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New Technology Research & Development Program
Grant Contract 582-5-70807-0004

Task 3 Deliverable Report

Note- See Task 4 Final Report for more complete data

16 October 2006

Task 3 Report:

PERFORM HEAVY DUTY ENGINE EMISSIONS TESTING

Prepared for:

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
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1.0 PROJECT OBJECTIVE

The objective of this project is to develop, emissions test, and emissions certify with EPA and CARB a low NOx LPG and Low NOx CNG fueling system for GM heavy duty 8.1L and 6.0L engines. The technology is based upon Baytech's Compressed Natural Gas (CNG) sequential Multi-Port Fuel Injection (MPFI) system, which will be modified to operate on LPG. Emissions testing will be conducted on both fuels. The NOx emission goal for both engines is 0.1 g/bhp-hr.

The project consists of four tasks:

Task 1: Modify Heavy Duty Vehicles with Baytech MPFI LPG System

Task 2: EPA and CARB Certification Applications

Task 3: Perform Heavy Duty Engine Emission Testing

Task 4: Program Management and Reporting

This task report documents the work performed on Task 3 of the project.

2.0   HEAVY DUTY ENGINE DYNAMOMETER TESTING

Baytech conducted heavy duty engine dynamometer testing on the 8.1L and 6.0L propane and CNG fueled engines at Southwest Research Institute (SwRI) in San Antonio. The 8.1L engine was tested in February 2005. The 6.0L engine was tested in July 2006.

Two exhaust system configurations of the 8.1L engine were tested, 1) a configuration with two catalytic converters that is used on the GM C/4500/5500 series heavy duty trucks, and 2) a configuration with one catalytic converter that is used on the GM C6500/7500/8500 series heavy duty trucks. The exhaust systems were cut/re-welded to fit the engine dynamometer apparatus and were drilled/tapped for thermocouple fittings to measure catalyst and exhaust temperatures during testing. Baytech developed different engine calibrations for each of these 8.1L heavy duty engine configurations,

A series of development tests were conducted on the propane and CNG fueled 8.1L and 6.0L engines. The results from developments test were used to make adjustments to the engine calibration between tests in order to achieve low-NOx certifcation levels.

Formal HD Transient Test Procedures test protocols required by US Environmental Protection Agency (EPA) and California Air Resources Board (CARB) for heavy duty engine certification were conducted for propane and CNG fuels, and for baseline gasoline. The HD Transient tests were performed according to the Federal Register and CA Title 13 regulations.

2.1 EMISSIONS TEST RESULTS

Baytech conducted a series of certification tests on the two 8.1L heavy duty engine configurations and the 6.0L heavy duty engine (three test series total). Each test series consisted of tests using the following fuels:

- Dedicated CNG

- Dual fuel CNG and gasoline

- Dedicated propane

- Dual fuel propane and gasoline

Table 1 presents the emissions results for each series of certification tests conducted by Baytech:

- The first column shows the Baytech Test Group, assigned by Baytech, that represents a distinct EPA certification. The seventh and eighth digits identify the engine (8.1 or 6.0).

- The second column shows the fuel tested.

- The third column presents two sets of emissions data for each test group. The "Test Results" line presents the actual test emissions results. The "Certification Level" line presents the emissions level after applying EPA-assigned deterioration factors, which are designed to represent end-of-life emissions levels. The "Certification Level" emissions numbers are used in the heavy duty engine emissions certification applications submitted to EPA and CARB. (Note: the 6.0L engine testing was conducted using end-of-life aged emissions components. Baytech achieved extremely low emissions test results, even under this worse case condition.)

- The fourth through tenth columns present emissions test results, and certification levels after applying deterioration factors, for Total Hydrocarbons (THC), Non-Methane Hydrocarbons (NMHC), Oxides of Nitrogen (NOx), Carbon Monoxide (CO), formaldehyde (HCHO), and Idle CO percent. Units for all emissions data are presented in grams per brake horsepower-hour (g/bhp-hr), except Idle CO expressed in percent.

Table 1 Heavy Duty 8.1L and 6.0L Engine Dynamometer Emission Test Results

Test Group	Fuel		THC (g/bhp-hr)	NMHC (g/bhp-hr)	NMHC+NOx (g/bhp-hr)	CO (g/bhp-hr)	NOx (g/bhp-hr)	HCHO (g/bhp-hr)	IDLE CO %
6BYTH08.1C13	dedicated CNG	Test Results	0.21	0.00		1.34	0.23	0.0006	0.001
		Certification Level		0.0	0.3	2.1	0.3	0.001	0.00
6BYTH08.1C23	dual fuel CNG	Test Results	0.21	0.00		1.34	0.23	0.0006	0.001
		Certification Level		0.0	0.3	2.1	0.3	0.001	0.00
	dual fuel Gasoline	Test Results	0.1	0.06		1.70	0.12	0.0007	0.005
		Certification Level		0.1	0.3	2.7	0.2	0.002	0.01
6BYTH08.1P13	dedicated Propane	Test Results	0.1	0.06		2.56	0.21	0.0006	0.003
		Certification Level		0.1	0.4	4.1	0.3	0.001	0.01
6BYTH08.1P23	dual fuel Propane	Test Results	0.1	0.06		2.56	0.21	0.0006	0.003
		Certification Level		0.1	0.4	4.1	0.3	0.001	0.01
	dual fuel Gasoline	Test Results	0.1	0.06		1.70	0.12	0.0007	0.005
		Certification Level		0.1	0.3	2.7	0.2	0.002	0.01
6BYTH08.1C12	dedicated CNG	Test Results	0.56	0.09		3.40	0.21	0.001	0.001
		Certification Level		0.2	0.5	5.4	0.3	0.002	0.00
6BYTH08.1C22	dual fuel CNG	Test Results	0.56	0.09		3.40	0.21	0.001	0.001
		Certification Level		0.2	0.5	5.4	0.3	0.002	0.00
	dual fuel Gasoline	Test Results	0.17	0.11		3.80	0.21	0.001	0.001
		Certification Level		0.2	0.5	6.1	0.3	0.002	0.00
6BYTH08.1P12	dedicated Propane	Test Results	0.34	0.26		5.45	0.25	0.001	0.001
		Certification Level		0.6	0.9	8.7	0.3	0.002	0.00
6BYTH08.1P22	dual fuel Propane	Test Results	0.34	0.26		5.45	0.25	0.001	0.001
		Certification Level		0.6	0.9	8.7	0.3	0.002	0.00
	dual fuel Gasoline	Test Results	0.17	0.11		3.80	0.21	0.001	0.001
		Certification Level		0.2	0.5	6.1	0.3	0.002	0.00
7BYTH06.0613	dedicated CNG	Test Results *	0.24	0.02		1.83	0.12	0.0006	0.001
		Certification Level		0.0	0.2	2.9	0.2	0.001	0.00
6BYTH06.0623	dual fuel CNG	Test Results *	0.24	0.02		1.83	0.12	0.0006	0.001
		Certification Level		0.0	0.2	2.9	0.2	0.001	0.00
	dual fuel Gasoline	Test Results *	0.05	0.04		1.28	0.21	0.0007	0.009
		Certification Level		0.1	0.4	2.0	0.3	0.002	0.01
6BYTH06.0633	dedicated Propane	Test Results *	0.05	0.03		4.09	0.11	0.0006	0.001
		Certification Level		0.1	0.2	6.5	0.1	0.001	0.00
6BYTH06.0643	dual fuel Propane	Test Results *	0.05	0.03		4.09	0.11	0.0006	0.001
		Certification Level		0.1	0.2	6.5	0.1	0.001	0.00
	dual fuel Gasoline	Test Results *	0.05	0.04		1.28	0.21	0.0007	0.009
		Certification Level		0.1	0.4	2.0	0.3	0.002	0.01

* Tested with End of Life Aged Emission Components
Certification Level represents test results with EPA-assigned Deterioration Factors applied

3.0   CONCLUSIONS

The certification level data, after applying EPA-assigned deterioration factors, meet EPA and CARB emissions standards for all test groups. These data were used in Baytech's heavy duty engine certification applications to EPA and CARB for all of the test groups shown in the first column of Table 1.

The challenging project goal was to achieve 0.1g/bhp-hr NOx certification test emissions on both the 8.1L and 6.0L propane heavy duty engines. This goal was achieved on the 6.0L heavy duty engine for both propane and CNG. This represents extremely low NOx emissions for a heavy duty engine. NOx certification test emissions achieved on the 8.1L engine were 0.2 g/bhp-hr for both propane and CNG, also very low NOx emissions for a heavy duty engine.