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Modeling Emission Factors for Compressed Natural Gas Vehicles

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1.0 Introduction

Under the Clean Air Act (CAA)Amendments of 1990, states which have serious, severe, or extreme ozone non-attainment areas, and areas with carbon monoxide design values greater than 16 ppm must establish a Clean Fuel Fleet (CFF) Program. Under the CFF program, a certain percentage of light-duty vehicles, light-duty trucks, and heavy-duty vehicles acquired by certain fleet owners located in covered areas will be required to meet clean-fuel emissions standards. Clean Fuel Fleet emissions standards are lower than those set by the CAA. Many states have incorporated compressed natural gas vehicles (CNGVs) into their CFF programs, and need to model the emission factors and benefits obtained through the addition of CNGVs to the in-use vehicle fleets in their states.

This document examines the emissions benefits of CNGVs and how these benefits will be modeled in MOBILE6. It also describes the data and methodology used to determine these benefits.

2.0 Background

The current version of the MOBILE model, MOBILE5, allows for two fuel types, gasoline and diesel. The model allows for variation in gasoline fuel by permitting a user to specify different Reid vapor pressures and oxygen content. It also estimates emissions of vehicles operating on reformulated gasoline. MOBILE5 also recognizes vehicles that certify to lower emission standards, such as Low Emitting Vehicles (LEVs), Ultra Low Emitting Vehicles (ULEVs), and Zero Emitting Vehicles (ZEVs). MOBILE5 assumes that all of these vehicles are used and accumulate mileage in the same way as other vehicles of the same age, and that all (except ZEVs) are fueled by gasoline.

MOBILE6 will allow users to specifically model the exhaust and evaporative emission benefits of certified Original Equipment Manufacturer (OEM) and certified conversion CNGVs, operating only on CNG fuel. Since any on-board supply of gasoline raises evaporative emissions issues and the magnitude of such emissions will be a function of details of the vehicle design and usage patterns, we are reserving development and release of guidance on estimating emission reduction benefits of hybrid or dual-fuel vehicles (such as those that may have a small supply of gasoline on board for emergency use) until better information on their design and likely in-use emissions performance is available. Users will be able to include both light- and heavy-duty CNG vehicles and trucks in their modeling.

3.0 Data

The data used in this analysis were provided in a report entitled "Comparison of Off-Cycle and Cold-Start Emissions from Dedicated NGVs and Gasoline Vehicles" by Engine, Fuel, and Emissions Engineering, Incorporated (EF&EE).[1] EF&EE was contracted by the Gas Research Institute (GRI) to conduct an automotive emission testing program that would compare emissions from CNGVs to emissions from their gasoline fueled counterparts. The study consisted of twelve vehicles, six CNGVs and six gasoline counterparts. For each fuel type there were two light-duty vehicles, two light-duty truck class 1 (LDT1, up to 6000 lb GVW) , and two light-duty truck class 2 (LDT2, 6001-8500 lb GVW). Exhaust emissions were measured using several different procedures, but this analysis considered only the data obtained through testing using the Federal Test Procedure (FTP).

4.0 Light-duty Analysis

4.1 Methodology

Many CNGVs can be certified to the ULEV emissions standards set by the Environmental Protection Agency (EPA). Manufacturers have tested CNG vehicles that have had emission rates lower than the ULEV standard. In order to insure that CNG vehicles are credited with the correct modeling benefit, EPA performed a comparison between the CNGV emission data and the ULEV emission factors proposed for use in MOBILE6. The CNG vehicles in the data set were relatively new and had low mileage accumulation, therefore they were compared with the emission factors for normal emitting ULEV vehicles at the same mileage. This comparison was performed for both the light-duty vehicles (LDV) and light-duty trucks (LDT) in the data sample. Table 1 contains the estimated emission values for M6 ULEVs, average measured emissions data from CNGVs, and the percent change between the two vehicle types. The standard deviation for CNGV emissions is also given for the readers information. Due to the limited sample size, p-values were not calculated.

Table 1: Emission Values and Percent Change for Predicted M6 ULEVs and Measured CNGVs

Vehicle Type and Pollutant	Estimated M6 ULEV Emissions	Average Emissions from CNGVs	Percent Change	Standard Deviation for CNGV Emissions
LDV - NMHC	.026	.025	3.9% decrease	.008
- CO	.544	.62	13.9% increase	.444
-NOx	.156	.058	62.8% decrease	.055
LDT1 - NMHC	.026	.03	15.4% increase	.007
- CO	.544	.23	57.7% decrease	.046
- NOx	.156	.122	21.8% decrease	.107
LDT2 - NMHC	.03	.03	N/A	.018
- CO	.781	1.09	39.5% increase	.548
- NOx	.265	.473	78.5% increase	.228

[1] A copy of this report can be obtained by contacting Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, Illinois 60631-3562

4.2 Light-Duty Vehicle Analysis

The average emissions at an average mileage for light-duty vehicles in the data set were compared to predicted MOBILE6 ULEV emission factors at the same mileage. Figure 1 shows the graphical comparison. Figure 1 shows a slight decrease in CNG non-methane hydrocarbons (NMHC) and a decrease in oxides of Nitrogen (NOx). An increase in carbon monoxide (CO) emissions for CNG vehicles, relative to gasoline vehicles, was observed using this comparison.

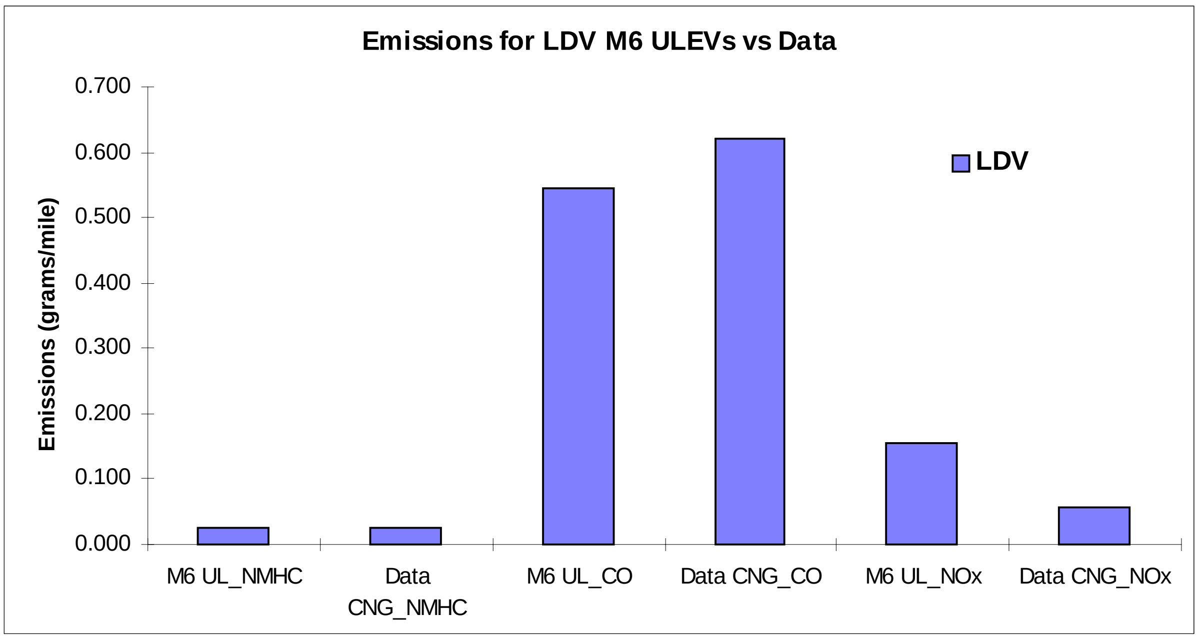

Figure 1: Emissions for LDV ULEVs M6 vs CNG Data

4.3 Light-Duty Truck Analysis

The data set used contained two weight classes of light-duty trucks, Light-Duty Truck 1 (LDT1) and Light-Duty Truck 2 (LDT2). The average emissions for each pollutant from each truck class were compared to the estimated MOBILE6 ULEV emission factors for that truck class at the same milage. Figures 2 and 3 show the comparison.

Figure 2: Emissions for LDT1 M6 ULEVs vs CNG Data

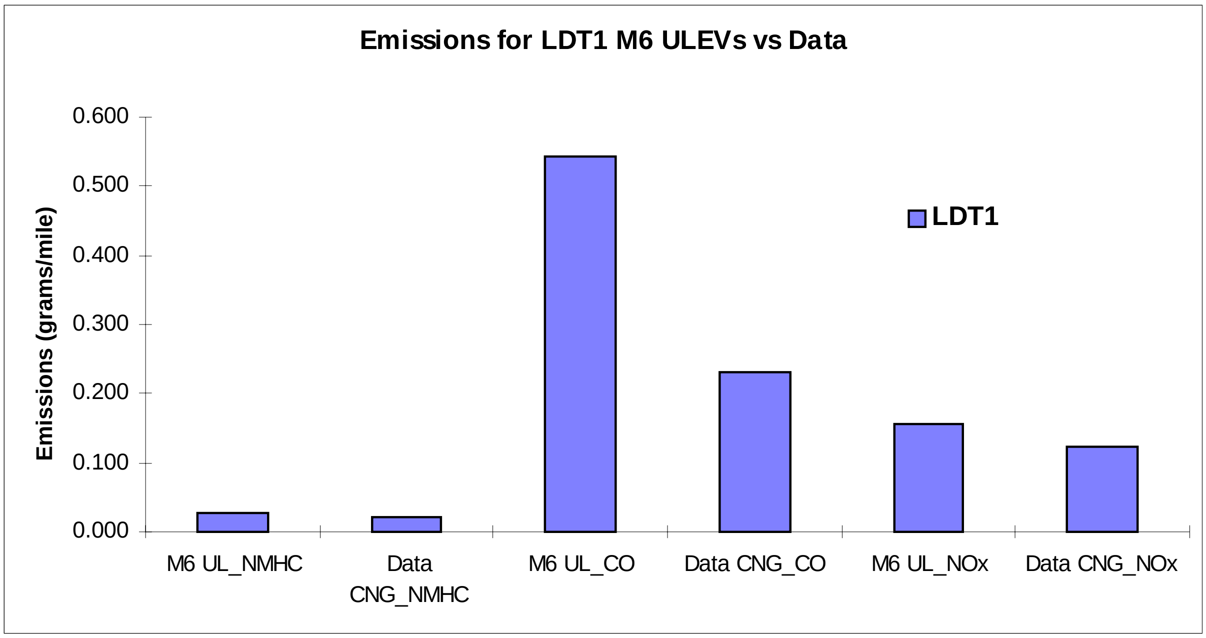

Figure 3: Emissions for LDT2 M6 ULEVs vs Data

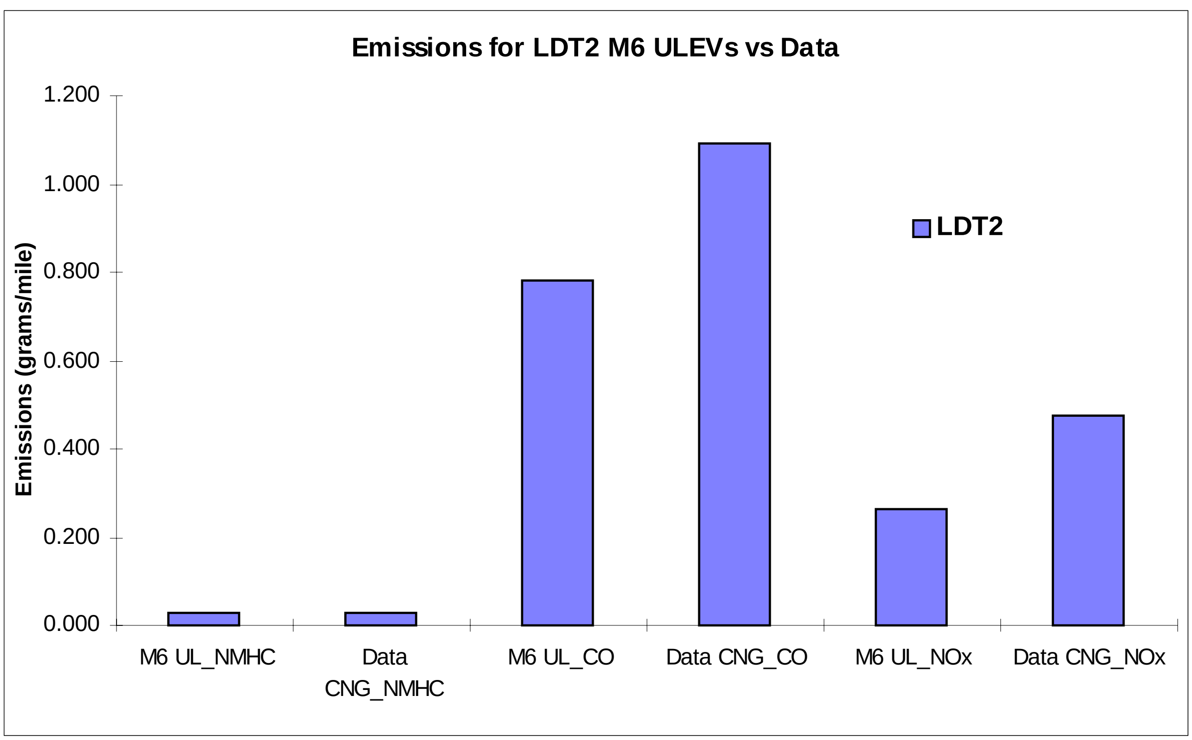

Figure 2 shows a decrease in CNG NMHC, CO, and NOx emissions. Figure 3 shows no change in CNG NMHC, while there is a noticeable increase in CO and NOx emissions. It is hard to justify the inconsistencies seen in these comparisons. It may be due to the small sample size (only two CNG vehicles of each vehicle type), or a problem with the vehicles themselves.

4.4 Results and Conclusions

The analysis shows some inconsistencies in the benefits associated with CNG vehicles. Based on this analysis, MOBILE6 will set NMHC, CO and NOx exhaust emissions for light-duty CNG vehicles and trucks equal to those of gasoline ULEV vehicles and trucks. Also, since there are no evaporative emissions associated with gaseous fueled vehicles (such as CNGVs), MOBILE6 will calculate zero evaporative emissions for CNG vehicles.

5.0 **Heavy-duty Vehicles**

5.1 Methodology

Some heavy-duty CNG engines are used in buses, sanitation trucks, long-distance hauling trucks, etc. and are replacing their diesel and gasoline counterparts. EPA will assume that these heavy-duty CNG vehicles operate and accumulate mileage in the same fashion as heavy-duty diesel and gasoline trucks. There was no in-use heavy-duty emissions data available at the time this analysis was completed, therefore the following methodology was developed to generate emission factors for MOBILE6

EPA proposes that emission factors for certified heavy-duty CNG vehicles are equal to the emission factors of heavy-duty diesel engines certified to the year 2004 emission standard of 2.5g/bhp-hr for NOx and NMHC combined. In MOBILE6, the NOx exhaust benefit associated with heavy-duty CNG vehicles will be determined by which fuel type vehicle and model year it is replacing in the fleet. For example, if a heavy-duty CNG vehicle is replacing a heavy-duty gasoline vehicle, current heavy-duty gasoline vehicles have a less stringent emission standard than heavy-duty diesel vehicles meeting the 2004 standard, therefore the benefit is given by the difference between the 2004 standard and the standard to which the vehicle it is replacing is certified. Also, there is an evaporative benefit associated with replacing a heavy-duty gasoline vehicle with a heavy-duty CNG vehicle. The same method applies if a heavy-duty CNG vehicle is replacing a heavy-duty diesel vehicle, except that diesel vehicles already exclude evaporative emissions. There will be no CO or NMHC benefit associated with heavy-duty CNG vehicles.

6.0 **CNG Vehicles in MOBILE6**

6.1 Start vs Running

MOBILE6 will estimate emission factors for start and running emissions separately for light-duty vehicles. Thus, the emissions estimates for light-duty CNGVs had to be separated into start and running components. EPA tried to use FTP bag data to distinguish start and running emissions, as was done for light-duty gasoline vehicles (as described for gasoline vehicles in M6.STE.002), but the results were inconsistent. This may be due to the limited sample size or it may be that the technology and combustion cycle of CNGVs are different enough from conventional vehicles that applying this methodology is incorrect. Because of the inconsistency, emissions from light-duty CNG vehicles will be split into start and running using the same proportions used to separate emissions for ULEV vehicles in MOBILE6 as documented in EPA report number M6.EXH.006.

MOBILE6 does not split heavy-duty diesel emissions into separate start and running emission factors. Hence, heavy-duty CNGV emissions also will not be separated into start and running.

6.2 Correction Factors

Several correction factors are applied to vehicle emissions in MOBILE6. These include off-cycle corrections, air conditioning corrections and fuel corrections. The same off-cycle and air conditioning correction factors that are applied to gasoline ULEVs will be applied to CNG vehicles. CNG vehicles, including heavy-duty, will not be affected by any fuel corrections.

6.3 Inspection and Maintenance, On-Board Diagnostics, and Tampering Assumptions

There are several assumptions made in MOBILE6 concerning the effects that inspection and maintenance(I/M) programs, on-board diagnostics, and tampering have on the emissions of such vehicles. The same assumptions that apply for gasoline ULEVs will apply for CNG vehicles in MOBILE6.

7.0 **Conclusion**

There are some emissions benefits associated with Compressed Natural Gas vehicles. MOBILE6 will model these benefits for light-duty and heavy-duty vehicles. For light-duty vehicles, CNG vehicle emissions will be modeled as being equal to the emissions of a ULEV vehicle for CO and NOx, and NMHC emissions. For heavy-duty vehicles, CNG vehicle NOx emissions will be equivalent to the emissions of heavy-duty diesel vehicle at the federal 2004 standard of 2.5 g/bhp-hr for NOx and NMHC. There will be no CO or NMHC benefit associated with heavy-duty CNG vehicles. There will be an evaporative benefit associated with heavy-duty CNG vehicles that replace heavy-duty gasoline vehicles.