge dilution with a low-boost supercharger to recuperate lost engine power.

For heavy-duty applications, the approach is the development of a replacement or OEM engine that is specifically designed to operate at an ultra-lean burn equivalence ratio of Φ=0.53. An important aspect of this engine is the cylinder head that has been redesigned to be compatible with hydrogen-containing fuels.

Results

The emissions results for the conversion kit are shown in Table 1 and compared with the same vehicle operating on natural gas and a similar vehicle operating on gasoline. The vehicle being tested is a Ford F150 pickup truck. The tests were performed using the 3-bag FTP driving cycle.

Emissions results for a heavy-duty engine that was designed and built by CTI are shown in Table 2. The V8 engine has a displacement of 8.9L, develops 200 hp and 450 ft-lbs of torque. The engine was tested using a steady state simulation of the heavy-duty engine test cycle. Emissions were measured at the indicated operating points and given a weighted average based on a relationship to engine operating conditions.

Table 1. Emissions of a Ford F150 Pickup Truck Operating on Gasoline and HCNG

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

Table 2. Emissions of an 8.9 Liter Heavy-Duty Engine Using HCNG Fuel

Individual Modes	NOx (g/hp-hr)	THC (g/hp-hr)	NMHC (g/hp-hr)	CO (g/hp-hr)	Weighting Factor
1800 rpm					
- 100% Load	0.37	3.70	0.07	0.00*	0.15
- 75% Load	0.20	5.80	0.10	0.00*	0.15
- 50% Load	0.10	5.48	0.10	0.00*	0.15
- 10% Load	0.25	5.10	0.10	0.00*	0.10
2800 rpm					
- 100% Load	0.10	5.63	0.26	0.00*	0.10
- 75% Load	0.09	4.71	0.19	0.00*	0.10
- 50% Load	0.11	6.01	0.26	0.00*	0.10
- Idle	0.40	17.44	0.36	0.00*	0.15
Weighted 8 Mode (g/hp-hr)	0.22	7.00	0.18	0.00*	
Weighted 8 Mode (g/kw-hr)	0.29	9.38	0.24	0.00*	

* Not detectible with instrumentation used for emission testing.

Conclusions

The technology associated with the use of at least 30% hydrogen, by volume, in natural gas for the purposes of reducing NO_x emissions from both light- and heavy-duty engines has been demonstrated. Further development can identify a pathway to allow hydrogen-natural gas mixtures to be considered a potentially advantageous fuel for reducing automotive emissions.