United States Environmental Protection Agency
Air and Radiation
EPA420-P-99-017
May 1999
M6.EXH.009

Determination of CO Basic Emission Rates, OBD and I/M Effects for Tier 1 and Later LDVs and LDTs

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Determination of CO Basic Emission Rates, OBD and I/M Effects for Tier 1 and later LDVs and LDTs

Report Number M6.EXH.009

May, 1999

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1.0 Introduction

This document (M6.EXH.009) describes the methodology, data analysis and results of the process used to develop basic CO emission factors, OBD (On-board Diagnostics II) effects, and I/M (Inspection / Maintenance) credits for Tier1, TLEV (Transitional Low Emitting Vehicle), LEV (Low Emitting Vehicle), ULEV (Ultra Low Emitting Vehicle) vehicles (referred collectively throughout the document as Future Standards Vehicles (FSV) for MOBILE6. The document "Determination of NOx and HC Basic Emission Rates, OBD and I/M Effects for Tier1 and Later LDVs and LDTs" (M6.EXH.007) shows the analogous methodology and the results for NOx and HC pollutants for the FSVs. These vehicles are current and future model year cars and light trucks which must meet increasingly stringent tailpipe exhaust emission limits. Of the four types, the first three types (Tier1, TLEV and LEV) are held to the same numerical CO standards. The fourth type (ULEV) meet a more stringent CO standard which is 50 percent of the Tier1 standard.

Table 1 shows the emission standards limits in grams per mile for each vehicle type and standard. The limits in units of grams per mile are shown for the 5 year / 50,000 mile certification point. The other important parameter in regards to the certification standards is the model year implementation schedule for all of the standards. This is the percentage of a particular model year and vehicle class that will be required to be certified to the lower standard. This schedule can be found in EPA document EPA420-B-98-001 "Exhaust Emission Certification Standards". It is available on the EPA-OMS website. The current website address is "http://www.epa.gov/oms/stds-lh.htm"

This document (M6.EXH.009) also provides a brief explanation of the derivation of CO start and running emissions for all FSV classes (i.e., Tier1, TLEV, LEV and ULEV). Results are also provided in tabular and graphical form. A more detailed explanation of the concept of start and running emissions and their derivation can be found in "Determination of Running Emissions as a Function of Mileage for 1981-1993 Model Year Light-Duty Cars" (M6.EXH.001) and "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-93 Model Year Light-Duty Vehicles" (M6.STE.003).

This document (M6.EXH.009) also explains the I/M credit methodology for 1994 and later model year vehicles, and discusses the algorithm used to predict OBD effectiveness. This OBD algorithm assumes: (1) that 1996 and later cars are equipped with an onboard electronic diagnostic (OBD) system, but that 1994 and 1995 model year vehicles are not equipped; (2) that the OBD system continuously monitors the performance of the car's emission control system, and detects serious problem(s) which cause the vehicle's FTP emissions to exceed 1.5 times its applicable certification standards, and (3) when such problems are detected, a code is registered in the car's computer and a dashboard warning light is turned on to notify the owner.

The I/M methodology presented in this document for FSVs (M6.EXH.009) is similar to the I/M methodology for 1981-93 model year vehicles presented in EPA document M6.IM.001. The two methodologies differ because of the presence of OBD and the different emission standards for the

FSVs. Also, a central I/M assumption for the OBD equipped vehicle fleet (1996+ model years) is that OBD tests will be performed in I/M stations, and that these OBD tests may eventually replace traditional emission tests for the 1996 and later model years. In contrast, the I/M methodology for the 1981-93 model years is based strictly on the use of traditional exhaust measurement tests.

Table 1
Tier1, LEV and ULEV CO Emission Certification Standards
(gram/mile units at 50K miles except where noted)

Veh Type	Tier0	Tier1	LEV	ULEV
LDV	3.4	3.4	3.4	1.7
LDT1 **(<6000GVW <3750 Loaded Wt)**	3.4	3.4	3.4	1.7
LDT2 **(<6000GVW >3750 Loaded Wt)**	10.0*	4.4	4.4	2.2
LDT3 **(>6000GVW <3750 Loaded Wt)**	9.0**	4.4	4.4	2.2
LDT4 **(>6000GVW >5750 Loaded Wt)**	9.0**	5.0	5.0	2.5

* 100K mile Standard
** 50K mile Standard

Most Tier 1 and later vehicles will be equipped with an OBD system and, if in an I/M area, subject to OBD-based I/M rather than traditional exhaust I/M. However, some Tier 1 vehicles will not be equipped with OBD (model years 1994 and 1995), and some OBD-equipped vehicles will be subject to an exhaust I/M program (prior to calendar year 2001). Basic emission rates are therefore required for the following cases, and are presented in this report:

No OBD/No IM (Base) applies to pre-OBD Tier 1 vehicles (1994 and 1995 model years). It is also used as a basis for the computations of BERs with OBD and/or OBD-based I/M.

OBD-Only (OBD/ No IM) applies to 1994 and later OBD equipped vehicles where an I/M program is not present.

OBD/IM applies to 1994 and later OBD equipped vehicles where an I/M program which conducts OBD checks is present. An exhaust test may or may not be performed; it is not differentiated from an I/M program with both OBD checks and exhaust testing, since additional I/M reductions are not given for exhaust testing if OBD checks are performed.

Exhaust I/M / OBD represents a situation in which an exhaust I/M test is conducted in an I/M program on vehicles which are equipped with OBD, but the OBD I/M test is not performed. This situation can only occur on 1996 and later model year vehicles equipped with OBD, and subject to an exhaust I/M test. It is a likely scenario until at least calendar year 2001 when the EPA approved OBD I/M test is expected to be available.

Exhaust I/M / No OBD represents a situation in which only an exhaust I/M test is conducted in an I/M program (an IM240, ASM, or Idle test). This scenario will apply only to the 1994 and 1995 model year vehicles which are not equipped with OBD systems.

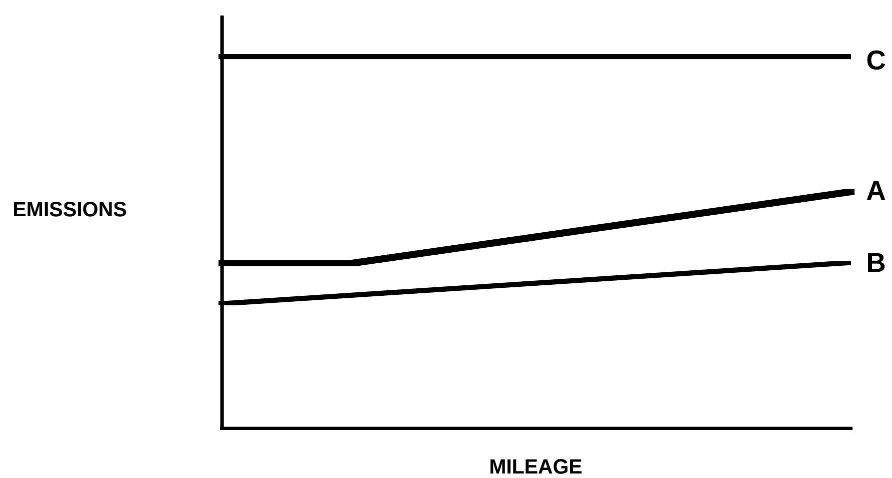
2.0 Basic Emission Rate Derivation Concept

The basic concept underlying the generation of Tier 1 and later BERs is similar to the approach used to develop the I/M credits for 1981 through 1993 vehicles. For the No OBD/No IM case, this concept segregates in-use vehicles into “normal” and “high” emitters. High emitters are those vehicles which have emission control systems which are malfunctioning in some way, and are producing average emission levels which are considerably higher than the overall mean emission levels; the threshold for defining a high emitter for CO is **3.0 times** the intermediate life (50,000 mile) certification emission standard. The remainder of the fleet are considered to be properly functioning, and are considered normal emitters; by definition, these vehicles are below **3.0 times** the intermediate life certification standard. It is important to note that all pollutants are considered independently when determining whether a vehicle is a high emitter. Thus, a vehicle could be a high CO emitter, but a normal HC emitter.

Although the segregation of vehicles into the “normal” and “high” categories (and their thresholds) is a somewhat arbitrary modeling method, the concept that average in-use emissions are driven by a group of vehicles emitting well above the applicable standard is supported by data from many years of EPA vehicle test and repair programs, as well as the bimodal nature of emission control technology functioning (e.g., EGR valves, air pumps, and oxygen sensors generally function correctly or not at all). Two important assumptions in the development of BERs for Tier 1 and later vehicles are a) the rate at which vehicles malfunction and become high emitters is independent of the certification standard level, and b) the average emission levels for high emitters becomes higher *relative to the standard* as the certification standard becomes lower.

The overall fleet emission factor is computed as a weighted average of the high and normal emitters. Figure 1 is a general graphical view of the concept with the y-axis representing emissions in grams per mile (grams for start emissions), and the x-axis representing mileage and/or age. Age and mileage are related in that a specific mileage is associated with each age. Three lines are shown in Figure 1 which show a) the average or basic emission rate, b) the normal emitter emission rate, and c) the high emitter emission level.

Figure 1
GENERAL EMISSION FACTOR SCHEMATIC



The basic emission rate is shown as Line A. This line represents the average emissions of the fleet as a function of both the normal vehicles and the high emitting vehicles.

Line B represents the average emissions of the normal-emitting vehicles. These are the vehicles which have emission control systems which are generally performing as designed. The line is shown as a linear function of mileage and/or age to reflect the gradual deterioration that normal vehicles experience, primarily due to catalyst degradation over the life of the vehicle. It was derived from a least squares linear regression of emissions versus mileage.

Line C represents the average emissions of high-emitting vehicles. This line is a flat horizontal line because emissions from these vehicles do not appear to be a strong function of mileage and/or age, based on previous analysis of Tier 0 data. The underlying phenomena expressed here is that emission control malfunction will lead to high emissions regardless of vehicle mileage; as discussed in subsequent sections, what changes as the vehicle ages is the probability of malfunction, rather than the emission levels resulting from a malfunction.

Line A represents the weighted average of lines B and C, based on appropriate weighting factor for normal and high emitters. On a fleet-wide basis, these weighting factor represent the fraction of high emitters in the fleet, as a function of vehicle age; on a per-vehicle basis, this weighting factor can be considered to be the probability the vehicle will be a high emitter at a given age. This weighting factor can be derived at any given vehicle age ***A*** by transforming Equations 1 and 2 into Equations 3 and 4.

Where:

Highs = fraction of High emitters, age = ***A***
Normals = fraction of Normal emitters, age = ***A***
AVE is the average emission rate, age = ***A***
High_ave is the high emitter emission average (independent of age)
Norm_ave is the normal emitter emission average, age = ***A***

$$\text{Highs} + \text{Normals} = 1 \qquad \text{Eqn 1}$$

and

$$\text{AVE} = \text{High\_ave} * \text{Highs} + \text{Norm\_ave} * \text{Normals} \qquad \text{Eqn 2}$$

Solving for the variables Highs and Normals produces:

$$\text{Highs} = (\text{AVE} - \text{Norm\_ave}) / (\text{High\_ave} - \text{Norm\_ave}) \qquad \text{Eqn 3}$$

$$\text{Normals} = 1 - \text{Highs} \qquad \text{Eqn 4}$$

3.0 CO Emission Methodology

3.1 Normal Emitter Emission Level

3.1.1 Overview

This section discusses the methodology and assumptions used to generate the basic CO emission factors and CO I/M credits for FSVs. A brief overview of the methodology is as follows:

1. Normal emitter running and start CO emission levels were calculated from 1994 and later vehicle FTP test results collected in an EPA test program. These data were used to calculate the zero mile emission level of normal vehicles.

2. CO emission deterioration of 1994+ model year normal emitters was assumed to be the same as the deterioration of the 1988-93 model year PFI normal emitting vehicles.

3. The average CO emissions of a 1994+ High emitter was assumed to be the same as the average CO emissions from a 1988-93 model year High emitter.

4. The fraction of high emitters in the fleet for NO OBD / NO I/M, and OBD and I/M cases were calculated.

5. The OBD and I/M assumptions were applied to generate a 'with I/M' emission line.

6. The ratio of certification standards between Tier1 and ULEV was calculated, and applied to the zero mile normal emitter CO emission level to reduce the zero mile level for ULEVs.

7. A summary of the important parameters such as normal emitter zero mile and deterioration rates, high emitter emission levels and after repair emission levels are shown in Table A-1.

   Each of these steps is discussed in detail in the sections below.

3.1.2 Normal Emitter Data

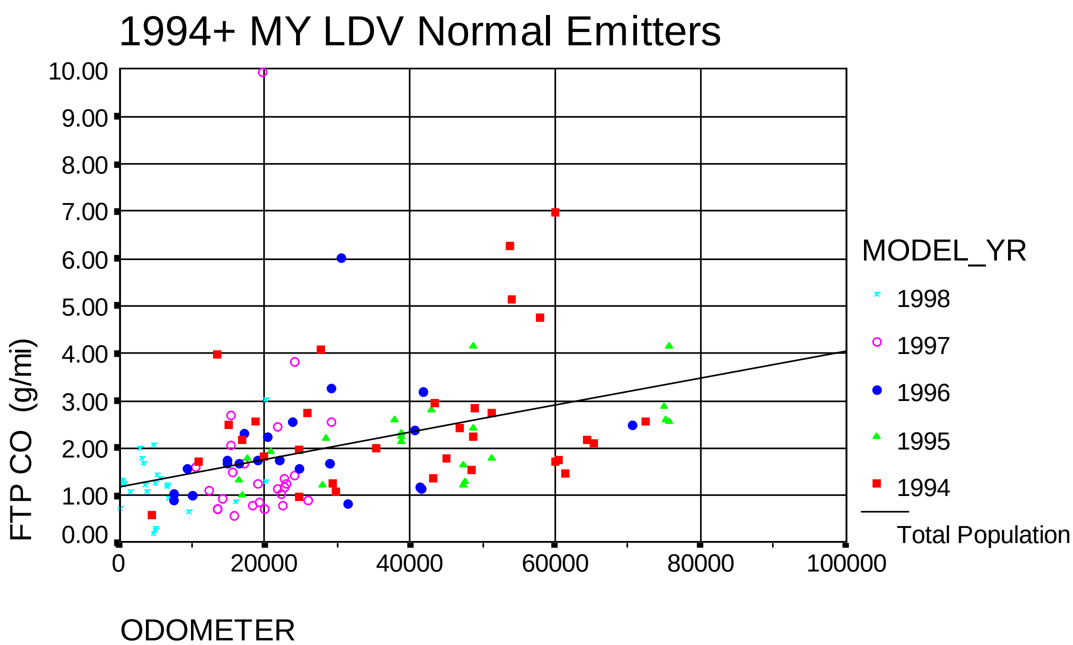
The data sample used to develop the normal emitter emission levels consisted of test results from128 cars and 108 light trucks with model years 1994 through 1998. It was collected by EPA as part of its regular emission factor testing program. This program recruits in-use vehicles from the general public, and subjects them to a battery of tests that include the FTP. This sample is not truly random, because of the recruitment process used by EPA and the potential for outliers (High emitters) to self-select themselves out of the program. This self selection bias has been thought to exist in past test programs, and can lead to understating of average emission levels. In this case however, the effect of any selection bias should be quite minor due to the young age of the vehicles, the low emission level of the vehicles (only normal emitters were selected), and the difficulty of the motorist to create a bias by determining outlier status in advance of recruitment and testing. As a result, this sample is thought to be reasonably representative of in-use emission behavior of vehicles with low mileage.

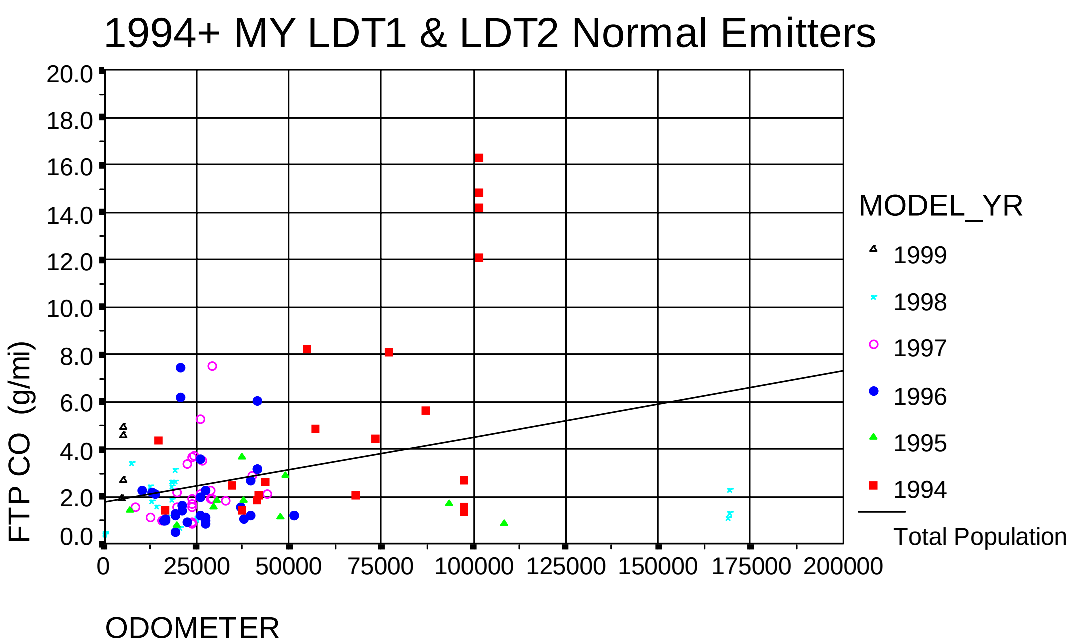
This sample contained a mixture of Tier1 and Tier0 certified vehicles (mostly Tier1). Unfortunately, it contained no TLEV, LEV or ULEV certified vehicles because these are not currently present in the regular fleet. Thus, in the MOBILE6 model, LEV vehicles will be considered to be equivalent to Tier1 vehicles in terms of CO emissions.   ULEVs will be given a slightly different treatment since their certification standard limits are half (more stringent) than those of Tier1 and LEV vehicles.

The EPA data sample was split into normal emitters and high emitters based on FTP CO emission levels. Vehicles with CO emission levels less than three times their certification level were judged to be normal emitters. Because most of the tested vehicles were new, virtually the entire sample consisted of normal emitters. The FTP CO emissions as a function of mileage are shown graphically in Figures 2 and 3 for the car and truck data samples.

The approach of reducing only the normal emitter emission levels between Tier0, Tier1 and LEV is fairly conservative. It assumes only small CO emission benefits will accrue due to technology changes designed to reduce HC emissions. It also assumes that high CO emitters (vehicles with malfunctions) will have as high CO emissions as the high Tier0 CO emitters.

Figures 2 and 3





3.1.3 Tier1 and LEV Vehicles

The goal of this analysis was to use the 1994 and later vehicle data to develop the basic CO emission factors for the normal emitting Tier1, LEV and ULEV vehicles. Originally, a simple least squares regression of the emission results versus mileage was to be used. This would produce a zero mile emission level and a deterioration rate versus mileage that could be applied in the MOBILE6 model.

Vehicle data from the FTP cycle were available, and were separated into running LA4 (Running emissions) and start emission using the method described in EPA document "The Determination of Hot Running Emissions from FTP Bag Emissions"(M6.STE.002). The running and start emission data were least squares regressed versus mileage to produce the zero mile emission level and deterioration rate (slope) for normal emitters. These values are shown in Appendix B in the Statistical Diagnosis Section. The results from this regression were not used in the MOBILE6 model. The zero mile emission values were not used in the analysis because the running emissions were found to be statistically not significant at a 95% confidence level or even an 80% confidence level. The CO start emission zero mile regression level was statistically significant, but was not used to keep consistency between the running and start emissions. The regression slope was not used to predict the deterioration of the Tier1 and later vehicle because of the relatively low mileage levels of the vehicles in the sample. Its use would have required complete extrapolation above 80,000 miles for cars and 100,000 miles for trucks.

Instead the data were sub-grouped into a sample of normal emitters which had odometer readings less than 25,000 miles, and the mean CO values for each car and truck sub-group were determined. These mean CO values were used as the zero mile emission level of the Tier1 and LEV normal emitting vehicles. The values are shown below in Equations 5a-d and 6a-d, and in summary form in Table A-1, and in statistical output form in Appendix C. For comparison, the difference between the zero mile CO emissions obtained from the two methods is fairly slight in absolute emission terms. For example, for running LA4 CO emissions from cars the regression zero mile level is 0.117 g/mi CO, and the mean CO of vehicles with less than 25,000 miles is 0.282 g/mi. This compares with a value of 0.48 g/mi running LA4 CO for the 1988-93 model year PFI (ported fuel injection) vehicles.

The CO deterioration rate for the 1994+ model year vehicles was assumed to be the same as the deterioration rate for the 1988-93 model year PFI vehicles (see EPA report - MOBILE6 "Inspection / Maintenance Benefits Methodology for 1981-93 Model Year Vehicles"). This assumption was made because EPA believes that the broader mileage range and larger sample size of 1988-1993 PFI vehicles better represents fleet CO deterioration than the newer low mileage sample. The combined effect of using the mean CO emission level of low mileage vehicles in the sample to represent the zero mile emission level of the FSVs, and the deterioration rate of the 1988-93 model year PFI vehicles to represent the in-use deterioration estimate of FSVs is to: (1) assume that the lowering of HC standards in response to Tier1 and later requirements (CO standards were not changed) will reduce new vehicle CO emissions slightly, but (2) that the long term deterioration levels will remain the same as the 1988-1993 model year vehicles.

Equations 5a-d are the equations used to model the CO running emissions from 1994 and later model year normal emitters. The variable 'odom' is in units of ten-thousand miles. Equation 5a shows value of the normal emitter CO running emissions from cars; Equation 5b is the analogous one for trucks. Both are in units of grams per mile. Equation 5c shows value of the normal emitter CO start emissions from cars; Equation 5d is the analogous one for trucks. Both start emission equations are in units of grams per start.

Running Cars:	Norm_Ave(g/mi)	=	0.2821 + 0.2293 * odom	Eqn 5a
Running Trucks:	Norm_Ave(g/mi)	=	0.3219 + 0.2678 * odom	Eqn 5b
Start Cars:	Norm_Ave(g/strt)	=	15.176 + 0.0703 * odom	Eqn 5c
Start Trucks:	Norm_Ave(g/strt)	=	21.884 + 0.1680 * odom	Eqn 5d

3.1.4 ULEV Vehicles

The normal emitter running and start CO emission levels of ULEVs are the same as the normal emitter running and start emission levels of the Tier1 and LEVs, except the zero mile levels are 50 percent less. The 50 percent reduction was used because the ULEV standards are numerically half of those of the LEVs. The actual values are shown in Equations 6a through 6d.

Running Cars:	Norm_Ave(g/mi)	=	0.1411 + 0.2293 * odom	Eqn 6a
Running Trucks:	Norm_Ave(g/mi)	=	0.1609 + 0.2678 * odom	Eqn 6b
Start Cars:	Norm_Ave(g/strt)	=	7.588 + 0.0703 * odom	Eqn 6c
Start Trucks:	Norm_Ave(g/strt)	=	10.942 + 0.1680 * odom	Eqn 6d

The Truck4 category also has a different certification standard than the Truck2 and Truck3 vehicles. Since no Truck4 data were available, its zero mile normal emitter CO emission level was determined by applying the ratio of the Truck4 and Truck3 certification standards to the Truck2/3 zero mile CO emission value. The values for the heavier Trucks are shown in Table A-1

The rationale for reducing the zero mile level of the ULEVs proportionally to the standard is that basic emission levels for properly operating vehicles should receive some benefit of reduced standards for lower standard levels. This approach assumes that brand new normal emitters for the ULEV standards will on average achieve the same compliance margin ("headroom") as the normal emitters observed in the sample.

3.2 High Emitter Emission Level

High Emitter basic CO emission rates (BERs) are meant to estimate emissions from vehicles that significantly exceed their certification standards due to malfunctioning emission control systems. A key assumption in the development of high-emitter CO BERs is that, as HC and NOx emission standards are lowered for Tier1 and LEV classifications (CO standards are not changed until ULEV), emission levels for CO high emitters will not change relative to the performance of the Tier0 High CO emitters. The rationale for this assumption is since emission control equipment on these high emitters will be degraded or completely malfunctioning, they will emit largely independent of their certification standard level. To illustrate, compliance with the 3.4 g/mi CO standards is primarily a function of the effectiveness of a vehicle's fuel delivery system control. Thus, vehicles which have become High CO emitters due to a loss of fuel delivery system control are expected to have similar CO emission performance regardless of whether they are Tier0, Tier1, or LEV certified. This assumption may not apply to ULEV certified vehicles, since their certification level is reduced by 50 percent from the LEV level, and different technologies may be used to control emissions on these vehicles. Nevertheless, this assumption is being extended to the ULEVs since there are no in-use data available on high emitting ULEVs.

The FTP high emitter average CO emission levels used for the 1994 and later model years are the same values used for the 1988-93 model year PFI vehicles (cars and trucks have separate values). These values for Running and Start emissions for cars and trucks are shown in Equations 7a through 7d. These values will be used for all 1994 and later model years including Tier1, LEV and ULEV vehicles.

Running Cars:	High_Ave(g/mi)	=	36.106	Eqn 7a
Running Trucks:	High_Ave(g/mi)	=	33.283	Eqn 7b
Start Cars:	High_Ave(g/strt)	=	38.060	Eqn 7c
Start Trucks:	High_Ave(g/strt)	=	83.862	Eqn 7d

These extrapolations from Tier0 vehicles could not be reliably verified from the relatively small 1994+ data sample, since only one High emitter was present in the 1994-1998 model year sample. However, this vehicle's FTP emissions were quite high at 215 g/mi CO.

3.3 High Emitter Fractions - No OBD / No I/M

This section describes the fraction of high emitters in the fleet given the base case of no OBD and No I/M. The numerical values are the same as the no I/M high emitter fractions of the 1988-93 PFI vehicles, and were derived from the general Equation 3 with Tier0 values. The rate at which vehicles become high emitters under the No OBD / No IM scenario was also assumed constant for all standard classes. The age-based high emitter fractions for Tier1 and later vehicles are shown in Appendix A. These values are referred mathematically as $High_{BASE}(i)$ in subsequent calculations.

Reduced CO certification standards are not expected to influence the rate at which emission control technology malfunctions, because a) manufacturer's design and durability practices are not expected to differ between Tier0 and later standards, and b) many cases of emission control degradation and/or malfunction are owner-induced, outside the manufacturer's liability for in-use emission performance, and unlikely to change due to the new standards. Separate rates of emission control technology malfunction were used for LDVs and LDTs, only because separate car and truck rates were used for the 1988-93 model year PFI vehicles.

3.4 High Emitter Fraction - OBD and OBD I/M

Separate BERs were developed for all standards and vehicle classes to account for the effects of OBD and OBD-based I/M programs. The methodology used to account for these programs is based on reducing the fraction of high emitters in the fleet from the No OBD/No IM case. Thus, emission levels for normal and high emitters were not changed under these programs, only the fraction of highs in the fleet. This methodology introduces a new category of vehicle into the fleet: "Repaired" emitters. These vehicles are high emitters that are flagged by an OBD system and undergo successful repair. For the OBD-only and OBD/IM cases, these vehicles are treated distinctly from normal and high emitters.

OBD effectiveness is defined by three parameters: a) the probability the OBD system will detect a failure (MIL-on Rate), b) the probability an owner will respond to a MIL-on (Response Rate), and c) the average after-repair emission level for responding vehicles (Repair Level). At the time of this analysis, sufficient in-use data were not available to empirically determine in-use patterns for these parameters. Thus, assumptions were developed for the projected likelihood of malfunction detection, owner response and repair level.

3.4.1 MIL-on Rate

For all vehicle classes and standards, it is assumed that OBD will detect (i.e., set an appropriate code and illuminate the MIL) 85 percent of the CO high emitters. Because high emitters are defined independently for all pollutants, this response rate is assumed to apply equally to all pollutants. The remaining 15 percent of the high emitters will not be identified, and thus will remain in the fleet as high emitters. No deterioration in the ability of the OBD system to correctly identify high emitters is assumed. Because this parameter is solely dependent on the vehicle's OBD system, it is the same for I/M and non-I/M areas.

3.4.2 Response Rate

In order to obtain emission reductions from a vehicle equipped with an OBD system, not only must the system correctly identify the vehicle, but the motorist must also respond to the MIL and take corrective action in a timely manner. A key assumption for this analysis is that the response rate in OBD-based I/M areas (where repair is required) will be much higher than in non-I/M areas. In OBD-based I/M areas, the MIL-on response rate is assumed to be 90 percent over the entire life of the vehicle. Response was not set at 100 percent to account for waivers from, or evasion of, or delay in responding to the I/M program.

For non-IM areas, OBD response is assumed to be a function of vehicle warranty. It is assumed that an owner is much more likely to respond to a MIL-on when repairs will be paid for by the manufacturer. Three mileage bins were therefore developed: 1) 0 through 36,000, the standard bumper-to-bumper warranty period; 2) 36,001 to 80,000, for which federal law mandates that catalysts and electronic control modules (ECMs) remain under warranty; and 3) above 80,000, for which no warranty is in effect (extended warranties are not accounted for in this methodology).

Under 36,000 miles, it is assumed that 90 percent of MIL-on vehicles will be repaired. This is based on the judgment that for new vehicles still under warranty, owners will have little hesitation in addressing a MIL-on. The 10 percent loss accounts for a delay in the response rate and the small percentage of owners who will not respond to a MIL-on even with the warranty incentive.

Between 36,000 miles and 80,000 miles, it is assumed that 10 percent of MIL-on vehicles will be repaired. This response rate is greatly reduced from the pre-36,000 mile level to account for the discontinuation of warranty coverage on several emission-related components (e.g. secondary air, EGR, oxygen sensors, fuel injectors), and reduced willingness of owners to make emission-related repairs on an aging vehicle in the absence of an I/M program.

Above 80,000 miles, it is assumed that no MIL-on vehicles will be repaired. This assumption reflects the end of warranties, the lower economic value of the vehicle, and the (further) reduced willingness of owners to make emission-related repairs in the absence of an I/M program.

3.4.3 Repair Level

The emission level after an OBD-induced repair is assumed to be 1.5 times the applicable 50,000 mile certification standard. This creates a third emitter category - “repaired” emitters. Repaired emitters are assumed to have constant emissions at the repaired level, although a subset of these vehicles “migrate” back to the high emitter category. The estimated post-repair level of 1.5 times the standard is the required threshold for illuminating the MIL. This level was chosen as the after repair emission level (as opposed to a lower value) after considering three issues. First, although many vehicles will likely be repaired below this level, others undergoing repair will continue to be higher than 1.5 times the standard due to synergistic effects of multiple malfunctions which considered independently would not trigger the MIL. Second, the OBD malfunction threshold requirement of 1.5 times the standard applies to the applicable full useful life standard; thus, repairing to 1.5 times the 50,000 mile standard is below the required threshold between 50,000 and 100,000 miles (in fact, ARB's most recent modification to OBD for LEVs requires detection at 1.75 times the full-useful standard (100,000 mile standard) at all mileages, thus increasing the gap between the repair level and MIL threshold). Third, these vehicles are assumed not to deteriorate for the remainder of their life, unless they migrate into the high emitter category. Thus, the repair levels can be lower than average normal emitter emissions at higher mileages.

3.4.4 High Emitter Fractions

Equations 8 through 10 were used to calculate the high emitter growth rate under the OBD and OBD-based I/M scenarios ($High_{OBD}$ and $Highh_{OBDIM}$). Overall, the high emitter fraction in a given year is a function of a) the number of high emitters in the previous year, b) the base high emitter "growth rate" in the absence of OBD or I/M, and c) the OBD effectiveness assumptions outlined in Section 3.4.1 and 3.4.2. The subscript 'i' is the vehicle age. High(0) is assumed to be zero. MOBILE6 will assign a value of 'odom' for each age 'i'.

$$\text{Nonhigh}(i) = 1.0 - High_{BASE}(i) \qquad \text{Eqn 8}$$

$$\text{Delta\_High}(i) = High_{BASE}(i) - High_{BASE}(i-1) \qquad \text{Eqn 9}$$

$$\text{Growth\_High}(i) = \text{Delta\_High} / \text{Nonhigh}(i) \qquad \text{Eqn 10}$$

$$High_{OBD}(i) = High_{OBD}(i-1) + [(1-OBD)*MIL*\text{Growth\_High}(i)*(1-High_{OBD}(i-1))] + [(1-MIL)*\text{Growth\_High}(i)*(1-High_{OBD}(i-1)] \qquad \text{Eqn 11a}$$

$$High_{OBDIM}(i) = High_{OBDIM}(i-1) + [(1-OBDIM)*MIL*\text{Growth\_High}(i)*(1-High_{OBDIM}(i-1))] + [(1-MIL)*\text{Growth\_High}(i)*(1-High_{OBDIM}(i-1)] \qquad \text{Eqn 11b}$$

Where:

$High_{OBD}(0) = 0.0$

$High_{OBDIM}(0) = 0.0$

'MIL' = 0.85

'OBD' is the OBD response rate; 0.90/0.10/0.0 for mileage bins (0 - 36K), (36K - 80K), and (80K+), respectively. These are used in conjunction with Equation 11a.

‘OBDIM’ = 0.90

It is the effectiveness of the OBD I/M program at identifying High emitters, and is set at 90%. It is used in conjunction with Equation 11b.

$High_{OBD}$ is the fraction of highs in the vehicle fleet equipped with OBD if no I/M program is present. $High_{OBDIM}$ is the fraction of highs in the vehicle fleet equipped with OBD if an OBD I/M program is present.

A further description of Equations 8 through 11b for a given vehicle age is listed below. The fraction of high emitters is the sum of the following:

1. The number of highs from the year before, plus;

2. The number of MIL-on highs added in that year due to OBD non-response (a function of “non-response” rate, MIL-on rate, and the high emitter growth rate applied to the available pool of “non-highs” - normals and repaired vehicles), plus;

3. The number of highs added in that year that the OBD system did not detect (a function of MIL-“off” rate and the high emitter growth rate applied to the available pool of “non-highs”). The high emitter growth rate for a given year is the absolute increase in high emitters under the No OBD / No IM case from the previous year divided by the fraction on Nonhigh - i.e., the available pool of vehicles which can become high emitters.

3.4.5 Repaired Fractions

Once the high emitter fraction is calculated for the OBD or OBD/IM cases, the fraction of repaired emitters can be calculated as the difference between the fraction of high emitters that would occur without OBD or I/M ($High_{BASE}$)and the fraction of high emitters with OBD and/or I/M from Equation 11. In equation form,

$$Repaired(i) = High_{BASE}(i) - High_{OBD}(i) \qquad \text{Eqn 12}$$

3.4.6 Normal Fractions

The normal emitters are those vehicles which are not high or repaired emitters. At a given age, the rate of normal emitters remains constant between the No OBD / No I/M, OBD-only and OBD/IM case; only the fraction of high emitters decrease, directly replaced by repaired emitters. However, over time (as age increases) the fraction of normal emitters decreases due to the growth in the fraction of high emitters.

The CO emission emitter fractions for normal, high and repaired emitters for the OBD Only and OBD/IM cases are shown in Appendix A by vehicle class.

3.5 High Emitter Fraction - Exhaust I/M and OBD and Exhaust I/M

For Tier1 and later vehicle standards classes, this option contains three possibilities which depend on vehicle model year and the presence of an exhaust test I/M program and an OBD I/M program. An exhaust test I/M program refers to any type of exhaust I/M test such as the Idle test, the Two Speed Idle test, the ASM test or the IM240 test.

3.5.1 Exhaust I/M / NO OBD

For Tier1 and later vehicles this combination can only occur in the 1994 and 1995 model years where OBD is not present on vehicles, and an exhaust I/M program is in place. Since this scenario is really just an extension of the 1981-93 model year (no OBD is present), the same I/M treatment of high emitters before and after I/M as is used for the 1981-93 model years will be used. The reader is encouraged to refer to EPA document M6.IM.001 for more details.

3.5.2 Exhaust I/M with OBD

For Tier1 and later vehicles this combination can only occur on 1996 and later model year vehicles equipped with an OBD system. Under this scenario the I/M program conducts an exhaust I/M test, but does not conduct an OBD I/M test. This is a likely scenario until at least calendar year 2001 when the EPA OBD I/M guidance is expected to be implemented. The fraction of fleet high emitters remaining after the I/M test under this scenario is the same as that presented in Section 3.5.1. It is a function of the stringency of the exhaust I/M test, and uses the same general treatment discussed in EPA document M6.IM.001. This scenario differs from the one presented in Section 3.5.1 in the 'before'I/M failure rates or base failure rates. These are lower than the exhaust I/M / No OBD because of the presence of the OBD systems on the vehicles. They are calculated using Equation 11a.

3.5.3 Exhaust I/M and OBD I/M

This scenario can exist for 1996 and later model year vehicles equipped with an OBD system, and subject to both an OBD I/M inspection and an exhaust I/M test. If an I/M program should choose to implement this type of program (both OBD and exhaust I/M on the same vehicles), the after I/M high emitter rate will be the same as the after OBD I/M high emitter rate calculated in Equation 11b. This assumes that a combined exhaust I/M and OBD I/M program will be as effective as the OBD I/M only program. This is not an unreasonable assumption since the OBD I/M only program is assumed to identify 90 percent of the high emitters, and the exhaust I/M tests have identification rates which are in most cases considerably lower.

4.0 Basic Emission Factor Calculations for Various I/M and OBD Scenarios

This section describes how the information described in the previous sections is consolidated to compute emissions for each of the possible OBD and I/M scenarios.

4.1 NO OBD and NO I/M

The No OBD and No I/M emission level for the Tier1 and later vehicles is the basic CO emission level. For CO emissions, it is essentially the same value as the 1988-93 model year PFI vehicle CO emission level, except basic emission rates for normal emitters ar calculated with a lower zero mile emission level. The No OBD and No I/M emission level is the basis for the subsequent CO emission levels; however, it only appears directly in the MOBILE6 CO output for the 1994 and 1995 model year vehicles with no installed OBD system and no I/M program.

The average No OBD and No I/M in-use running and start CO emission levels are calculated for each vehicle, standard and age combination using the general Equation 2 repeated here as Equation 13. The parameters in Equation 13 such as "High_ave" and "Norm_ave" are calculated from Equations (5a-d or 6a-d) and 7a-d. The fraction of high emitters which is used in Equation 13 is the value of $High_{BASE}(i)$) found in Appendix A in Table A-2 in column "Base". Figures 4 and 5 show the CO emission levels for the cars and trucks for Tier1 and LEV, and ULEV vehicles. The line on each figure labeled "Base" is the NO OBD and NO I/M CO emission line shown in terms of FTP emissions (running and start are combined together).

$$Base(i) = High_{Base}(i) * High\_ave + Normal(i)*Norm\_ave(i) \qquad \text{Eqn 13}$$

4.2 OBD and NO I/M

The OBD and No I/M emission level for the Tier1 and later vehicles is used in MOBILE6 as the CO emission level for 1996 and later vehicles if no I/M program is present. It differs from the NO OBD and NO I/M case because of the ability of OBD to identify high emitters and induce the vehicle owner to repair them absent an I/M program. Calculation of the average CO emission rate for OBD and NO I/M uses Equation 14. It is similar to the calculation described above in Section 4.1 for the No OBD and No I/M case, and uses the same values for the normal and high emitter emission level average parameters. The differences are the use of $High_{OBD}$ rather than $High_{BASE}$ for the high emitter fraction parameter, and the after repair emission term. The after repair emission term is the product of the after repair emission level (Rep_ave) and the fraction of high emitters which are repaired ("Repaired" from equation 12). The value of "Rep_ave" is the CO emission level which is 1.5 times the applicable 50,000 mile FTP certification standard (See Section 5.0 for more details on Rep_ave).

$$OBD(i) = High_{OBD}(i) * High\_ave + Normal(i)*Norm\_ave(i) + Repaired(i) * Rep\_ave \quad \text{Eqn 14}$$

The FTP CO emission levels for cars and trucks and Tier1 and LEV and ULEV for the case of OBD and NO I/M are shown in Figures 4 and 5. These are indicated by the dotted line and are under the legend heading of "OBD". In general, they are very similar to the "Base" NO OBD emission levels. This reflects the relatively small impact of OBD on overall fleet CO emissions in the absence of an I/M program.

4.3 OBD and OBD I/M

The OBD and OBD I/M emission level for the Tier1 and later vehicles is used in MOBILE6 as the CO emission level for 1996 and later vehicles if an OBD I/M program is present. It differs from the OBD and NO I/M case because of the ability of OBD I/M to identify and force the vehicle owner to repair a high emitter. Contrasting the two, the OBD and NO I/M case can be viewed as a voluntary OBD I/M program, and the OBD and OBD I/M case can be viewed as a mandatory I/M program. Calculation of the average CO emission rate for OBD and NO I/M is done using Equation 15. It is similar to the calculation done in Equation 14 for the No OBD and No I/M case, and uses the same values for the normal and high emitter emission level average parameters. The difference is the use of $High_{OBDIM}$ rather than $High_{OBD}$ for the high emitter fraction parameter.

$$OBDIM(i) = High_{OBDIM}(i) * High\_ave + Normal(i)*Norm\_ave(i) + Repaired(i) * Rep\_ave \quad \text{Eqn 15}$$

The CO emission levels for cars and trucks and Tier1 and LEV and ULEV for the case of OBD and OBD I/M are shown in Figures 4 and 5. These are indicated by the line with the circles on it and are under the legend heading of "OBD+IM". In general, these emissions are considerably lower than the "Base" and "OBD" lines. This difference reflects the relatively large impact of a mandatory OBD I/M program on overall fleet CO emissions after the main warranty ends. The difference between the OBD line and the OBD+IM line is the I/M benefit.

4.4 Exhaust I/M / NO OBD

As mentioned in Section 3.5.1, for Tier1 and later vehicles this combination can only occur in the 1994 and 1995 model years where OBD is not present on vehicles, and an exhaust I/M program is in place. Since this scenario is really just an extension of the 1981-93 model year (no OBD is present), the same general calculation of before and after I/M CO emissions levels will be done for the Tier1 and later vehicles as was done for the 1981-1993 model year vehicles. The "before" I/M CO emission levels are those calculated using Equation 13 and labeled as "Base" in Figures 4 and 5. The "after" I/M CO emission levels "ExhBase" are calculated using Equation 16. Except for the use of the $High_{BASE}$ variable, this is the same equation that is used to calculate the after I/M emission levels for the 1981-1993 model year vehicles. However, for more details on the development of 1981-1993 model years I/M credits, the reader is encourage to refer to EPA document M6.IM.001.

$$ExhBase(i) = Norm\_ave*(1-High_{BASE}) + High\_ave*High_{BASE}*(1-IDR) + High_{BASE}*IDR*W*High\_ave*RW + Norm\_ave*R*High_{BASE}*IDR*FIX + High\_ave*High_{BASE}*IDR*NC \quad \text{Eqn 16}$$

IDR is the identification rate of high emitters using an exhaust emission test.
R is the after repair emission level of vehicles repaired to pass an exhaust I/M test.
Fix is the fraction of vehicles which are repaired.
NC is the fraction of vehicles which are in non-compliance following their I/M test
W is the fraction of vehicles which receive a cost or other type of waiver.
RW is the after repair level of the vehicles which get waivered. It is shown as a fraction of the high emitter level.

4.5 Exhaust I/M with OBD

As mentioned in Section 3.5.2, for Tier1 and later vehicles this combination can only occur on 1996 and later model year vehicles equipped with an OBD system. Under this scenario the I/M program conducts an exhaust I/M test, but does not conduct an OBD I/M test. This is a likely scenario until at least calendar year 2001 when the EPA OBD I/M guidance is expected to be implemented. The only difference between this scenario and the one discussed in Section 4.4 above is the different "before" I/M high emitter fractions. For example, this case uses the value of $High_{OBD}$ and the previous case uses the value of $High_{BASE}$ for high emitter fraction. This difference can be seen by comparing Equation 16 with Equation 17. Another comparison is that this case uses the before I/M CO emission line labeled in Figures 4 and 5 as "OBD", and the previous case of Exhaust I/M and NO OBD uses the line labeled as "Base".

$$ExhOBD(i) = Norm\_ave*(1-High_{OBD}) + High\_ave*High_{OBD}*(1-IDR) + High_{OBD}*IDR*W*High\_ave*RW + Norm\_ave*R*High_{OBD}*IDR*FIX + High\_ave*High_{OBD}*IDR*NC \quad \text{Eqn 17}$$

4.6 Exhaust I/M and OBD I/M

As mentioned in Section 3.5.3, this scenario can exist for 1996 and later model year vehicles equipped with an OBD system, and subject to both an OBD I/M inspection and an exhaust I/M test. If an I/M program should choose to implement this type of program (both OBD and exhaust I/M on the same vehicles), the before and after I/M emission levels will be the same as the before and after OBD I/M emission level. This emission level is shown in Figures 4 and 5 under the legend label "OBD+IM". This is the lowest CO emission level which can be obtained for a given standards class, vehicle type, and I/M program. It assumes that the additional exhaust I/M program in conjunction with an effective OBD program is redundant.

5.0 OBD Repair Effects

Separate running and start CO emission factors for normal and high emitters were developed directly from start and running test data. However, development of the after OBD repair CO emission levels are more problematic because there are no after repair test data, and because of the OBD requirement for MIL illumination at 1.5 times a vehicle's FTP standard (see Section 3.4.3 for a description and justification for the 1.5 times standard after repair level). The requirement of MIL illumination if the vehicle's emissions exceed 1.5 times the standard is a difficulty in the context of this analysis because it is expressed in terms of FTP emissions rather than separately in terms of the running or start emissions which are used in MOBILE6.

Two simple multiplicative factors to express the 1.5 times FTP standard MIL illumination in terms of running and start emissions were developed based on a sub-sample of 1994 and later model year test results. The sub-sample consisted of 17 cars and trucks which had FTP CO emissions greater than 5.0 g/mi (approximately 1.5 times standards) and less than 3.0 times certification CO standards. The factors were developed by taking the ratio of the running and/or start emissions and the FTP emissions. They are shown below as ratios of running emissions over FTP emissions, and start emissions over the FTP emissions. The values are:

Running CO (g/mi)/ FTP CO(g/mi) = 0.338 Eqn 18

Start CO(grams/start) / FTP CO (g/mi) = 4.149 Eqn 19

The approach of using a sub-sample of 17 vehicles rather than the overall 1994+ sample was selected because the ratios are a function of the FTP CO emission level. The overall sample contains mostly low normal emitters rather than the sub-sample vehicles which are close to the 1.5 times certification standards emission level that is being modeled. The limited data and simple analysis suggests that the low emitters have smaller running / FTP ratios and larger start / FTP ratios than the vehicles which are close to the 1.5 times the standards level. For example, use of the entire sample would produce a running / FTP CO ratio of 0.164 and a start / FTP CO ratio of 9.74 versus the values of 0.338 and 4.15. These "full sample ratios" would likely improperly raise the after repair start emission level and lower the after repair running emission level versus the ratios based on the sub-sample.

For the statistically minded, the 90 percent confidence interval around the sub-sample running / FTP ratio is from 0.277 to 0.398. The corresponding sub-sample start / FTP ratio confidence level ranges from 2.82 to 5.48.

These ratios are used to calculate the value of Rep_ave (After repair emission level for OBD vehicles) for start and running emissions used in Equations 14 and 15. For example, the after OBD repair CO running emission level for a Tier1 or LEV car is:

1.5 X * High Emitter Running Fraction * CO Standard

1.5 * 0.338 * 3.4 g/mi = 1.724 g/mi running LA4 CO

and

1.5 X * High Emitter Start Fraction * CO Standard

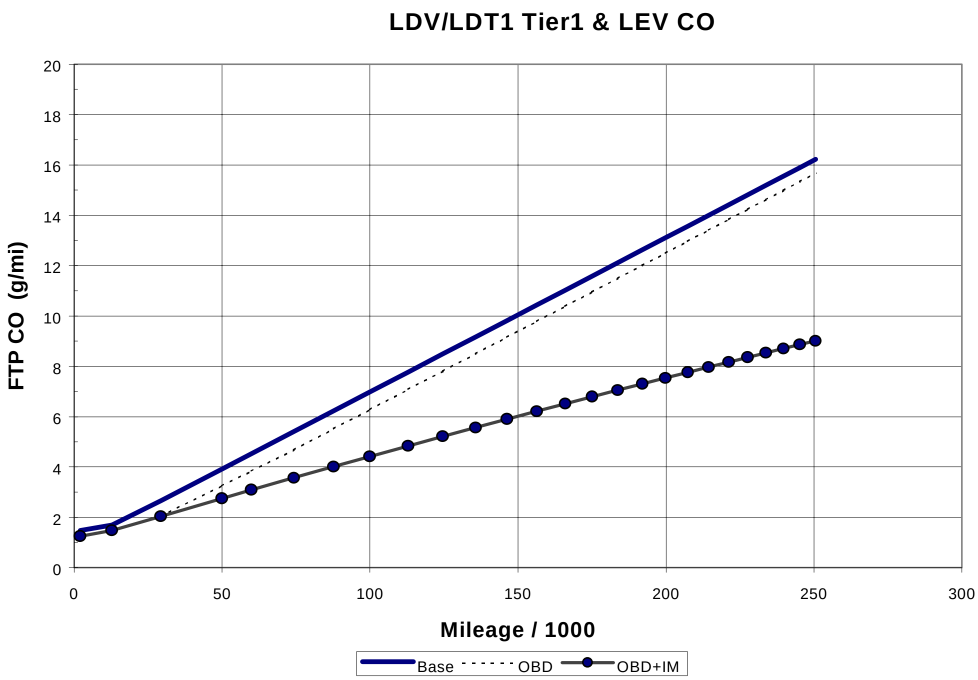
1.5 * 4.149 * 3.4 g/mi = 21.160 grams CO / start

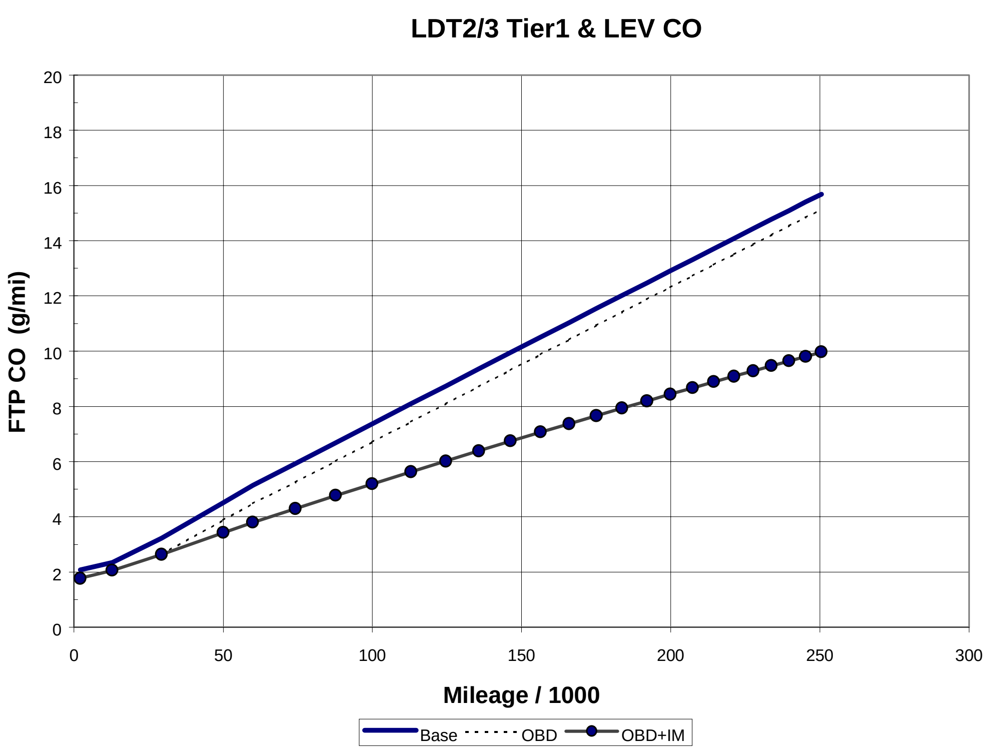
Table A-1: CO Basic Emission Rates							
Vehicle Class	**Standard Class**	**50K Standard (g/mi)**	**Mode**	**"Normal" BER (g/mi)**		**"High" BER (g/mi)**	**"Repaired" BER (g/mi)**
				ZML	**DR**		
LDV/T1	**Tier1 / LEV**	3.4	Running	0.282	0.229	36.11	1.724
			Start (grams)	15.176	0.070	38.06	21.160
	ULEV	1.7	Running	0.141	0.229	36.11	0.862
			Start (grams)	7.588	0.070	38.06	10.580
LDT2/3	**Tier 1 / LEV**	4.4	Running	0.322	0.268	33.28	2.228
			Start (grams)	21.884	0.168	83.86	27.383
	ULEV	2.2	Running	0.161	0.268	33.28	1.114
			Start (grams)	10.942	0.168	83.86	13.692
LDT4	**Tier 1 / LEV**	5.0	Running	0.366	0.268	33.28	2.532
			Start (grams)	24.868	0.168	83.86	31.118
	ULEV	2.5	Running	0.183	0.268	33.28	1.266
			Start (grams)	12.434	0.168	83.86	15.559

Table A-2: CO Emitter Fractions

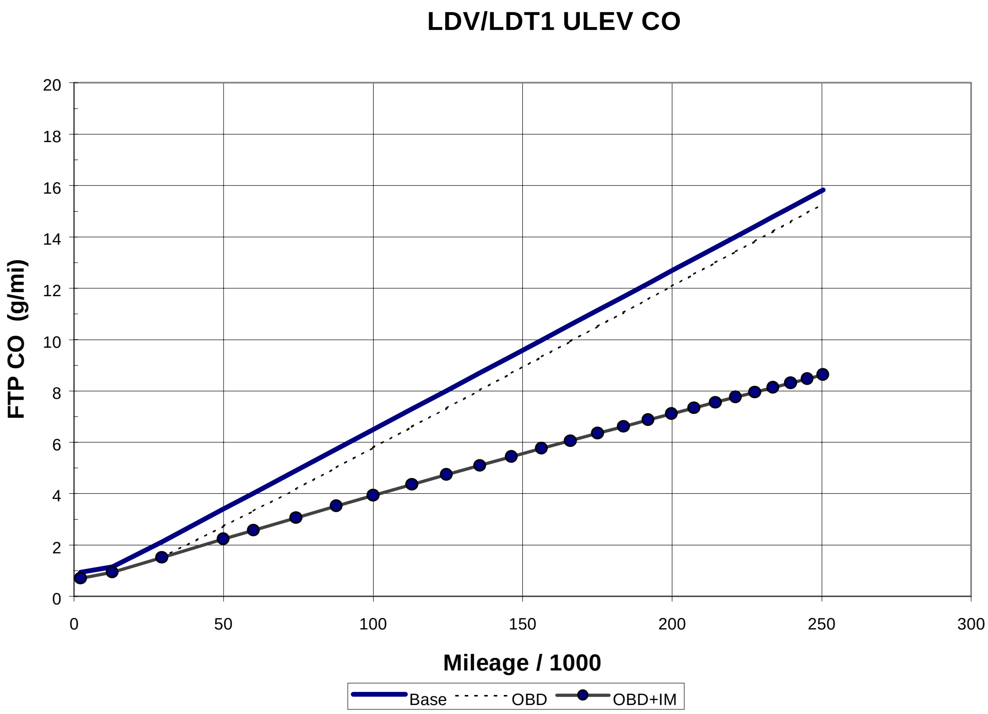
Age (Years)	LDV / LDT1						LDT2 / 3					
	All	Base	OBD Only		OBD/IM		All	Base	OBD Only		OBD/IM	
	Normal	High	High	Repair	High	Repair	Normal	High	High	Repair	High	Repair
0	0.991	0.009	0.002	0.007	0.002	0.007	0.988	0.012	0.003	0.009	0.003	0.009
1	0.992	0.008	0.002	0.006	0.002	0.006	0.988	0.012	0.003	0.009	0.003	0.009
2	0.976	0.024	0.006	0.018	0.006	0.018	0.976	0.024	0.006	0.018	0.006	0.018
3	0.954	0.046	0.026	0.020	0.011	0.035	0.955	0.045	0.025	0.020	0.011	0.034
4	0.943	0.057	0.036	0.021	0.014	0.043	0.946	0.054	0.034	0.020	0.013	0.041
5	0.928	0.072	0.051	0.022	0.017	0.055	0.933	0.067	0.046	0.021	0.016	0.051
6	0.913	0.087	0.066	0.021	0.021	0.066	0.921	0.079	0.058	0.021	0.019	0.060
7	0.899	0.101	0.080	0.021	0.025	0.076	0.911	0.089	0.069	0.021	0.022	0.068
8	0.884	0.116	0.095	0.021	0.028	0.088	0.899	0.101	0.081	0.020	0.025	0.076
9	0.870	0.130	0.109	0.020	0.032	0.098	0.888	0.112	0.092	0.020	0.027	0.085
10	0.857	0.143	0.123	0.020	0.035	0.107	0.878	0.122	0.102	0.020	0.030	0.092
11	0.844	0.156	0.136	0.020	0.039	0.117	0.868	0.132	0.113	0.020	0.033	0.100
12	0.832	0.168	0.149	0.019	0.042	0.126	0.858	0.142	0.123	0.019	0.035	0.107
13	0.820	0.180	0.161	0.019	0.045	0.135	0.849	0.151	0.132	0.019	0.038	0.114
14	0.809	0.191	0.173	0.019	0.048	0.143	0.840	0.160	0.141	0.019	0.040	0.120
15	0.798	0.202	0.184	0.019	0.051	0.151	0.831	0.169	0.150	0.019	0.042	0.127
16	0.787	0.213	0.195	0.018	0.054	0.159	0.823	0.177	0.159	0.019	0.045	0.133
17	0.777	0.223	0.205	0.018	0.057	0.166	0.814	0.186	0.167	0.018	0.047	0.139
18	0.767	0.233	0.216	0.018	0.060	0.173	0.807	0.193	0.175	0.018	0.049	0.144
19	0.757	0.243	0.225	0.018	0.063	0.180	0.799	0.201	0.183	0.018	0.051	0.150
20	0.748	0.252	0.235	0.017	0.066	0.186	0.792	0.208	0.190	0.018	0.053	0.155
21	0.739	0.261	0.244	0.017	0.068	0.193	0.785	0.215	0.197	0.018	0.055	0.160
22	0.731	0.269	0.252	0.017	0.071	0.199	0.778	0.222	0.204	0.018	0.057	0.165
23	0.723	0.277	0.261	0.017	0.073	0.204	0.772	0.228	0.210	0.017	0.059	0.169
24	0.715	0.285	0.269	0.017	0.075	0.210	0.766	0.234	0.217	0.017	0.060	0.174
25	0.707	0.293	0.276	0.016	0.078	0.215	0.760	0.240	0.223	0.017	0.062	0.178

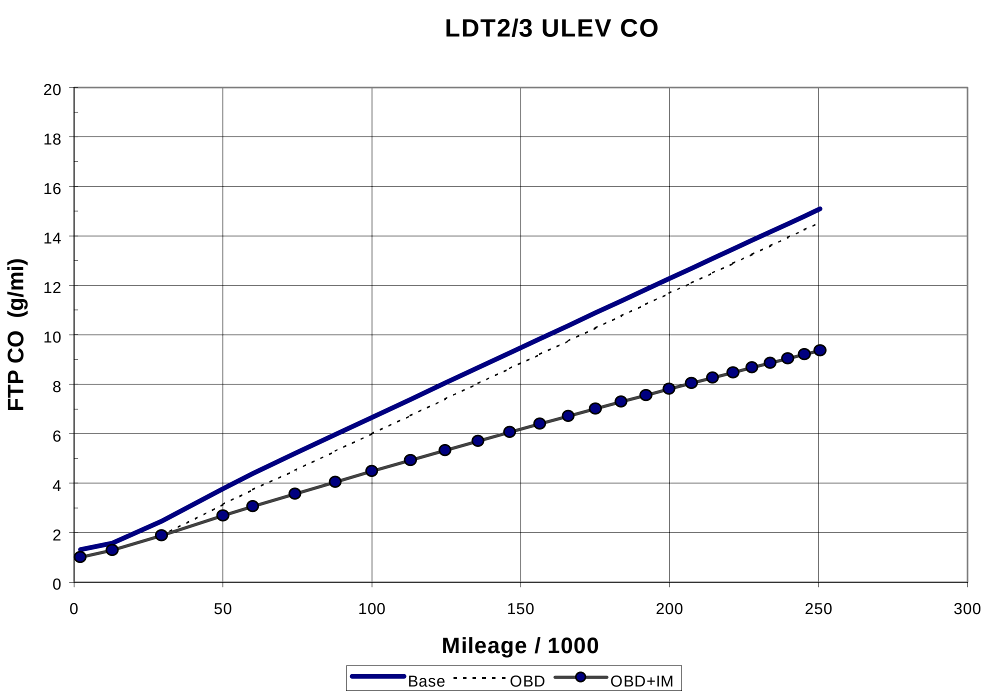
Figures 4 and 5
CO Emission Factors from Cars and Truck1 Vehicles





Figures 6 and 7
CO Emission Factors from Truck2 and Truck3 Vehicles





APPENDIX B
Statistical Diagnostics for CO Running and Start Normal Emitter Levels

This Appendix contains the statistical diagnostics from the regression of the normal emitter CO emission versus odometer. Standard least squares regressions were done on running CO emissions versus odometer for cars and trucks separately, and start CO emissions versus odometer for cars and trucks separately.

```
           * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Regression for 1994+ cars

Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..   HR505_CO

Block Number  1.  Method:  Enter      ODOMETER


Variable(s) Entered on Step Number
   1..    ODOMETER


Multiple R           .37098
R Square             .13763
Adjusted R Square    .13079
Standard Error       .61807

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             7.68187          7.68187
Residual           126            48.13358           .38201

F =      20.10894       Signif F =  .0000


---------------------- Variables in the Equation -----------------------

Variable              B        SE B     95% Confdnce Intrvl B       Beta

ODOMETER    1.24335E-05  2.7727E-06  6.94648E-06  1.79206E-05    .370985
(Constant)      .117206     .091991     -.064842      .299254


----------- in ------------

Variable           T  Sig T

ODOMETER       4.484  .0000
(Constant)     1.274  .2050


           * * * *   M U L T I P L E   R E G R E S S I O N   * * * *


Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..   STRT_CO
```

Block Number 1. Method: Enter ODOMETER

Variable(s) Entered on Step Number
1.. ODOMETER

Multiple R	.07287
R Square	.00531
Adjusted R Square	-.00258
Standard Error	8.82307

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	52.35654	52.35654
Residual	126	9808.65890	77.84650

F = .67256 Signif F = .4137

---------------------- Variables in the Equation -----------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta
ODOMETER	3.24599E-05	3.9580E-05	-4.58687E-05	1.10788E-04	.072866
(Constant)	14.753554	1.313187	12.154795	17.352312	

----------- in ------------

Variable	T	Sig T
ODOMETER	.820	.4137
(Constant)	11.235	.0000

End Block Number 1 All requested variables entered.

* * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Listwise Deletion of Missing Data

Equation Number 1   Dependent Variable..   CO

Block Number 1. Method: Enter   ODOMETER

Variable(s) Entered on Step Number
1..   ODOMETER

Multiple R	.41750
R Square	.17430
Adjusted R Square	.16775
Standard Error	1.23853

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	40.80123	40.80123
Residual	126	193.27996	1.53397

F =   26.59849   Signif F = .0000

---------------------- Variables in the Equation -----------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta
ODOMETER	2.86548E-05	5.5561E-06	1.76595E-05	3.96502E-05	.417497
(Constant)	1.187217	.184338	.822418	1.552017	

----------- in ------------

Variable	T	Sig T
ODOMETER	5.157	.0000
(Constant)	6.440	.0000

End Block Number   1   All requested variables entered.

* * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Listwise Deletion of Missing Data

Equation Number 1   Dependent Variable..   HR505_CO

Block Number 1. Method: Enter   ODOMETER

Variable(s) Entered on Step Number
1..   ODOMETER

Multiple R	.34670
R Square	.12020
Adjusted R Square	.11190
Standard Error	1.05037

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	15.97724	15.97724
Residual	106	116.94662	1.10327

F =   14.48171   Signif F = .0002

---------------------- Variables in the Equation -----------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta
ODOMETER	1.14258E-05	3.0025E-06	5.47314E-06	1.73785E-05	.346696
(Constant)	.173842	.150593	-.124724	.472408	

----------- in ------------

Variable	T	Sig T
ODOMETER	3.805	.0002
(Constant)	1.154	.2509

End Block Number   1   All requested variables entered.

* * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Listwise Deletion of Missing Data

Equation Number 1   Dependent Variable..   STRT_CO

Block Number 1. Method: Enter   ODOMETER

Variable(s) Entered on Step Number
1..   ODOMETER

Multiple R	.00946
R Square	.00009
Adjusted R Square	-.00934
Standard Error	13.38235

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	1.69800	1.69800
Residual	106	18983.24665	179.08723

F =   .00948   Signif F = .9226

---------------------- Variables in the Equation -----------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta
ODOMETER	-3.72482E-06	3.8253E-05	-7.95656E-05	7.21160E-05	-.009457
(Constant)	21.096190	1.918655	17.292269	24.900111	

----------- in ------------

Variable	T	Sig T
ODOMETER	-.097	.9226
(Constant)	10.995	.0000

End Block Number   1   All requested variables entered.

* * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Listwise Deletion of Missing Data

Equation Number 1   Dependent Variable..   CO

Block Number 1. Method: Enter   ODOMETER

Variable(s) Entered on Step Number
1..   ODOMETER

Multiple R	.33380
R Square	.11142
Adjusted R Square	.10304
Standard Error	2.65967

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	94.02251	94.02251
Residual	106	749.83013	7.07387

F =   13.29152   Signif F = .0004

---------------------- Variables in the Equation -----------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta
ODOMETER	2.77174E-05	7.6026E-06	1.26444E-05	4.27903E-05	.333797
(Constant)	1.778813	.381323	1.022802	2.534823	

----------- in ------------

Variable	T	Sig T
ODOMETER	3.646	.0004
(Constant)	4.665	.0000

VEHICLE by MODEL_YR

MODEL_YR   Page 1 of 1

VEHICLE	Count	1994	1995	1996	1997	1998	1999	Row Total
	1.00	32	21	22	26	27		128
								54.2
	2.00	20	10	30	24	20	4	108
								45.8
	Column Total	52	31	52	50	47	4	236
		22.0	13.1	22.0	21.2	19.9	1.7	100.0

Appendix C

1994+ Normal Emitters < 25,000 Miles

VEHICLE		Running CO (g/mi)	Start CO (g/start)	FTP CO (g/mi)
CAR	Mean	.28205	15.17562	1.55696
	N	77	77	77
	Std. Deviation	.64849	9.26452	1.20706
	Median	.13200	13.89300	1.27800
TRUCK	Mean	.32188	21.88350	2.14848
	N	50	50	50
	Std. Deviation	.64250	12.51306	1.44522
	Median	6.0500E-02	19.85450	1.74850
Total	Mean	.29773	17.81652	1.78984
	N	127	127	127
	Std. Deviation	.64387	11.11251	1.33239
	Median	.10300	15.67400	1.43700

1994+ Normal Emitters All

VEHICLE		Running CO (g/mi)	Start CO (g/start)	FTP CO (g/mi)
CAR	Mean	.44910	15.62002	1.95212
	N	128	128	128
	Std. Deviation	.66294	8.81168	1.35763
	Median	.19100	13.93250	1.68150
TRUCK	Mean	.59868	20.95769	2.80940
	N	108	108	108
	Std. Deviation	1.11458	13.32026	2.80829
	Median	.16000	18.42950	1.94450
Total	Mean	.51755	18.06269	2.34443
	N	236	236	236
	Std. Deviation	.89929	11.39519	2.18407
	Median	.18450	15.45700	1.75150