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NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY
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March 26, 1999

MEMORANDUM

SUBJECT: Development of Heavy-Duty Gasoline Emissions Inventories for the Tier 2/Sulfur NPRM

FROM: John W. Koupal
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TO: Docket A-97-10

The purpose of this memo is to document the methods and assumptions used to create the emission inventory estimates for Heavy-Duty Gasoline Vehicles (HDGVs) presented in the Notice of Proposed Rulemaking (NPRM) for Tier 2 and Sulfur standards. The proposed gasoline sulfur program is projected to reduce NOx, VOC, SOx and PM emissions from HDGVs; thus, the methodology used to generated inventory results for both the baseline and control cases is discussed. The methodology for generating VOC and NOx inventories relied on updates to EPA's on-highway emission inventory model MOBILE5b, as discussed in Section 1. PM and SOx inventories were generated based on updates to EPA's PART5 model, and are discussed in Section 2.

1 VOC and NOx

Heavy-Duty Gasoline Vehicles are gasoline-powered trucks with a gross vehicle weight (GVW) greater than 8,500 pounds. MOBILE5 treats these vehicles as a single class; MOBILE6 will divide this category of trucks into eight distinct weight classes, ranging from 8,500 to over 60,000 pounds.[1] MOBILE6 will also include updated basic emission rates (BERs) and conversion factors (used to convert the BERs from units of grams per brake horsepower-hour to grams per

[1] Jackson, T., "Fleet Characterization Data for MOBILE6:Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates, and Projected Vehicle Counts for Use in MOBILE6", Draft MOBILE6 Report M6.FLT.007, March 1999. Hereafter referred to as "Draft MOBILE6 Fleet Report".

mile) for model years 1988 and later, as well as mileage accumulation and age distribution rates. For this analysis, adjustments were made to these BERs to account for off-cycle effects (encompassing aggressive driving and air conditioning), fuel effects, and the presence of "high emitters" in the fleet. In addition, the inventories developed in support of the proposed Tier 2 and Sulfur standards took into account new emission standard expected to be proposed for HDGVs under 14,000 pounds, which would take effect in 2004.

For NOx and exhaust VOC, HDGV inventories were updated by entering the updated HDGV emission estimates into MOBILE5b. This required adjusting the updated basic emission rates to account for off-cycle, fuel and high emitter effects. The method used to generate these adjusted emission rates (termed "final" emission rates, or FERs) is detailed in Section 1.1. The next step, discussed in Section 1.2, required consolidating the final emission rates for the eight heavy-duty gasoline classes into a single HDGV class to accommodate the MOBILE5b treatment of HDGVs. The final step was to run MOBILE5b with the updated inputs and generate emission inventory estimates for the five areas used in the Tier 2 inventory analysis: 47-state, New York, Chicago, Atlanta and Charlotte. As described in Section 1.3, nonexhaust (i.e., evaporative and refueling) VOC inventories were also generated for these areas using MOBILE5b.

1.1 Generation of Final Emission Rates (FERs)

1.1.1 Basic Emission Rates

1.1.1.1 Grams Per Brake Horsepower - Hour

For the 1988 through 2003 model years, updated HDGV BERs (comprised of a zero-mile level and deterioration rate) proposed for MOBILE6 were used.[2] Table 1 presents the zero-mile level in grams per brake horsepower-hour (g/bhp-hr) and the deterioration rate in g/bhp-hr per 10,000 miles for 1988 and later model year heavy-duty gasoline engines. For pre-1988 vehicles, MOBILE5b BERs were used directly.

[2] Jackson, T., and Lindhjem, C., "Update of Heavy-Duty Emission Levels (Model Years 1988- 2004+) for Use in MOBILE6," MOBILE6 Report No. M6.HDE.001, March 1999

Table 1
Baseline Exhaust Emission Rates for 1988 through 2003 Model Year HDGVs

Model Year	Zero-Mile Level g/bhp-hr		Deterioration Rate g/bhp-hr per 10,000 miles	
	NOx	NMHC	NOx	NMHC
1988-1989	4.96	0.62	0.044	0.023
1990	3.61	0.35	0.026	0.023
1991-1997	3.24	0.33	0.038	0.021
1998-2003	2.59	0.33	0.038	0.021

1.1.1.2 Conversion to Grams Per Mile

To convert the emissions of engines certified to g/bhp-hr standards to g/mi levels, MOBILE6 will multiply the emissions rated presented in Table 1 by conversion factors expressed in units of bhp-hr/mi.[3] These conversion factors are determined based on fuel density, brake specific fuel consumption and fuel economy, and vary across the eight HDGV weight classes planned for MOBILE6. Thus, although basic emission rates in terms of g/bhp-hr are the same for all HDGVs. they are not the same on a gram per mile basis. Table 2 contains the HDGV conversion factors used for this analysis. For Classes 2b (8,500 to 10,000 lbs) and 3 (10,001 to 14,000 lbs), the conversion factors proposed for MOBILE6 were used; for Classes 4 and higher (greater than 14,001 lbs), a composite weighting was generated using proposed MOBILE6 conversion factors and VMT fractions.

Table 2
Conversion Factors for 1988 through 2003 HDGVs (bhp-hr/mi)

Model Year	Class 2b	Class 3	Class 4 and higher
1988-1989	1.073	1.150	1.269
1990	1.076	1.150	1.270
1991-1997	1.089	1.149	1.273
1998-2003	1.096	1.150	1.273

[3]"Update Heavy-Duty Engine Emission Conversion Factors for MOBILE6," EPA Report No. EPA420-P-98-015, prepared for EPA by ARCADIS Geraghty & Miller, Inc., May 1998.

1.1.1.3 Proposed 2004 HDGV Program

EPA is currently developing a proposal for new emission standards for HDGVs which would be applicable to all model year 2004 and later HDGVs. Under this proposal, most HDGVs under 14,000 (Classes 2b and 3) would be certified on a chassis test cycle, referred to as "complete" vehicles; these vehicles will be subject to a gram per mile emission standard. Conversely, "incomplete" vehicles (encompassing a small portion of HDGVs below 14,000 lbs, and all vehicles over 14,000 lbs) will continue to certify on an engine dynamometer. Basic emission rates for 2004 and later HDGVs (complete and incomplete) were developed in grams per mile, accounting for the estimated effects of the expected standards.

At the 120,000 mile useful life for heavy-duty gasoline engines, a typical 1998 and later model year heavy-duty gasoline engine is estimated to emit roughly 3.0 g/bhp-hr of NOx, or 75 percent of the level of the standard of 4.0 g/bhp-hr. Assuming manufacturers maintain the same amount of cushion below the standard, emissions levels associated with the proposed standards were estimated by applying this cushion to the new standards. Table 3 presents the resulting baseline zero-mile levels and deterioration rates for Class 2b complete vehicles, Class 3 complete vehicles, and incomplete HDGVs for the 2004 and later model years.

Table 3
Estimated Baseline Exhaust Emission Rates for
2004 and later Model Year HDGVs

Vehicle Category	Zero-Mile Level, grams per mile (g/mi)		Deterioration Rate g/mi per 10,000 miles	
	NOx	NMHC	NOx	NMHC
Class 2b Completes	0.574	0.119	0.008	0.008
Class 3 Completes	0.638	0.140	0.009	0.009
Incomplete HDGVs	0.565	0.094	0.008	0.006

1.1.2 Off-Cycle Effects

The basic emission rates described above represent the emission levels of an engine or vehicle tested and operated over EPA's federal test procedure for heavy-duty gasoline engines or vehicles. The current test procedures used to measure emissions from heavy-duty gasoline engines and vehicles do not reflect the full range of in-use operating characteristics for such vehicles, including "aggressive driving" (high speed operation and/or heavy accelerations), and the use of air-conditioning. For this analysis, adjustments were therefore applied to the base emission rates to account for these effects.

At the time of this analysis, sufficient data were not available to assess the effects of off-cycle emissions from HDGVs. Off-cycle adjustments developed for LDT4s were instead used as the basis for the heavy-duty corrections in the 1980 and later model years;[4] LDT4s are the heaviest light-duty trucks, and hence the ones whose emission characteristics would most closely resemble those for HDGVs. The method for determining the appropriate adjustment involved mapping base emission levels and emission control technology for HDGVs with light-duty trucks before and after the expected 2004 standards, focusing primary on NOx For 1980 through 2003 model years, base NOx emission levels for heavy-duty vehicles are consistent with base emissions from early late 1970's and early 1980's light duty trucks. The off-cycle adjustment factors from light-trucks in this period were therefore assumed to be appropriate for 1980 through 2003 HDGVs. For 1980 and earlier light-duty trucks, these adjustments were 1.03 g/mi NOx and 0.15 g/mi NMHC, added to the base emission rate; these adjustments were therefore added to the BERs for all 1980 through 2003 HDGVs.

With the advent of the yet-to-be-proposed 2004 standards, heavy-duty vehicles are expected to be equipped with emission control technology consistent with more advanced light-duty trucks. The off-cycle adjustments for 2004 and later HDGVs were therefore based on those developed for LEV LDT4s. For light-duty trucks, off-cycle adjustments were developed using a fairly complex methodology which took into account the relative mix of “normal” and “high” emitters, and deterioration over the life of the vehicle. For HDGVs, these effects were accounted for implicitly by developing a multiplicative adjustment developed based on the percent difference in total tons emitted over the life of an LDT4 (lifetime tons) with and without off-cycle effects. The methodology used for generating lifetime tons for LDT4s was identical to that used for calculating per-vehicle lifetime tons used in the Tier 2 cost effectiveness analysis,[5] with one exception: no discounting factor was applied, since the goal was to compute total tons over the life of the vehicle, rather than net present value tons.

As noted, heavy-duty gasoline emission inventories were calculated for five regions: the 47-state region defined by the U.S. minus California, Alaska and Hawaii; and New York, Chicago, Atlanta, and Charlotte. Off-cycle adjustments for the 47-state case required accounting for the appropriate mix of I/M and fuel programs within the region; this was accomplished using weighting factors developed as part of the light-duty inventory analysis.[6] To develop off-cycle

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[4]Koupal, J. “Development of Light-Duty Emission Inventory Estimates In The Notice Of Proposed Rulemaking for Tier 2 and Sulfur Standards”, EPA Report No. EPA420-R-99-005, March 1999. Hereafter referred to as “Tier 2 Light-Duty Inventory Report”.

[5]Ibid.

[6]Ibid.

adjustments which reflected the 47-state region, 48 percent of the regional population was estimated to reside in I/M areas. The fuel program weightings were developed to reflect the annual basis of the 47-state inventories: 13.5 percent RFG versus 86.5 non-RFG. The "with I/M" and "without I/M" scenarios assumed the presence of On-Board Diagnostic (OBD) systems, which are expected to be required under the proposed 2004 HDGV standards. The "No I/M" scenarios reflected only the presence of an OBD system, while the "with I/M" scenario assumed the presence on an I/M program based on OBD checks. Fuel program scenarios under the baseline case included RFG, with an estimated sulfur level of 150 ppm, and conventional gasoline, with an estimated sulfur level of 330 ppm; these sulfur levels were combined based on the population fractions within RFG and non-RFG areas across the 47-state region to result in an average baseline sulfur level of 306 ppm. For the control case, the sulfur level was set at 30 ppm across the entire 47-state region.

Lifetime LDT4 tons with and without off-cycle effects, calculated for the 47-state area as described above, are shown in Table 4. From these tonnages, multiplicative adjustments were developed based on the percent increases shown (e.g., a 53 percent increase translates to an adjustment factor of 1.53); these were applied directly to 2004 and later BERs from Table 3.

Table 4
LDT4 Lifetime Tons With and Without Off-Cycle (47-State Annual)

Fuel	NOx			Exhaust NMHC		
	Without Off-Cycle	With Off-Cycle	Increase	Without Off-Cycle	With Off-Cycle	Increase
306 ppm	0.246	0.376	53%	0.089	0.106	19%
30 ppm	0.186	0.285	53%	0.076	0.090	18%

1.1.3 Fuel Effects

1.1.3.1 Non-Sulfur Fuel Adjustments

When heavy-duty gasoline engines and vehicles are tested for certification purposes, the properties of the gasoline used in the vehicle must comply with regulations set forth by EPA. Once vehicles are sold and operated in use, the properties of the gasolines available in the marketplace will be different in some ways from the certification fuel. Fuel adjustments were therefore developed which reflected the non-sulfur fuel properties of both RFG and conventional gasoline relative to certification fuel. These adjustments were derived directly from the MOBILE5b fuel adjustment. The non-sulfur component of this adjustments was broken out for RFG and conventional gasoline using EPA's Complex Model. Table 5 presents the non-sulfur fuel adjustments applied to all heavy-duty gasoline vehicles across all model years, averaged on the basis of the 47-state region and annual period. These factors are multiplicative and were applied to both the zero-mile levels and deterioration rates, following the off-cycle adjustments discussed in Section 1.1.2.

Table 5
Non-Sulfur Fuel Adjustment (47-State Annual)

NOx	NMHC
1.032	1.075

1.1.3.2 Sulfur Adjustments

The amount of sulfur in gasoline significantly affects the emission levels of low-emitting vehicles (particularly NOx) by affecting the efficiency of the catalytic converter.[7] The 2004 standards expected to be proposed for HDGVs will likely result in emission control technologies comparable to current light-duty LEVs; hence updated sulfur effects for 2004 and later HDGVs were developed from LEV LDT4s. These sulfur effects were derived in a manner similar to off-cycle effects; namely, lifetime tonnages were generated for LDT4s at 30 ppm (no sulfur effect), and at the baseline 47-state annual average sulfur level of 306 ppm. These tonnages included on- and off-cycle emissions, and hence accounted for sulfur effects over all driving. Table 6 presents the LDT4 tonnages and the resulting sulfur fuel adjustments which were applied to heavy-duty gasoline vehicles. For pre-2004 vehicles, the sulfur component of the MOBILE5 fuel adjustment were applied (because the non-sulfur component of the MOBILE5 fuel adjustment was also applied, the overall fuel adjustment for these vehicles is unchanged from MOBILE5). The factors listed in the "percent increase" column are multiplicative and are applied to both the zero-mile levels and deterioration rates after correction for off-cycle driving and non-sulfur fuel effects. The sulfur control case (30 ppm) was modeled by removing these adjustments for all model year vehicles.

Table 6
LDT4 Lifetime Tons With and Without Sulfur Effects (47-State Annual)

	NOx			NMHC		
Model Year	30 ppm	306 ppm	Percent Increase	30 ppm	306 ppm	Percent Increase
1980-2003	n/a	n/a	11%	n/a	n/a	5%
2004+	0.285	0.376	32%	0.090	0.106	18%

[7] "EPA Staff Paper on Gasoline Sulfur Issues," EPA Report No. EPA420-R-98-005, May 1998.

1.1.4 High-Emitter Adjustments

The yet-to-be-proposed 2004 standards are expected to require the adoption of emission control technologies which are similar to those currently used on light-duty vehicles and trucks. This is expected to increase the potential for "high-emitter" vehicles that have significantly higher emissions compared to the original certification levels because of emission control systems failures. Because the emission rates presented in Table 3 were derived using certification data and thus represent properly operating vehicles, a "high emitter" adjustment was developed to reflect the probability of heavy-duty vehicles emitting well above the proposed 2004 standards due to emission control system failure..

Onboard diagnostic controls and inspection and maintenance programs can help to identify such high-emitting vehicles. We assumed for this analysis that the 2004 and later emission rates presented in Table 3 reflect in-use emissions with the presence of OBD and an I/M program; adjustments which reflected the potential for increased emissions due to unrepaired emission control failure were then developed for the 47-state region, based on LDT4 lifetime tons. These adjustments were developed based on the percent increase between LDT4 lifetime tonnages for an I/M case and a case which reflected the mix of I/M and no I/M (48 and 52 percent) across the 47-state region. Table 7 shows these tonnage estimates, and the resulting percent increases. These increases were applied to the off-cycle and fuel-adjusted BERs (zero-mile levels and deterioration rates) for 2004 and later HDGVs (e.g., for a percent increase of 5.3 percent, the BERs were multiplied by 1.053).

Table 7
LDT4 Lifetime Tons a) With I/M and, b) Across 47-State Region

	NOx			NMHC		
	With I/M	47-State Average	Percent Increase	With I/M	47-State Average	Percent Increase
306 ppm	0.357	0.376	5.3%	0.085	0.106	25%
30 ppm	0.265	0.285	7.6%	0.071	0.090	27%

1.1.5 Final Emission Rates By HDGV Class

Final emission rates are the basic emission rates from Tables 1 and 3 with the off-cycle, fuel and high emitter adjustments discussed above. These were calculated individually by model year grouping and weight class (2b complete/incomplete, 3 complete/incomplete, 4 and higher). These rates are shown in Appendix A, Tables A-1 through A-4.

1.2 Modeling Methodology

The next step in the generation of the heavy-duty gasoline NOx and exhaust VOC emission inventories was to generate emission factors (EFs) which represent the average gram per mile emissions of the heavy-duty gasoline fleet in a given calendar year. This step was performed by using the final emission rates generated in Section 1.1 as input into MOBILE5b as alternate emission rates via the NEWFLG option. Three steps were required in order to generate final emission rates appropriate for MOBILE5b:

1) Because MOBILE5b treats HDGVs as a single class, a weighted average FER was calculated for each model year grouping by combining the class-based FERs from Section 1.1.5. Class weightings developed from sales information provided by manufacturers were used to develop these weighted FERs. The sales fractions and weighted average FERs are shown in Appendix A.

2) MOBILE5b automatically assesses a fuel adjustment to account for the same fuel effects discussed in Section 1.1.3. Because the weighted FERs already included these fuel effects, they required modification to avoid the "double counting" which would result from the MOBILE5b correction being applied. The weighted FERs were therefore divided by the MOBILE5b fuel adjustment (estimated at 1.16 for both NOx and NMHC).

3) Alternate HDGV emission rates input into MOBILE5b must be expressed in terms of grams per brake horsepower-hour. These rates are then multiplied by conversion factors internal to MOBILE5b to generate emission factors in terms of grams per mile. The gram per mile FERs from Step (2) were therefore divided by the MOBILE5b correction factors to ensure that, when corrected by these same factors, the desired gram per mile output would result.

The final product of Steps (1) through (3) was composite HDGV FERs expressed in grams per brake horsepower-hour, for both the baseline (current in-use fuel) and control (30 ppm) cases. The latter FERs are only applicable to calendar years 2004 (the first year of sulfur control) and later.

Annual mileage accumulation rates and age distributions proposed for use in MOBILE6 were also input into MOBILE5.[8] Because the proposed inputs for MOBILE6 are disaggregated by heavy-duty weight class, a single composite set of each input was needed for MOBILE5b. These composites were generated at each age level (one through 25) using the disaggregated values proposed for MOBILE6 and weighting factors based on fleet size in a given year.[9]

Using the alternate inputs (emission rates, mileage accumulation and age distribution), MOBILE5b was run so as to provide no additional speed or temperature corrections. The

[8] Draft MOBILE6 Fleet Report

[9] "Modifications to Heavy-Duty Diesel Emission Rates, Heavy-Duty Mileage Accumulation, and Age Distributions in MOBILE5b for the Tier 2/Sulfur NPRM, Memorandum from Janet Kremer to Docket A-97-10

average speed was set at 19.6 mph, and the daily temperature range was set from 72° to 96° F. No additional programs (e.g. I/M) were specified. The model was run for the following years: 1995, 2000 through 2010, 2012, 2015, 2020 and 2030.

The EFs produced by MOBILE5b represented the 47-state region on an annual basis. Inventories were also generated for the four urban areas (New York, Chicago, Atlanta and Charlotte) on a summertime basis. Baseline EFs for these areas were developed directly from the 47-state EFs, accounting for the fuel differences between the areas. Sulfur effects were modeled by interpolating between (or extrapolating from) 47-state in-use fuel (306 ppm) and 30 ppm to generate EFs for 150 ppm (New York and Chicago), or 330 ppm (Atlanta and Charlotte). Non-sulfur fuel effects (for HC only) were modeled by multiplying the sulfur-adjusted EFs by the ratio of the non-sulfur adjustment for RFG or conventional gasoline (from MOBILE5b) by the non-sulfur adjustment in the 47-state region (1.075, from Table 5). For RFG, this ratio was 0.884; for conventional gasoline, this ratio was 1.017.

Nonexhaust HC estimates were generated for HDGVs using MOBILE5b directly, without any further modifications. The detailed methodology used to generate heavy-duty nonexhaust EFs was identical to that described in Section 7 of the report "Development of Light-Duty Emission Inventory Estimates in the Notice of Proposed Rulemaking for Tier 2 and Sulfur Standards" contained in the Tier 2 Docket (Docket No. A-97-10), and thus is not covered here. In general, MOBILE5b was run over a series of scenarios covering permutations of region (North and South), fuel program and I/M program. The results from each scenario were then weighted together based on population fractions to develop the EFs appropriate to each analysis region. No additional control of heavy-duty nonexhaust emissions is included in the proposed Tier 2 program, so the EFs are applicable to both the baseline and control cases.

The resulting EFs for each analysis region are shown in Appendix B for NOx, exhaust VOC and nonexhaust VOC.[10]

1.3 VMT estimates

In order to generate tonnage estimates from the EFs developed in Section 3, estimates of vehicle miles traveled (VMT) were required. For the 47-state analysis, VMT estimates from 1995 through 2010 were generated from EPA's Trends Report.[11] Total VMT across the 47-state region was multiplied by the nationwide fraction of VMT by HDGVs in each year. Beyond 2010, VMT estimates were calculated through linear extrapolation of the 1995 through 2010 estimates.

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[10] VOC and NMHC were assume equal for this analysis.

[11] "Documentation of Mobile Source Inventories Used in OAQPS Trends Report", Report prepared for EPA by E.H. Pechan & Associates under EPA Contract No. 68-D3-0035/Work Assignment No. III-115, September 1997

These estimates reflected total VMT by all HDGVs over an entire year.

Estimates of HDGV VMT in New York, Chicago, Atlanta and Charlotte during the summer months (May through September) of 1995 and 2007 were provided to OMS by E.H. Pechan and Associates, based on work for the Ozone Transport Assessment Group (OTAG). Projections for all other years were developed based on linear interpolation or extrapolation of these two years.

The resulting VMT estimates in the modeled years are shown in Appendix B, for the 47-state region (annual) and each urban area (summer).

1.4 Results

The final heavy-duty gasoline VOC and NOx inventories, expressed in tons produced over the analysis period, are shown in Appendix B for both the baseline and control cases. Tonnages were calculated according to the following equation:

$$TONS = \frac{EF * VMT}{902{,}700}$$

Where:

TONS = tons emitted by heavy-duty gasoline vehicles during the analysis period
VMT = vehicle miles traveled by heavy-duty gasoline vehicles during the the analysis period
*902,700 = 453.6 grams per pound * 2000 pounds per short ton*

2 PM and SOx

Emission factors for HDGV PM and SOx emissions were derived from a version of the PART5 emission factor model updated to reflect new information on heavy duty conversion factors and mileage accumulation rates.[12] This modified version of PART5 was run at an average speed of 19.6 mph and a daily temperature range of 72° F to 96°, for calendar years 2005, 2007, 2010, 2015, and 2020. These emission factors were multiplied by the same VMT estimates described above (and presented in Appendix B) to estimate the PM and SOx inventories for the 47 states and for the four urban nonattainment areas (Atlanta, Charlotte, Chicago, New York). These inventories are presented in full in Chapter III of the Tier 2 Regulatory Impact Analysis (Appendix III-A).

[12] "Updating the PART5 Model", Memorandum from Edward Glover to Docket A-97-10

APPENDIX A

NOx and Exhaust VOC Final Emission Rates (FERs)

Table A-1
NOx Final Emission Rates for Heavy Duty Gasoline Vehicles: Baseline Fuel

Model Year	FINAL EMISSION RATES BY CLASS										WEIGHTED FER (g/mi)		DIVIDE BY MOBILE5b FUEL ADJUSTMENT & CONVERSION FACTOR		MODIFIED MOBILE5B FER (g/bhp-hr)	
	2b Complete		2b Incomplete		3 Complete		3 Incomplete		4+ Incomplete							
	Weight = 0.741		Weight = 0.029		Weight = 0.016		Weight = 0.113		Weight = 0.101							
	ZML	DR	ZML	DR	ZML	DR	ZML	DR	ZML	DR	ZML	DR			ZML	DR
80											7.58	0.069	1.16	0.961	6.80	0.062
81-83											7.25	0.057	1.16	0.912	6.85	0.054
84											7.23	0.057	1.16	0.907	6.87	0.054
85					n/a						7.15	0.034	1.16	0.896	6.88	0.033
86											7.14	0.034	1.16	0.894	6.88	0.033
87											7.15	0.034	1.16	0.897	6.87	0.033
88-89	7.28	0.054	7.28	0.054	7.71	0.058	7.71	0.058	8.39	0.064	7.45	0.056	1.16	0.894	7.18	0.054
90	5.63	0.032	5.63	0.032	5.94	0.034	5.94	0.034	6.43	0.038	5.75	0.033	1.16	0.893	5.55	0.032
91-97	5.22	0.047	5.22	0.047	5.44	0.050	5.44	0.050	5.90	0.055	5.32	0.049	1.16	0.890	5.15	0.047
98-03	4.43	0.048	4.43	0.048	4.59	0.050	4.59	0.050	4.96	0.055	4.51	0.049	1.16	0.885	4.39	0.048
04 +	1.27	0.018	1.25	0.018	1.41	0.020	1.25	0.018	1.25	0.018	1.27	0.018	1.16	0.885	1.23	0.017

Table A-2
NOx Final Emission Rates for Heavy Duty Gasoline Vehicles: 30 ppm Fuel

Model Year	FINAL EMISSION RATES BY CLASS										WEIGHTED FER (g/mi)		DIVIDE BY MOBILE5b FUEL ADJUSTMENT & CONVERSION FACTOR		MODIFIED MOBILE5B FER (g/bhp-hr)	
	2b Complete		2b Incomplete		3 Complete		3 Incomplete		4+ Incomplete							
	Weight = 0.741		Weight = 0.029		Weight = 0.016		Weight = 0.113		Weight = 0.101							
	ZML	DR	ZML	DR	ZML	DR	ZML	DR	ZML	DR	ZML	DR			ZML	DR
80											6.83	0.062	1.16	0.961	6.13	0.056
81-83											6.53	0.052	1.16	0.912	6.17	0.049
84											6.51	0.052	1.16	0.907	6.19	0.049
85	n/a										6.44	0.031	1.16	0.896	6.20	0.030
86											6.43	0.031	1.16	0.894	6.20	0.030
87											6.44	0.031	1.16	0.897	6.19	0.030
88-89	6.56	0.049	6.56	0.049	6.95	0.052	6.95	0.052	7.56	0.058	6.71	0.050	1.16	0.894	6.47	0.048
90	5.07	0.029	5.07	0.029	5.35	0.031	5.35	0.031	5.79	0.034	5.18	0.030	1.16	0.893	5.00	0.029
91-97	4.70	0.043	4.70	0.043	4.90	0.045	4.90	0.045	5.32	0.050	4.79	0.044	1.16	0.890	4.64	0.042
98-03	3.99	0.043	3.99	0.043	4.14	0.045	4.14	0.045	4.47	0.050	4.06	0.044	1.16	0.885	3.95	0.043
04 +	0.97	0.014	0.96	0.014	1.08	0.015	0.96	0.014	0.96	0.014	0.97	0.014	1.16	0.885	0.95	0.013

Table A-3
Exhaust HC Final Emission Rates for Heavy Duty Gasoline Vehicles: In-Use Fuel

Model Year	THC FINAL EMISSION RATES BY CLASS										WEIGHTED FER (g/mi)		DIVIDE BY MOBILE5b FUEL ADJUSTMENT & CONVERSION FACTOR		MODIFIED MOBILE5B FER* (g/bhp-hr)	
	2b Complete		2b Incomplete		3 Complete		3 Incomplete		4+ Incomplete							
	Weight = 0.741		Weight = 0.029		Weight = 0.016		Weight = 0.113		Weight = 0.101							
	ZML	DR	ZML	DR	ZML	DR	ZML	DR	ZML	DR	ZML	DR			ZML	DR
80	n/a										4.29	0.203	1.16	0.961	3.85	0.182
81-83											4.08	0.191	1.16	0.912	3.85	0.180
84											4.06	0.191	1.16	0.907	3.86	0.181
85											2.89	0.060	1.16	0.896	2.79	0.057
86											2.56	0.060	1.16	0.894	2.47	0.058
87											1.15	0.107	1.16	0.897	1.11	0.103
88-89	0.97	0.029	0.97	0.029	1.03	0.032	1.03	0.032	1.11	0.035	0.99	0.030	1.16	0.894	0.95	0.029
90	0.62	0.030	0.62	0.030	0.65	0.032	0.65	0.032	0.70	0.035	0.64	0.030	1.16	0.893	0.61	0.029
91-97	0.60	0.027	0.60	0.027	0.63	0.029	0.63	0.029	0.68	0.032	0.61	0.028	1.16	0.890	0.59	0.027
98-03	0.61	0.027	0.61	0.027	0.63	0.029	0.63	0.029	0.68	0.032	0.62	0.028	1.16	0.885	0.60	0.027
04 +	0.23	0.015	0.18	0.011	0.27	0.017	0.18	0.011	0.18	0.011	0.21	0.014	1.16	0.885	0.21	0.014

*** NMHC FER = THC FER * 0.867**

Table A-4
Exhaust HC Final Emission Rates for Heavy Duty Gasoline Vehicles: 30 ppm Fuel

Model Year	THC FINAL EMISSION RATES BY CLASS										WEIGHTED FER (g/mi)		DIVIDE BY MOBILE5b FUEL ADJUSTMENT & CONVERSION FACTOR		MODIFIED MOBILE5B FER* (g/bhp-hr)	
	2b Complete		2b Incomplete		3 Complete		3 Incomplete		4+ Incomplete							
	Weight = 0.741		Weight = 0.029		Weight = 0.016		Weight = 0.113		Weight = 0.101							
	ZML	DR	ZML	DR	ZML	DR	ZML	DR	ZML	DR	ZML	DR			ZML	DR
80											3.87	0.183	1.16	0.961	3.47	0.164
81-83											3.67	0.172	1.16	0.912	3.47	0.163
84											3.66	0.172	1.16	0.907	3.48	0.163
85	n/a										2.61	0.054	1.16	0.896	2.51	0.052
86											2.31	0.054	1.16	0.894	2.22	0.052
87											1.04	0.097	1.16	0.897	1.00	0.093
88-89	0.87	0.027	0.87	0.027	0.92	0.028	0.92	0.028	1.00	0.031	0.89	0.027	1.16	0.894	0.86	0.026
90	0.56	0.027	0.56	0.027	0.59	0.028	0.59	0.028	0.63	0.031	0.57	0.027	1.16	0.893	0.55	0.026
91-97	0.54	0.025	0.54	0.025	0.56	0.026	0.56	0.026	0.61	0.029	0.55	0.025	1.16	0.890	0.54	0.024
98-03	0.55	0.025	0.55	0.025	0.56	0.026	0.56	0.026	0.61	0.029	0.55	0.025	1.16	0.885	0.54	0.025
04 +	0.19	0.013	0.15	0.010	0.23	0.015	0.15	0.010	0.15	0.010	0.18	0.012	1.16	0.885	0.18	0.012

*** NMHC FER = THC FER * 0.867**

APPENDIX B

NOx and VOC Emission Inventory Results

Table B-1
Heavy-Duty Gasoline Vehicle Inventory Results: 47-State Annual

Year	VMT (Millions)	NOx				Exhaust VOC			
		Baseline		Control		Baseline		Control	
		EF	Tons	EF	Tons	EF	Tons	EF	Tons
1995	44,963	5.88	291,425	5.88	291,425	6.95	344,555	6.95	344,555
2000	51,764	5.34	304,641	5.34	304,641	4.76	271,831	4.76	271,831
2001	53,262	5.25	308,052	5.25	308,052	4.46	262,082	4.46	262,082
2002	54,777	5.19	313,313	5.19	313,313	4.19	253,114	4.19	253,114
2003	56,309	5.14	319,221	5.14	319,221	3.94	244,676	3.94	244,676
2004	57,814	4.88	310,929	4.40	280,658	3.73	237,897	3.62	230,695
2005	59,335	4.44	290,394	3.99	261,093	3.54	231,792	3.44	224,990
2006	61,024	4.06	273,305	3.64	244,649	3.38	227,362	3.29	220,971
2007	62,735	3.72	257,315	3.32	229,377	3.25	224,606	3.16	218,382
2008	64,479	3.44	244,498	3.05	216,921	3.04	215,784	2.96	210,169
2009	66,201	3.21	233,876	2.83	206,512	2.84	207,387	2.77	202,352
2010	67,940	2.98	223,473	2.62	196,362	2.77	207,596	2.71	202,803
2012	70,509	2.63	204,642	2.29	178,061	2.63	204,720	2.58	200,290
2015	75,155	2.21	182,669	1.89	156,574	2.53	209,262	2.47	204,871
2020	82,899	1.84	168,320	1.55	141,363	2.42	221,045	2.37	216,568
2030	98,386	1.54	166,904	1.26	136,755	2.35	254,749	2.30	249,868

Table B-2
Heavy-Duty Gasoline Vehicle Inventory Results:New York Summer

Year	VMT (Millions)	NOx				Exhaust VOC			
		Baseline		Control		Baseline		Control	
		EF	Tons	EF	Tons	EF	Tons	EF	Tons
1995	782	5.88	5,072	5.88	5,072	6.15	5,301	6.15	5,301
2000	886	5.34	5,215	5.34	5,215	4.21	4,113	4.21	4,113
2001	907	5.25	5,245	5.25	5,245	3.95	3,944	3.95	3,944
2002	928	5.19	5,305	5.19	5,305	3.71	3,789	3.71	3,789
2003	948	5.14	5,376	5.14	5,376	3.48	3,642	3.48	3,642
2004	969	4.61	4,924	4.40	4,704	3.24	3,464	3.20	3,418
2005	990	4.19	4,567	3.99	4,355	3.08	3,361	3.04	3,317
2006	1,010	3.82	4,257	3.64	4,051	2.94	3,275	2.90	3,234
2007	1,031	3.49	3,970	3.32	3,770	2.83	3,212	2.79	3,173
2008	1,052	3.22	3,734	3.05	3,539	2.64	3,066	2.61	3,031
2009	1,073	2.99	3,539	2.83	3,346	2.48	2,930	2.45	2,898
2010	1,093	2.78	3,350	2.62	3,160	2.42	2,915	2.39	2,885
2012	1,135	2.44	3,052	2.29	2,866	2.30	2,877	2.28	2,849
2015	1,197	2.03	2,674	1.89	2,494	2.21	2,911	2.19	2,884
2020	1,300	1.68	2,402	1.55	2,218	2.11	3,030	2.10	3,003
2030	1,508	1.38	2,297	1.26	2,096	2.05	3,414	2.04	3,385

Table B-3
Heavy-Duty Gasoline Vehicle Inventory Results: Chicago Summer

Year	VMT (Millions)	NOx				Exhaust VOC			
		Baseline		Control		Baseline		Control	
		EF	Tons	EF	Tons	EF	Tons	EF	Tons
1995	417	5.88	2,700	5.88	2,700	6.15	3,193	6.15	3,193
2000	464	5.34	2,732	5.34	2,732	4.21	2,155	4.21	2,155
2001	474	5.25	2,741	5.25	2,741	3.95	2,061	3.95	2,061
2002	483	5.19	2,765	5.19	2,765	3.71	1,974	3.71	1,974
2003	493	5.14	2,794	5.14	2,794	3.48	1,893	3.48	1,893
2004	502	4.61	2,553	4.40	2,439	3.24	1,796	3.20	1,772
2005	512	4.19	2,363	3.99	2,253	3.08	1,739	3.04	1,716
2006	522	3.82	2,197	3.64	2,091	2.94	1,690	2.90	1,669
2007	531	3.49	2,044	3.32	1,942	2.83	1,654	2.79	1,634
2008	541	3.22	1,919	3.05	1,819	2.64	1,576	2.61	1,558
2009	550	2.99	1,815	2.83	1,716	2.48	1,503	2.45	1,486
2010	560	2.78	1,715	2.62	1,618	2.42	1,492	2.39	1,477
2012	579	2.44	1,556	2.29	1,461	2.30	1,467	2.28	1,453
2015	607	2.03	1,357	1.89	1,265	2.21	1,477	2.19	1,464
2020	655	1.68	1,210	1.55	1,117	2.11	1,526	2.10	1,513
2030	750	1.38	1,143	1.26	1,043	2.05	1,699	2.04	1,685

Table B-4
Heavy-Duty Gasoline Vehicle Inventory Results: Atlanta Summer

Year	VMT (Millions)	NOx				Exhaust VOC			
		Baseline		Control		Baseline		Control	
		EF	Tons	EF	Tons	EF	Tons	EF	Tons
1995	316	5.88	2,049	5.88	2,049	7.07	2,464	7.07	2,464
2000	384	5.34	2,259	5.34	2,259	4.84	2,050	4.84	2,050
2001	397	5.25	2,299	5.25	2,299	4.54	1,989	4.54	1,989
2002	411	5.19	2,351	5.19	2,351	4.26	1,931	4.26	1,931
2003	425	5.14	2,407	5.14	2,407	4.01	1,876	4.01	1,876
2004	438	4.92	2,376	4.40	2,127	3.81	1,838	3.68	1,778
2005	452	4.48	2,230	3.99	1,987	3.61	1,799	3.50	1,742
2006	465	4.10	2,102	3.64	1,865	3.45	1,767	3.34	1,713
2007	479	3.76	1,982	3.32	1,750	3.31	1,747	3.21	1,695
2008	492	3.47	1,885	3.05	1,656	3.09	1,679	3.01	1,632
2009	506	3.24	1,805	2.83	1,578	2.90	1,615	2.82	1,572
2010	519	3.02	1,726	2.62	1,501	2.82	1,617	2.75	1,577
2012	546	2.66	1,604	2.29	1,380	2.68	1,616	2.62	1,579
2015	587	2.23	1,445	1.89	1,223	2.57	1,665	2.52	1,627
2020	655	1.87	1,348	1.55	1,117	2.46	1,779	2.41	1,740
2030	790	1.56	1,362	1.26	1,098	2.39	2,084	2.34	2,041

Table B-5
Heavy-Duty Gasoline Vehicle Inventory Results: Charlotte Summer

Year	VMT (Millions)	NOx				Exhaust VOC			
		Baseline		Control		Baseline		Control	
		EF	Tons	EF	Tons	EF	Tons	EF	Tons
1995	49	5.88	318	5.88	318	7.07	376	7.07	376
2000	59	5.34	350	5.34	350	4.84	317	4.84	317
2001	62	5.25	356	5.25	356	4.54	308	4.54	308
2002	64	5.19	364	5.19	364	4.26	299	4.26	299
2003	66	5.14	372	5.14	372	4.01	290	4.01	290
2004	68	4.92	367	4.40	329	3.81	284	3.68	275
2005	70	4.48	345	3.99	307	3.61	278	3.50	269
2006	72	4.10	325	3.64	288	3.45	273	3.34	265
2007	74	3.76	306	3.32	270	3.31	270	3.21	262
2008	76	3.47	291	3.05	256	3.09	259	3.01	252
2009	78	3.24	279	2.83	244	2.90	249	2.82	243
2010	80	3.02	267	2.62	232	2.82	250	2.75	243
2012	84	2.66	248	2.29	213	2.68	250	2.62	244
2015	91	2.23	223	1.89	189	2.57	257	2.52	251
2020	101	1.87	208	1.55	172	2.46	274	2.41	268
2030	122	1.56	210	1.26	169	2.39	321	2.34	315

Table B-6
Heavy-Duty Gasoline Vehicle Evaporative VOC Inventory Results: All Regions

Year	47-State Annual		New York Summer		Chicago Summer		Atlanta Summer		Charlotte Summer	
	EF	Tons	EF	Tons	EF	Tons	EF	Tons	EF	Tons
1995	1.36	67,404	0.99	853	0.99	454	1.18	409	1.18	64
2000	0.77	44,026	0.46	448	0.46	235	0.60	254	0.60	39
2001	0.73	42,759	0.42	423	0.42	221	0.56	244	0.56	38
2002	0.69	41,363	0.39	396	0.39	206	0.51	232	0.51	36
2003	0.64	39,835	0.35	367	0.35	191	0.47	219	0.47	34
2004	0.61	38,573	0.32	344	0.32	178	0.43	209	0.43	32
2005	0.57	37,411	0.29	321	0.29	166	0.40	200	0.40	31
2006	0.54	36,617	0.27	304	0.27	157	0.37	192	0.37	30
2007	0.52	35,731	0.25	285	0.25	147	0.35	184	0.35	28
2008	0.49	35,068	0.23	271	0.23	139	0.33	177	0.33	27
2009	0.47	34,304	0.22	257	0.22	132	0.31	170	0.31	26
2010	0.45	33,460	0.20	241	0.20	123	0.28	163	0.28	25
2012	0.42	32,255	0.18	221	0.18	113	0.26	154	0.26	24
2015	0.38	31,513	0.15	201	0.15	102	0.22	145	0.22	22
2020	0.35	31,863	0.13	183	0.13	92	0.19	140	0.19	22
2030	0.34	36,671	0.12	206	0.12	103	0.19	163	0.19	25