United States Environmental Protection Agency

Air and Radiation

EPA420-P-99-009
March 1999
M6.EXH.007

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

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Printed on Recycled Paper

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1 Introduction

This report discusses proposed MOBILE6 NOx and exhaust HC basic emission rates (BERs) for Tier 1 and later light-duty vehicles (LDVs) and light-duty trucks (LDTs), and the effects of On-Board Diagnostic (OBD) systems and Inspection/Maintenance (I/M) on these vehicles. The methodology discussed in this paper can be applied to generate BERs across all vehicle classes (LDV and LDT1 through 4) for all Tier 1 and later standards, including the TLEV, LEV, and ULEV standards under the California LEV I and Federal NLEV program, and LEV II standards recently adopted by California. For brevity, however, the results presented here focus on the Tier 1, LEV and ULEV standards for each vehicle class.

Sufficient in-use data on LDVs or LDTs complying with Tier 1 or later standards were generally not available at the time of the analysis. Thus, the methodology used in the development of Tier 1 and later BERs is based on the differences in certification standards across standard level and vehicle class. For NOx, Tier 1 and later BERs were based on a sample of 186 LDVs certified to a 50,000 mile 0.4 gram/mile NOx standard (the Federal Tier 1 standard). For HC, Tier 1 and later emission rates were based on BERs developed for 1988 through 1993 Ported Fuel Injection (PFI) LDVs. Using certification standard as the base for Tier 1 and later BERs has two implicit ramifications. First, the BERs reflect the fuel which a vehicle is certified on the meet the standard: Indolene for Tier 1 standards, and California Phase II RFG for LEV and later standards. Second, the HC BERs are expressed as non-methane hydrocarbon (NMHC) for Tier 1 LDV/LDTs, and non-methane organic gas (NMOG) for LEV and later LDVs/LDTs.

On-Board Diagnostics systems were required on all LDVs and LDTs sold outside California beginning in 1996. Tier 1 vehicles began entering the fleet in 1994, and for two years (1994 and 1995) were not equipped with OBD. For MOBILE6, it will be assumed that all 1996 and later LDVs and LDTs are equipped with OBD systems, which are designed to detect emission system malfunctions resulting in emissions at or above 1.5 times the applicable emission standard.[1] If this criteria is met, a light on the vehicle's dashboard (the malfunction indicator light, or MIL) is illuminated to alert the driver that an emissions system repair is required. Thus, the rate of emission deterioration for Tier 1 and later vehicles must take into account the impact OBD systems will have overall in-use emissions, including a) the effectiveness of these systems in detecting emission malfunctions, b) the owner response rate to illuminated MILs, and c) the effectiveness of repair in addressing the detected problem.

Beginning in 2001, all Inspection/Maintenance programs will require an OBD system check for OBD-equipped vehicles. In I/M areas, this will greatly increase the rate at which illuminated MILs are addressed, hence further improving the average rate of in-use deterioration for Tier 1 and

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[1] The "1.5 times the standard" criteria was initially required by ARB, while EPA adopted a different malfunction threshold approach. However, manufacturers were allowed to meet the federal program through compliance with ARB's requirement, and most chose this option. EPA's requirement has recently been amended to harmonize with ARB by requiring the "1.5 times the standard" criteria for vehicle sold federally. For MOBILE6, it will be assumed that all vehicle equipped with OBD since 1996 comply with the "1.5 times" malfunction criteria.

later vehicles.

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).

To model emissions under these scenarios, a methodology for generating basic emission rates was developed for the following cases:

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 computation of BERs under the OBD-only and OBD/IM cases.

OBD-Only (OBD/ No IM) applies to 1996 and later OBD-equipped vehicles where an I/M program is not present.

OBD/IM applies to 1996 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 represents a situation in which only an exhaust test is conducted in an I/M program (an IM240, ASM, or Idle test). This will apply to 1994 and 1995 model year Tier 1 vehicles in all calender years, and all vehicles in calender years prior to 2001.

This report gives an overview of the basic approach for generating BERs, then describes the specific details of BER development for NOx and exhaust HC for each case.

2 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.[2] 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 NOx and HC is 2.0 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 2.0

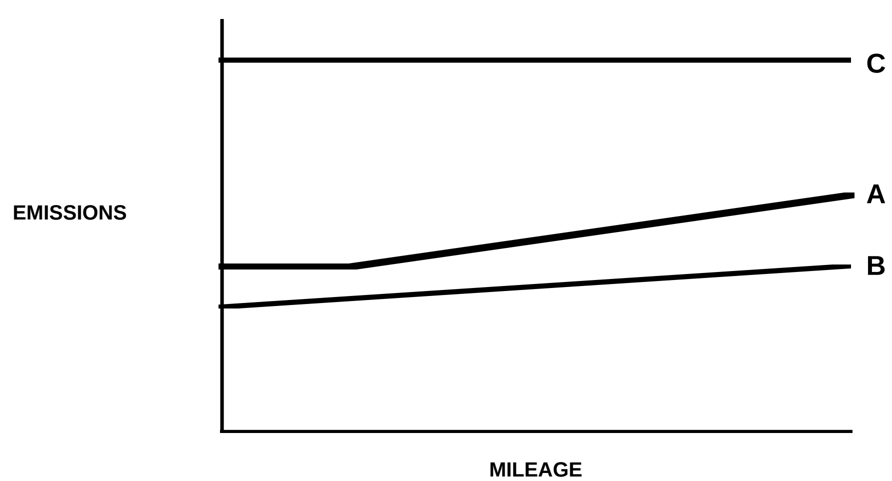
[2]Glover, E., and Brzezinksi, D., "MOBILE6 Inspection/Maintenance Benefits Methodology for 1981 through 1993 Model Year Light Vehicles", Draft MOBILE6 Report No. M6.IM.001, March 1999. Hereafter referred to as "Tier 0 I/M Report"

times the intermediate life certification standard. It is important to note that both pollutants are considered independently when determining whether a vehicle is a high emitter. Thus, a vehicle could be a high NOx 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. This phenomena is contributed to by the "go/no go" nature of emission control technology components such as EGR valves and air pumps, and the high sensitivity of emissions to degradations in performance of other critical components such as the catalyst, oxygen sensor(s) and fuel injectors. 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.

Under this methodology, average in-use emissions are computed as a weighted average of high and normal emitters. Figure 1 is a general graphical view of the concept with the y-axis representing emissions in grams per mile, (or grams for start emissions) and the x-axis representing mileage.[3] 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



[3]MOBILE6 uses vehicle mileage as a surrogate for vehicle age. Age and mileage are used interchangeably throughout this document.

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

Line B represents the average emissions of 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 to reflect the gradual deterioration that normal vehicles experience, primarily due to catalyst degradation over the life of the vehicle. Normal emitter emissions are generally expressed by 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, based on previous analysis of Tier 0 data[4] and born out by analyses of Tier 1 NOx data presented in the following section. The underlying phenomena expressed here is that emission control malfunction will drive 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 factors for normal and high emitters. On a fleet-wide basis, this weighting factor represents 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*** (represented by vehicle mileage) by transforming Equations 1 and 2 into Equations 3 and 4 below.

[4] Tier 0 I/M report

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

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:

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

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

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***

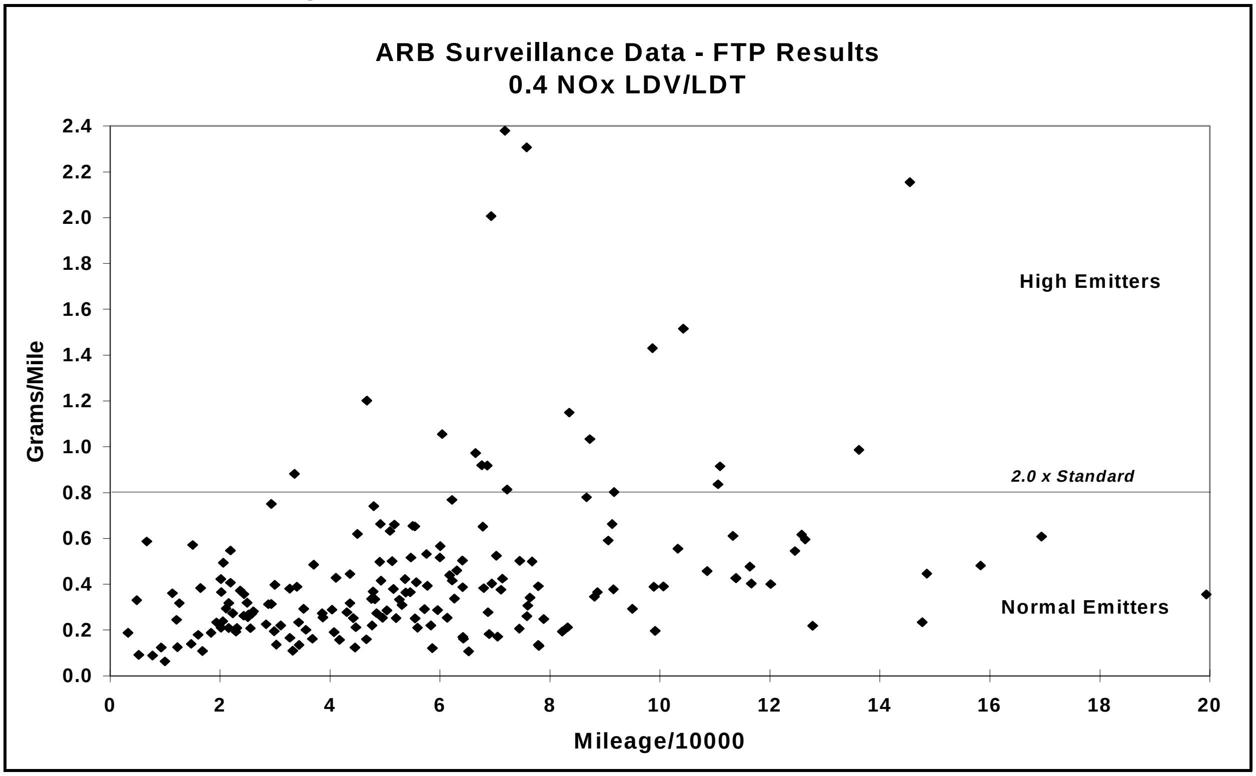
3 NOx BERs and Emitter Fractions: No IM/No OBD Case

3.1 Tier 1 LDVs

The No IM / No OBD case was developed first because it did not require accounting for high emitters which underwent repair due to OBD MIL-on; hence, the methodology closely followed the basic emission rate derivation concept outlined in the previous section. Tier 1 LDVs served as the basis for developing BERs across vehicle class (LDT1 through 4), and standard level (LEV, ULEV) for both NOx and NMHC. Thus, the derivation of these BERs is the first step in the generation of all BERs for all OBD/IM cases, vehicles classes and standards. Tier 1 and later BERs were first generated in FTP space and subsequently split into running and start components, as discussed in Section 7; this deviates from the approach used 1981 through 1993 vehicles, for which start and running BERs were developed independently.

The data used to generate No OBD/No IM BERs for Tier 1 LDVs were 186 LDVs and LDTs tested by the California Air Resources Board (ARB) as part of Surveillance Programs 12 through 14; these data were provided to EPA by ARB specifically for this analysis. The model years of these vehicles ranged from 1989 through 1996, and all were certified to a 50,000 mile intermediate useful life NOx standard of 0.4 g/mi, the same as the Federal Tier 1 LDV/LDT1 standard. Figure 2 graphically presents the ARB data, in terms of FTP emissions versus mileage (in ten thousand mile units).

Figure 2 - ARB Surveillance Data FTP NOx Results



Using these data as a starting point, emissions for normal emitters, high emitters and the fraction of high emitters were derived, as outlined in the following sections.

3.1.1 Normal and High Emitter Emission Level

The average FTP normal emitter emission level was obtained by separating the normal emitters from the high emitters in the ARB sample according to the "2.0 times the standard" criteria (i.e. all vehicles in the sample above 0.8 g/mi were defined as high emitters, as shown in Figure 2). Using this cutpoint, 19 vehicles were defined as high emitters, and the remainder (167) were defined as normal emitters. The BER for normal emitters was developed by fitting a linear regression of FTP emissions versus mileage; the result of this regression is shown in Equation 5 (the variable 'odom' is in units of ten thousand miles).

Norm_Ave(g/mi) = 0.265 + 0.0147 * odom Eqn 5

The high emitter NOX emission level was obtained by calculating the mean emission level of the 19 vehicles defined as High Emitters:

High_Ave(g/mi) = 1.278 Eqn 6

3.1.2 High Emitter Fractions

As discussed in Section 2, high emitter fractions allow the computation of average in-use emissions based on normal and high emitting BERs. These fractions increase with vehicle age, and for OBD-equipped vehicles will be used as the basis for computing OBD and/or I/M benefits. It is at this stage of the NOx BER computation that key assumptions regarding the representativeness of recruitment-based[5] in-use emission testing program become relevant. In general, there is concern that recruitment-based in-use emission testing programs are less likely to procure dirtier vehicles, and hence do not gather data over the full range of the in-use fleet. These programs typically have low response rates (less than 25 percent), and in-use data from programs with higher rates of participation (e.g. I/M programs) show higher emissions than voluntary recruitment programs. As such, for the purpose of developing MOBILE6 basic emission rates for 1981 through 1993 vehicles, a "high emitter adjustment factor" was added to voluntary recruitment data to account the potential bias in recruitment.[6] Since the ARB surveillance program is also a recruitment-based program, a similar methodology was applied for Tier 1 and later vehicles

In addition to a high-emitter correction factor, a second adjustment was required to "remove" the impact of California's I/M program, which he vehicles included in the ARB sample were subjected to. This was necessary in order to develop basic emission factors which reflected no I/M program.

Both the high-emitter and "no I/M" adjustments are relevant at this stage of the calculation because they only affected the weighting of high and normal emitters - in other words, they were used to increase only the *number* of high emitters estimated in the fleet. As discussed in Section 2 (and shown in Equations (1) through(4)), the high/normal weighting factor is a function of normal and high emitter emission levels and their combined average in-use emission level. Emissions for normal and high emitters as computed in Equations (5) and (6) were not affected by these adjustments. The high-emitter and "no I/M" adjustments were instead applied directly to the in-use average emission levels; based on normal and high emitter emissions computed from Equations (5) and (6), the high emitter fractions were then derived using Equations (1) through (4). This had the effect of increasing the weighting of high emitters in the fleet relative to the pre-adjustment level. This methodology is detailed in the following steps:

(1) The unadjusted average in-use NOx emission level as a function of mileage was computed from the ARB dataset. This FTP NOx emission average was obtained by linear regression

[5] "Recruitment-based" in-use emission testing programs are defined here as programs in which vehicles are procured for testing from the general population in exchange for money and/or other incentives. Participants are initially contacted through mail or phone solicitation based on registration mailing lists, and participation is strictly voluntary.

[6] Enns, P. et al, "Determination of Running Emissions as a Function of Mileage for 1981 through 1993 Model Year Light-Duty Cars and Trucks", MOBILE6 Report No. M6.EXH.00. Referred to as "Tier 0 Running BER Report"

of the raw ARB data (all 186 vehicles) versus mileage. The intercept of the regression was set equal to the normal emitter intercept from Equation (5) (0.265 g/mi). The resulting regression equation is as shown:

NOx FTP (g/mi) = 0.265 + 0.031 * Odom   Eqn 7

(2) The second step was to generate an additive high emitter correction factor to account for the potential effects of recruitment bias on the ARB sample. The Tier 0 high emitter correction factor proposed for 1988 through 1993 PFI LDVs (obtained from comparison of IM240 data and data collected through voluntary recruitment programs)[7] was calculated in FTP space, and fit with a linear regression as a function of mileage. The Tier 0 adjustment was reduced by 25 percent to account for reductions in high emitter emissions expected between Tier 0 and Tier 1 vehicles, and to prevent unduly large high emitter fractions. The resulting high emitter correction factor is shown in Equation 8. It is in units of FTP grams per mile, and is a function of mileage. This adjustment is added to the average NOx emission function from Step 1 above.

HECF = 0.00795 * Odom   Eqn 8a

Where:

HECF is the high emitter correction factor.
Odom is the mileage, in ten thousands

At zero miles, this adjustment adds 3 percent to the average in-use emission level; at 100,000 miles it adds 14 percent. These percent increases are comparable to those calculated from the data for 1988 through 1993 PFI LDVs with and without a high-emitter adjustment.

(3) The third step was to generate a multiplicative "No I/M" correction factor to account for the I/M effect in the ARB sample. Most vehicles under California's Smog Check II program will undergo a basic idle I/M test,[8] adjustment factors by vehicle age were developed by using MOBILE5 program with and without an idle I/M program (using by-model year output for a run in the year 2010). At each vehicle age, a correction factor based on the ratio of the "without I/M" and "with I/M" runs was computed; these factors were regressed with mileage to create a correction factor as a function of mileage. The resulting equations are shown as follows:

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[7]Tier 0 Running BER Report

[8]"Smog Check Program Fact Sheet: A History of Inspection and Maintenance Programs in California", Smog Check Web Site (http://smogcheck.ca.gov), July 1997

NOIMC	=	1.057 - 0.0038 * Odom	Eqn 8b
(NOIMC	$\geq$	1.00)	
NOIMC	=	1.00	Eqn 8c
(NOIMC	<	1.00)	
NOIMC	=	0.00	Eqn 8d
(Odom =	0)		

(4) The corrected in-use average NOx FTP results (C_NOXFTP) were obtained by applying the high emitter and No I/M correction factors from Equations 8a through 8d to the raw NOx FTP value from Equation 7, as shown in Equation 9.

C_NOXFTP = (NOx FTP + HECF) * NOIMC   Eqn 9

(5) The fraction of high emitters in the fleet under NO I/M and NO OBD conditions (labeled $High_{BASE}$) is calculated by inserting the value of C_NOXFTP, Norm_ave, and High_ave (from Equations (5) and (6)) into Equation (3). Mathematically, this is shown in Equation 10.

$High_{BASE}$ = (C_NOXFTP - Norm_ave) / (High_ave - Norm_ave)   Eqn 10

The resulting high emitter fractions for the No OBD/No IM case for ages one through 25 are shown in Appendix A, Table A-1 (mileage levels as a function of age are shown in Appendix A, Table A-3).

The average in-use FTP-based NOx emission level for Tier 1 LDVs can be calculated at any vehicle age using Equation (2), based on the terms "High_ave" (Equation 6), "Norm_ave" (Equation 5), and "Highs" (Equation 10). According to Equation (4), "Normals" is simply 1 - Highs.

3.2 All Other Standard Levels and Vehicle Classes

NOx BERs for No OBD / No IM conditions are required for LDVs under post-Tier 1 standards, and all Tier 1 and later LDTs (LDT1 through 4). At the time of this analysis, EPA was not aware of any dataset which provided an adequate sample of in-use data for these combinations of vehicles class and standard level. BERs for these classes were derived from the Tier 1 LDV BERs developed above, using a set of specific assumptions about how average emissions for normal and high emitters, and high emitter fraction, would apply across standard level and class.

3.2.1 Normal Emitters

It was assumed that for post-Tier 1 LDVs and Tier and later LDTs, normal emitter NOx emissions will on average maintain the same performance relative to the applicable 50,000 mile standard as Tier 1 LDVs. Thus, normal emitter BERs for all post-Tier 1 LDVs and Tier 1 and later LDTs were developed by calculating the ratio of the applicable standard level ("std") to the Tier 1 LDV standard, and applying this ratio to the Tier 1 BER (zero-mile level and deterioration rate), as follows:

Norm_ave ZML(std) = Norm_ave ZML(tier1ldv) * (Cert Std(std) / Cert Std(tier1 ldv)) Eqn 11a

Norm_ave DR(std) = Norm_ave DR(tier1 ldv) * (Cert Std(std) / Cert Std(tier1 ldv)) Eqn 11b

For example, normal-emitting LDV LEV BERs were generated by multiplying the normal-emitting Tier 1 ZML and DR from Equation (5) by 0.5 (0.2 g/mi divided by 0.4 g/mi, the 50,000 miles standards).

The rationale behind this approach is that basic emission levels for properly operating vehicles should receive the full benefit of reduced standards, including lower deterioration rates for lower standard levels. This approach presumes that normal emitters for all standards and vehicle classes will on average achieve the same compliance margin ("headroom") with the 50,000 mile certification standard as the normal emitters observed in the ARB data. With regards to trucks, this approach acknowledges that LDT emission performance relative to the standard is expected to be similar to LDVs because of increased similarities in a) emission control technology, b) manufacturer design practices, and c) driving and usage patterns.

3.2.2 High Emitters

High Emitter 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 BERs is that, as emission standards are lowered (or "raised" for truck BERs), emission levels for high emitters will not be changed in proportion to the standard change. Because emission control equipment on these vehicles will be degraded or completely malfunctioning, high emitter emissions would be less dependent of certification standard level. To illustrate, compliance with LEV NOx standards are expected to result from improved catalyst performance rather than reductions in engine-out emissions; as such, engine-out emissions from LEVs and Tier 1s are likely more similar than the difference in standards, on a relative basis. A degraded catalyst on a LEV would thus result in emissions more similar to a Tier 1 with a comparably degraded catalyst.

BERs for high emitters were developed for post-Tier 1 LDVs and Tier 1 and later LDTs by taking the average of the Tier 1 LDV high emitter NOx BER (1.278 g/mi) and the BER that would result if the ratio of 50,000 mile standards were applied to the Tier 1 BER, according to Equation 12:

High_ave(std) = average[High_ave(tier1ldv) * (Cert Std(std) / Cert Std(tier1 ldv), High_ave(tier1ldv)] Eqn 12

The result of this average is a high emitter BER which is 50 percent proportional to the change in standard, reflecting that malfunctioning vehicles will derive some benefit on average from lower emission standards, but not the full benefit as afforded to normal emitters. High emitter emissions are therefore tied closely to the Tier 1 LDV high emitter level, and the change in high emitter emissions is “muted” relative to changes in standard.

Normal and high emitter BERs for LDVs and LDTs complying with Tier 1, LEV and ULEV standards are presented in Appendix B.

3.2.3 High Emitter Fractions

The rate at which vehicles become high emitters under the No OBD / No IM scenario was assumed constant for all vehicles and standard classes. Thus, the age-based high emitter fractions developed in Equation 10 and presented in Appendix A were applied to Tier 1 and later BERs for all classes. The rate of emission control technology malfunction was assumed the same between LDVs and LDTs, given that their emission technology and usage patterns are increasingly similar. Reduced certification standards are also 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 Tier 1 and later standards, and b) many cases of emission control degradation and/or malfunction are owner-induced, and hence outside the manufacturer’s liability for in-use emission performance. It should be noted that the high-emitter fractions in Appendix A are shown to vary by class, due to differences in accumulated mileage at a given age. At the same mileage, the high emitter fractions are the same across all classes.

The No OBD / NO I/M average in-use NOx emission rate for *vehicle/standard = (V,S)* can be calculated at any vehicle age using Equation (2), based on a) the Tier 1 LDV “High_ave” and “Norm_ave” terms from Equations (5) and (6) adjusted as described above based on the *(V,S)* standard level, and b) the base (No OBD / No IM) high emitter fractions from Appendix A, Table A-1.

4 NMHC/NMOG BERs and Emitter Fractions: No IM/No OBD Case

The development of NMHC/NMOG BERs shared many of the methodological assumptions outlined for NOx in Section 3. As with NOx, NMHC BERs for Tier 1 and NMOG BERs for LEV and later LDVs and LDTs were developed off of “base” LDV BERs; the primary difference between the methodologies for the two pollutants was the source of the base data. At the time of this analysis, sufficient in-use data on vehicles complying with EPA’s Tier1 NMHC standards (for any vehicle class) were not available. The ARB surveillance dataset used for the NOx analysis included 58 LDVs certified to a 0.25 g/mi 50,000 mile NMHC standard, the same as Federal Tier 1. However, these vehicles did not start entering the market until 1993; hence, most of the vehicles were of age three years or less at the time of testing (the average mileage of this sample was roughly 38,000 miles, versus 58,000 for the 0.40 NOx sample). As such, these data were judged to be inadequate for assessing overall in-use emission performance of Tier 1 LDVs.

Tier 1 and later HC BERs were instead based on proposed MOBILE6 BERs for model year 1988 through 1993 Tier 0 LDVs with ported fuel injection (PFI). These BERs were developed based on several thousand vehicles tested by auto manufacturers, EPA, and through I/M programs. The Tier 0 emission rates were considered a good starting point for developing Tier 1 and later BERs because emission control technology used on later Tier 0 vehicles (e.g., 3-way catalysts and ported fuel injection) are generally similar to those used on Tier 1 and later vehicles. A comprehensive treatment of Tier 0 BERs and the datasets used to derive them are contained in the reports under Reference 7, and thus are not presented here. However, for this analysis a simplifying step was performed to generate a linear form of Tier 0 normal-emitter BERs, since as proposed for MOBILE6 these are expressed as nonlinear functions. The resulting normal and high emitting Tier 0 BERs (expressed as Total Hydrocarbon, or THC) used as a basis for Tier 1 and later BERs are shown in Equations (13) and (14).

$$\text{Norm\_Ave(g/mi)} = 0.16 + 0.0186 * \text{odom} \qquad \text{Eqn 13}$$

$$\text{High\_Ave(g/mi)} = 2.076 \qquad \text{Eqn 14}$$

"odom" represents mileage in units of ten thousand miles.

Using these values for normal and high emitters as a starting point, normal and high emitter NMHC/NMOG BERs for all Tier 1 and later LDVs and LDTs were developed using the identical methodology as for NOx (described in Sections 3.2.1 and 3.2.2) based on the ratio of the applicable 50,000 mile standard level to the Tier 0 level of 0.41 g/mi. Since Tier 1 standards are expressed as NMHC and LEV and later standards are expressed as NMOG, the shift from THC to these pollutants is accounted for in the standard ratios.

The high emitter fractions developed for 1988 through 1993 Tier 0 PFI LDVs were used as the No OBD/No IM emitter fractions for all Tier 1 and later vehicles, because of the expected similarity in vehicle malfunction rates across standard level and vehicle class as discussed in Section 3.2.3. These fractions are show in Appendix A, Table A-2.

The No OBD / No IM average in-use NMHC/NMOG emission rate for *vehicle/standard = (V,S)* can be calculated at any vehicle age using Equation (2), based on a) the Tier 0 "High_ave" and "Norm_ave" terms from Equations (13) and (14) adjusted based on the *(V,S)* standard level, and b) the base (No OBD / No IM) high emitter fractions from Appendix A, Table A-2.

5 Effects of OBD and OBD-based I/M for NOx and HC

Separate BERs were developed for all standard and vehicle classes to account for the effects of OBD and OBD-based I/M programs. The methodology used to account for these programs were identical for NOx and HC, 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.

5.1 OBD Effectiveness

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 determine in-use patterns for these parameters. Thus, estimates were developed for the projected likelihood of malfunction detection, owner response and repair level; stakeholder comments on these estimates are encouraged. These are presented in Sections 5.1.1 through 5.1.3 for both the OBD-only and OBD/IM cases.

5.1.1 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 high emitters. Because high emitters are defined independently for HC and NOx, this response rate is assumed to apply equally to both pollutants. The remaining 15 percent of fleet 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.

5.1.2 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 , 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 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.

5.1.3 Repair Level

Implementation of OBD requires a third emitter category - "repaired" emitters. Repaired emitters are assumed to have constant emissions at the after-repaired emission level, although a subset of these vehicles "migrate" back to the high emitter category. The emission level after an OBD-induced repair is assumed to be 1.5 times the applicable 50,000 mile certification standard. For Tier 1 LDVs and LDTs, this repair level is the required threshold for illuminating the MIL up to 50,000 miles; the repair level is lower than the OBD threshold above 50,000 miles, since the 1.5 times the standard criteria applies to the full useful life standard above this mileage. For LEVs, OBD detection is required at 1.75 times the full useful life standard at all mileages; hence, the estimated repair level is below the OBD threshold at all mileages. Because repaired emitters are assumed not to deteriorate for the remainder of their life (unless they migrate into the high emitter category), the benefit of repair increases over the life of the vehicle. Repaired emitter emissions levels are generally lower than average normal emitter emissions at higher mileages. The repaired emitter "BERs" are presented across standard and vehicle class in Appendix B.

5.2 High Emitter Fractions for OBD and OBD-based I/M

Equations 15 through 17 were used to calculate the high emitter growth rate under the OBD and OBD-based I/M scenarios ($High_{OBD}$). 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 5.1. 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'.

$$Nonhigh(i) = 1.0 - High_{BASE}(i) \qquad \text{Eqn 15}$$

$$Delta\_High(i) = High_{BASE}(i) - High_{BASE}(i-1) \qquad \text{Eqn 16}$$

$$\text{Growth\_High}(i) = \text{Delta\_High} / \text{Nonhigh}(i) \qquad \text{Eqn 17}$$

$$\text{High}_{OBD}(i) = \text{High}_{OBD}(i-1) + [(1-\text{OBD})*\text{MIL}*\text{Growth\_High}(i)*(1-\text{High}_{OBD}(i-1))] + [(1-\text{MIL})*\text{Growth\_High}(i)*(1-\text{High}_{OBD}(i-1)] \qquad \text{Eqn 18}$$

Where:

$\text{High}_{OBD}(0)$	=	0.0
MIL	=	0.85
Nonhigh	=	the fraction of normal and repaired vehicles
Growth_High	=	the growth rate of high emitters (or, the rate at which “nonhighs” migrate into the high emitter category)

‘OBD’ is the OBD response rate; 0.90 for OBD-based I/M, and 0.90/0.10/0.0 for mileage bins (0 - 36K), (36K - 80K), and (80K+).

An elaboration on Equations 15 through 18 is as follows: for a given vehicle age, the fraction of high emitters is a) the number of highs from the year before, plus b) the number of MIL-on highs added in that year due to OBD nonresponse (a function of “nonresponse” rate, MIL-on rate, and the high emitter growth rate applied to the available pool of normal and repaired vehicles), plus c) 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 nonhighs - i.e., the available pool of vehicles which can become high emitters.

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}, from Equation (10)) and the fraction of high emitters with OBD and/or I/M from Equation 18. In equation form,

$$\text{Repaired}(i) = \text{High}_{BASE}(i) - \text{High}_{OBD}(i) \qquad \text{Eqn 19}$$

The rate of normal emitters remains constant between the No OBD / No I/M, OBD-only and OBD/IM case; only the number of high emitters decrease, directly replaced by repaired emitters. The emitter fractions for normal, high and repaired emitters for the OBD Only and OBD/IM cases are shown in Appendix A (Tables A-1 and A-2) for NOx and HC, by vehicle class.

5.3 BER Calculation for OBD and OBD-based I/M

Calculation of average in-use FTP-based NOx and NMHC emission rates at a given vehicle age for the OBD-Only and OBD/IM cases are similar to the methodology for No OBD / No I/M vehicles (Equation (2)); the primary differences are a) use of High_{OBD} rather than High_{BASE} emitter fractions, and b) addition of a term to account for repaired emitters. As mentioned, the normal and high emissions rates are unchanged from the No OBD / No I/M case. This computation is as follows:

$$AVE = High_{OBD} * High\_ave + Normal*Norm\_ave + Repaired * Rep\_ave \qquad \text{Eqn 20}$$

Rep_ave is 1.5 times the applicable 50,000 mile certification standard.

5.4 Results

FTP-based BERs for the No OBD / No IM, OBD only and OBD/IM cases for Tier 1, LEV and ULEV standards across all vehicle classes are shown in Appendix C for NOx and Appendix D for NMHC/NMOG. The full range of standards that will be handled by MOBILE6 (primarily TLEV) are not shown, but can be derived using the methodology outlined in this paper. These charts highlight a key outcome of the "50 percent proportional" treatment of high emitters discussed in Section 3.2.2. BERs for standards *below* the base standard (Tier 1 LDV) are higher relative to the applicable standard, but have more OBD and/or I/M benefit (on a percent basis) relative to Tier 1 LDVs. BERs for standards *above* the base standard (Tier 1 LDV) are lower relative to the applicable standard, but have less OBD and/or I/M benefit (on a percent basis) relative to Tier 1 LDVs. This is rooted in the assumption that average high emitter emissions are not reduced in proportion to the standard change, thus increasing the disparity between normal and high emitter for lower standards. As standards are lowered, high emitters will have a more pronounced effect on average in-use emissions, and repair of these high emitters will result in greater relative emission benefit.

6 NOx and HC BERs for Exhaust-Only I/M

Since an OBD check is currently an unproven concept in an I/M program, some I/M credit scenario must be developed for those areas that use traditional exhaust I/M test procedures. This scenario will be likely used frequently until calendar year 2001. By that time, it is assumed that I/M test procedures utilizing OBD checks on vehicles equipped with OBD will be in place.

6.1 No OBD with Exhaust I/M

The "No OBD / Exhaust I/M" emission levels for this scenario are calculated using the methodology described in draft MOBILE6 document M6.IM.001 ("MOBILE6 Inspection / Maintenance Benefits Methodology for 1981 through 1993 Model Year Light Vehicles"). This methodology utilizes I/M exhaust test identification rates and after repair effectiveness levels based on data collected from the Arizona I/M program. The "No I/M" and the "With Exhaust I/M" emission rates are used to calculate the I/M emission level and I/M credits for situations where exhaust-only I/M tests are being performed on Tier 1 vehicles without OBD. The only vehicles which will fall in this category are the 1994 and 1995 model years certified to Tier1 standards. In this case, the structure of the I/M credits is identical to the Tier 0 I/M credits with the exception that the Norm_ave, High_ave, and fraction of highs in the fleet ($High_{BASE}$) are different from analogous

Tier 0 parameters. Equation 21 defines this case mathematically.

$$AVE = Norm\_ave*(1-High_{BASE}) + High\_ave*High_{BASE}*(1-IDR) + High_{BASE}*IDR*W*High\_ave*RW + Norm\_ave*R*High_{BASE}*IDR*FIX + High\_ave*High_{BASE}*IDR*NC \quad \text{Eqn 21}$$

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 waived. It is shown as a fraction of the high emitter level.

(see report M6.IM.001 for a full explanation of these terms).

6.2 OBD and Exhaust I/M

In this scenario, the vehicles in the fleet are OBD compliant, but the state continues to conduct an exhaust I/M test; this is most likely scenario prior to calendar year 2001. For this scenario, the same I/M equations and assumptions used to model the 1981-93 Tier 0 vehicles are used. The primary difference is the fraction of high emitters is reduced somewhat due to the effects of OBD program (i.e., $High_{OBD}$ is substituted for a higher rate of high emitters used in Tier0.

$$AVE = Norm\_ave*(1-High_{BASE}) + Rep\_ave*(Repaired) + High\_ave*High_{OBD}*(1-IDR) + High_{OBD}*IDR*W*High\_ave*RW + Norm\_ave*R*High_{OBD}*IDR*FIX + High\_ave*High_{OBD}*IDR*NC \quad \text{Eqn 22}$$

7 Derivation of Running and Start BERs for NOx and HC

MOBILE6 requires a split between running and start emissions; because Tier 1 and later BERs were developed on an FTP-basis, factors will be required allow derivation of running and start BERs from FTP-based BERs.   Running fractions were first derived by applying the methodology outlined in MOBILE6 report number M6.STE.002 (“The Determination of Hot Running Emissions From FTP Bag Emissions”) to separate Tier 1 and LEV datasets. For Tier 1s, a sample of 31 LDVs and LDTs vehicles tested by auto manufacturers as part of the SFTP rulemaking were used.[9] For LEVs, a sample of 34 LDVs and LDTs tested by auto manufacturers, CRC and API and used for the development of proposed MOBILE6 fuel sulfur effects.[10]   Based on an analysis of separate factors for LDVs and LDTs, a single factor which applied to both LDVs and LDTs was judged to be adequate. For NOx, the resulting Tier 1 and LEV factors were found to be identical; the following equation was therefore used to generate running BERs for all standards and classes:

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[9]SFTP Data CD

[10]Rao, V., “Fuel Sulfur Effects On Exhaust Emissions", EPA Draft MOBILE6 Report No. M6.FUL.001

Running NOx BER (g/mi) = 0.60 * FTP NOx BER Eqn 23

For NMHC/NMOG, separate factors were developed for Tier 1s and LEVs:

Tier 1 Running NMHC BER (g/mi) = 0.16 * FTP NMHC BER Eqn 24
LEV Running NMOG BER (g/mi) = 0.30 * FTP NMOG BER Eqn 25

In MOBILE6, start BERs are related to FTP and Running BERs as shown in Equation (26):[11]

FTP BER = (Running BER*7.5 +Start BER*0.43+Start BER*0.57*0.16) / 7.5 Eqn 26

Where:

Running BERs	=	the results of Equations (23) through (25)
7.5	=	total miles of the LA4
0.43/0.57	=	Bag 1/Bag 3 weighting across total FTP
0.16	=	the ratio of Bag 3 emissions to Bag 1 emissions, based on HC 1988-1993 PFI BERs proposed for MOBILE6 (applied to both HC and NOx)[12]

Using this equation and the running and FTP BERs developed above, start factors were derived according to Equation (27):

Tier 1/LEV Start NOx BERs (grams) = 5.75 * FTP BER Eqn 27
Tier 1 Start NMHC BER (grams) = 12.1 * FTP BER Eqn 27
LEV Start NMOG BER (grams) = 10.1 * FTP BER Eqn 27

These factors were applied equally to each emitter class: normal, high and repaired. The resulting BERs for Tier 1, LEV and ULEV across all classes are shown in Appendix B.

[11]Glover, E., and Carey, P., "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-1993 Model Year Light-Duty Vehicles", MOBILE6 report number M6.STE.003

[12]This factor varies somewhat across pollutant and vehicle grouping, but was held constant for the derivation of start factors.

APPENDIX A:
a) Emitter Fractions: No OBD/No IM, OBD Only, OBD/IM Cases
b) Vehicle Mileage As A Function of Age

Table A-1: NOx Emitter Fractions																		
Age (Years)	LDV						LDT1/2						LDT3/4					
	All	Base	OBD Only		OBD/IM		All	Base	OBD Only		OBD/IM		All	Base	OBD Only		OBD/IM	
	Normal	High	High	Repair	High	Repair	Normal	High	High	Repair	High	Repair	Normal	High	High	Repair	High	Repair
0	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
1	0.946	0.054	0.013	0.041	0.013	0.041	0.934	0.066	0.015	0.050	0.015	0.050	0.929	0.071	0.017	0.054	0.017	0.054
2	0.909	0.091	0.022	0.069	0.022	0.069	0.885	0.115	0.063	0.052	0.028	0.088	0.876	0.124	0.069	0.056	0.030	0.094
3	0.872	0.128	0.058	0.070	0.031	0.097	0.837	0.163	0.110	0.054	0.040	0.123	0.824	0.176	0.119	0.057	0.043	0.133
4	0.836	0.164	0.094	0.070	0.041	0.123	0.790	0.210	0.156	0.055	0.053	0.158	0.773	0.227	0.168	0.058	0.057	0.169
5	0.801	0.199	0.128	0.071	0.050	0.149	0.744	0.256	0.204	0.052	0.066	0.190	0.725	0.275	0.221	0.055	0.071	0.204
6	0.767	0.233	0.162	0.071	0.059	0.174	0.700	0.300	0.251	0.049	0.079	0.221	0.678	0.322	0.271	0.051	0.085	0.237
7	0.734	0.266	0.199	0.068	0.069	0.197	0.657	0.343	0.297	0.046	0.092	0.251	0.633	0.367	0.319	0.048	0.099	0.267
8	0.701	0.299	0.234	0.065	0.079	0.220	0.617	0.383	0.341	0.043	0.105	0.278	0.590	0.410	0.366	0.044	0.114	0.296
9	0.670	0.330	0.268	0.062	0.088	0.242	0.577	0.423	0.383	0.040	0.118	0.304	0.548	0.452	0.411	0.041	0.129	0.323
10	0.639	0.361	0.302	0.059	0.098	0.263	0.540	0.460	0.423	0.037	0.132	0.328	0.505	0.495	0.457	0.038	0.145	0.351
11	0.609	0.391	0.334	0.056	0.108	0.283	0.500	0.500	0.465	0.035	0.147	0.353	0.461	0.539	0.504	0.035	0.162	0.377
12	0.580	0.420	0.366	0.054	0.118	0.302	0.462	0.538	0.506	0.032	0.162	0.376	0.419	0.581	0.549	0.032	0.180	0.401
13	0.552	0.448	0.397	0.051	0.128	0.320	0.426	0.574	0.545	0.030	0.178	0.397	0.378	0.622	0.593	0.028	0.199	0.423
14	0.524	0.476	0.428	0.048	0.139	0.338	0.391	0.609	0.581	0.027	0.193	0.415	0.339	0.661	0.635	0.026	0.218	0.442
15	0.494	0.506	0.461	0.046	0.150	0.356	0.359	0.641	0.616	0.025	0.209	0.432	0.302	0.698	0.676	0.023	0.239	0.460
16	0.465	0.535	0.492	0.043	0.162	0.373	0.328	0.672	0.649	0.023	0.225	0.447	0.265	0.735	0.715	0.020	0.260	0.474
17	0.436	0.564	0.523	0.040	0.174	0.390	0.300	0.700	0.679	0.021	0.241	0.459	0.231	0.769	0.752	0.017	0.283	0.486
18	0.409	0.591	0.553	0.038	0.186	0.405	0.273	0.727	0.708	0.019	0.256	0.470	0.197	0.803	0.788	0.015	0.307	0.495
19	0.382	0.618	0.583	0.035	0.199	0.419	0.249	0.751	0.734	0.017	0.272	0.479	0.165	0.835	0.822	0.012	0.334	0.501
20	0.356	0.644	0.611	0.033	0.212	0.433	0.227	0.773	0.758	0.016	0.287	0.486	0.135	0.865	0.855	0.010	0.362	0.503
21	0.330	0.670	0.639	0.031	0.225	0.445	0.206	0.794	0.779	0.014	0.302	0.491	0.106	0.894	0.886	0.008	0.394	0.499
22	0.305	0.695	0.666	0.028	0.239	0.456	0.188	0.812	0.799	0.013	0.317	0.495	0.079	0.921	0.916	0.006	0.431	0.490
23	0.281	0.719	0.693	0.026	0.253	0.466	0.171	0.829	0.817	0.012	0.331	0.498	0.052	0.948	0.944	0.004	0.476	0.472
24	0.258	0.742	0.718	0.024	0.267	0.475	0.156	0.844	0.833	0.011	0.345	0.499	0.027	0.973	0.971	0.002	0.535	0.438
25	0.236	0.764	0.743	0.022	0.282	0.482	0.142	0.858	0.848	0.010	0.359	0.499	0.004	0.996	0.996	0.000	0.629	0.367

Table A-2: NMHC/NMOG Emitter Fractions

Age (Years)	LDV						LDT1/2						LDT3/4					
	All	Base	OBD Only		OBD/IM		All	Base	OBD Only		OBD/IM		All	Base	OBD Only		OBD/IM	
	Normal	High	High	Repair	High	Repair	Normal	High	High	Repair	High	Repair	Normal	High	High	Repair	High	Repair
0	0.982	0.018	0.004	0.014	0.004	0.014	0.982	0.018	0.004	0.014	0.004	0.014	0.982	0.018	0.004	0.014	0.004	0.014
1	0.975	0.025	0.006	0.019	0.006	0.019	0.969	0.031	0.007	0.023	0.007	0.023	0.967	0.033	0.008	0.025	0.008	0.025
2	0.958	0.042	0.010	0.032	0.010	0.032	0.942	0.058	0.033	0.025	0.014	0.044	0.936	0.064	0.037	0.027	0.015	0.049
3	0.934	0.066	0.033	0.033	0.016	0.050	0.910	0.090	0.063	0.027	0.022	0.068	0.902	0.098	0.069	0.029	0.024	0.074
4	0.910	0.090	0.056	0.035	0.022	0.068	0.879	0.121	0.092	0.029	0.029	0.091	0.869	0.131	0.100	0.031	0.032	0.099
5	0.887	0.113	0.077	0.036	0.028	0.086	0.850	0.150	0.123	0.028	0.037	0.113	0.837	0.163	0.133	0.030	0.040	0.122
6	0.865	0.135	0.099	0.037	0.033	0.102	0.821	0.179	0.152	0.027	0.045	0.134	0.807	0.193	0.165	0.029	0.049	0.145
7	0.843	0.157	0.121	0.036	0.039	0.118	0.794	0.206	0.180	0.026	0.052	0.154	0.778	0.222	0.195	0.028	0.057	0.165
8	0.822	0.178	0.143	0.035	0.045	0.133	0.767	0.233	0.207	0.025	0.060	0.173	0.750	0.250	0.223	0.027	0.064	0.185
9	0.801	0.199	0.164	0.034	0.050	0.148	0.743	0.257	0.233	0.024	0.067	0.191	0.724	0.276	0.250	0.026	0.072	0.204
10	0.782	0.218	0.185	0.033	0.056	0.163	0.719	0.281	0.257	0.024	0.074	0.207	0.699	0.301	0.276	0.025	0.080	0.221
11	0.763	0.237	0.205	0.032	0.061	0.176	0.697	0.303	0.280	0.023	0.080	0.223	0.675	0.325	0.301	0.024	0.087	0.238
12	0.744	0.256	0.224	0.032	0.066	0.189	0.676	0.324	0.302	0.022	0.087	0.237	0.653	0.347	0.324	0.023	0.094	0.253
13	0.727	0.273	0.242	0.031	0.072	0.202	0.656	0.344	0.322	0.021	0.093	0.251	0.631	0.369	0.346	0.022	0.101	0.267
14	0.710	0.290	0.260	0.030	0.077	0.214	0.638	0.362	0.341	0.021	0.099	0.263	0.611	0.389	0.367	0.022	0.108	0.281
15	0.693	0.307	0.277	0.029	0.082	0.225	0.621	0.379	0.358	0.020	0.105	0.274	0.592	0.408	0.387	0.021	0.115	0.294
16	0.677	0.323	0.294	0.029	0.087	0.236	0.606	0.394	0.375	0.020	0.110	0.284	0.574	0.426	0.406	0.020	0.121	0.305
17	0.662	0.338	0.310	0.028	0.092	0.246	0.591	0.409	0.390	0.019	0.115	0.294	0.557	0.443	0.423	0.020	0.127	0.316
18	0.647	0.353	0.325	0.028	0.096	0.256	0.578	0.422	0.403	0.019	0.120	0.302	0.541	0.459	0.440	0.019	0.133	0.326
19	0.633	0.367	0.340	0.027	0.101	0.266	0.566	0.434	0.416	0.019	0.124	0.310	0.526	0.474	0.456	0.019	0.139	0.336
20	0.620	0.380	0.354	0.026	0.106	0.275	0.555	0.445	0.427	0.018	0.128	0.317	0.511	0.489	0.471	0.018	0.144	0.345
21	0.606	0.394	0.368	0.026	0.110	0.284	0.545	0.455	0.437	0.018	0.132	0.323	0.498	0.502	0.485	0.018	0.149	0.353
22	0.594	0.406	0.381	0.025	0.114	0.292	0.536	0.464	0.446	0.018	0.135	0.329	0.485	0.515	0.498	0.017	0.155	0.360
23	0.582	0.418	0.393	0.025	0.118	0.300	0.528	0.472	0.455	0.017	0.138	0.334	0.473	0.527	0.510	0.017	0.159	0.367
24	0.570	0.430	0.405	0.024	0.123	0.307	0.521	0.479	0.462	0.017	0.141	0.338	0.462	0.538	0.522	0.016	0.164	0.374
25	0.559	0.441	0.417	0.024	0.127	0.314	0.515	0.485	0.469	0.017	0.143	0.342	0.452	0.548	0.532	0.016	0.168	0.380

Table A-3: Draft MOBILE6 Cumulative Mileages (10,000 miles)							
Age (Years)	**LDV**	**LDT1/2**	**LDT3/4**	**Age (Years)**	**LDV**	**LDT1/2**	**LDT3/4**
1	1.491	1.950	2.133	14	15.338	18.453	19.583
2	2.908	3.788	4.120	15	16.072	19.165	20.371
3	4.256	5.519	5.970	16	16.770	19.815	21.104
4	5.537	7.146	7.692	17	17.434	20.406	21.786
5	6.755	8.672	9.297	18	18.064	20.941	22.422
6	7.912	10.100	10.791	19	18.664	21.425	23.014
7	9.013	11.436	12.183	20	19.234	21.861	23.566
8	10.059	12.681	13.478	21	19.776	22.252	24.079
9	11.054	13.839	14.685	22	20.291	22.602	24.557
10	12.000	14.914	15.809	23	20.781	22.914	25.003
11	12.899	15.910	16.856	24	21.247	23.191	25.418
12	13.753	16.829	17.830	25	21.690	23.438	25.804
13	14.566	17.676	18.738				

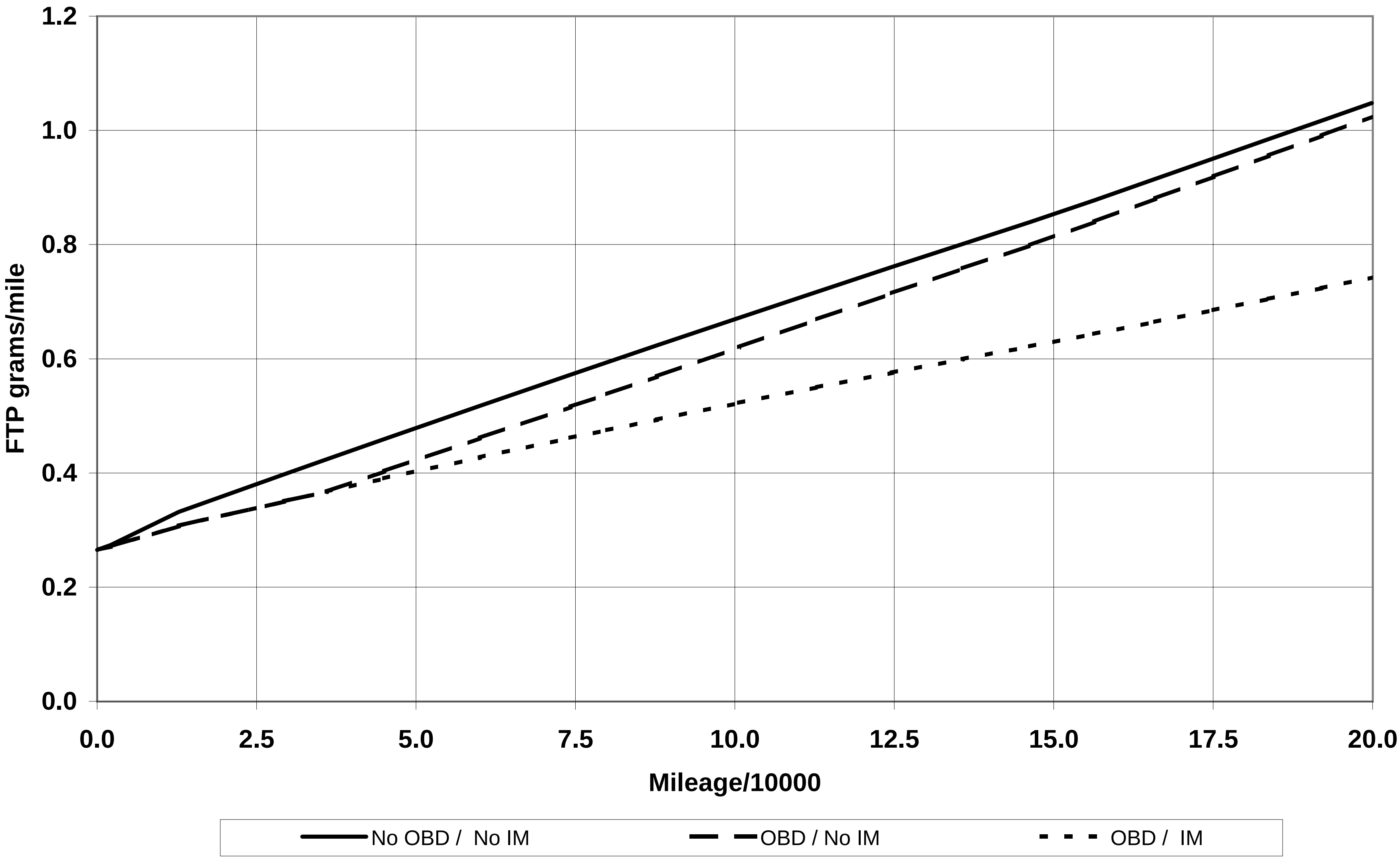
APPENDIX B:
TIER 1, LEV and ULEV BERs By Emitter Category

Table B-1: NOx 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	**Tier 1**	0.4	FTP	0.265	0.0147	1.28	0.600
			Running	0.159	0.0088	0.77	0.360
			Start (grams)	1.524	0.0845	7.35	3.450
	LEV/ULEV	0.2	FTP	0.133	0.0074	0.96	0.300
			Running	0.080	0.0044	0.58	0.180
			Start (grams)	0.765	0.0426	5.51	1.725
LDT2/3	**Tier 1**	0.7	FTP	0.464	0.0257	1.76	1.050
			Running	0.278	0.0154	1.05	0.630
			Start (grams)	2.668	0.1478	10.10	6.038
	LEV/ULEV	0.4	SAME AS LDV/T1 TIER 1				
LDT4	**Tier 1**	1.1	FTP	0.730	0.0404	2.40	1.650
			Running	0.438	0.0242	1.44	0.990
			Start (grams)	4.198	0.2323	13.78	9.488
	LEV/ULEV	0.6	FTP	0.398	0.0220	1.60	0.900
			Running	0.239	0.0132	0.96	0.540
			Start (grams)	2.289	0.1265	9.200	5.175

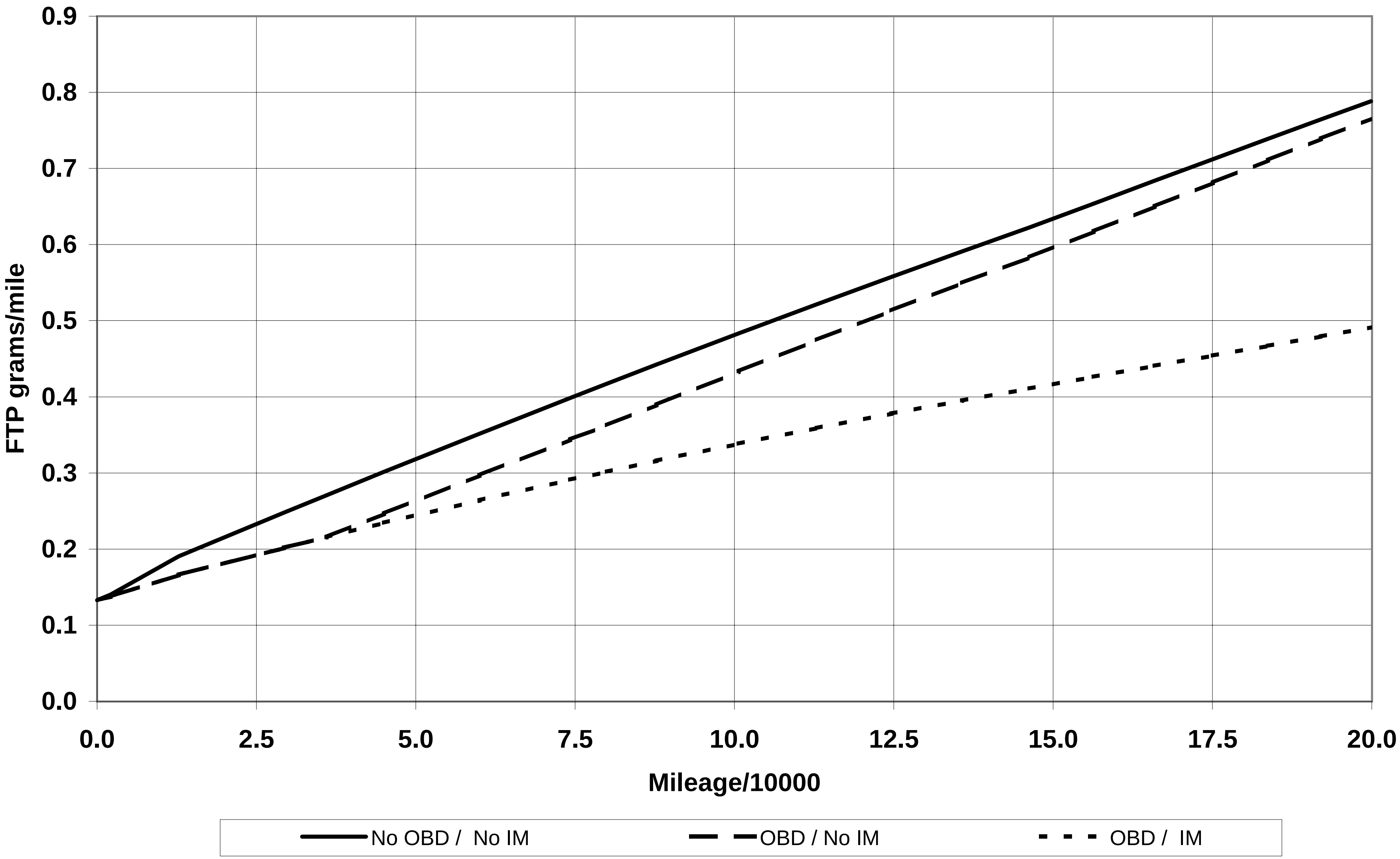
Table B-2: NMHC/NMOG Basic Emission Rates							
Vehicle Class	**Standard Class**	**50K Standard (g/mi)**	**Mode**	**"Normal" BER (g/mi)**		**"High" BER (g/mi)**	**"Repaired" BER (g/mi)**
				ZML	**DR**		
LDV/T1	**Tier 1**	0.25	FTP	0.098	0.0113	1.67	0.375
			Running	0.016	0.0018	0.27	0.060
			Start (grams)	1.183	0.1364	20.17	4.526
	LEV	0.075	FTP	0.029	0.0034	1.23	0.113
			Running	0.009	0.0010	0.37	0.034
			Start (grams)	0.293	0.0343	12.40	1.141
	ULEV	0.04	FTP	0.016	0.0018	1.14	0.060
			Running	0.005	0.0005	0.34	0.018
			Start (grams)	0.162	0.0182	11.51	0.606
LDT2	**Tier 1**	0.32	FTP	0.125	0.0145	1.85	0.480
			Running	0.020	0.0023	0.30	0.077
			Start (grams)	1.509	0.1750	22.31	5.794
	LEV	0.10	FTP	0.039	0.0045	1.29	0.150
			Running	0.012	0.0013	0.38	0.045
			Start (grams)	0.394	0.0455	13.04	1.515
	ULEV	0.05	FTP	0.020	0.0023	1.17	0.075
			Running	0.006	0.0007	0.35	0.022
			Start (grams)	0.197	0.0229	11.77	0.758
LDT3	**Tier 1**	0.32	FTP	0.125	0.0145	1.85	0.480
			Running	0.020	0.0023	0.30	0.077
			Start (grams)	1.509	0.1750	22.31	5.794
	LEV	0.16	FTP	0.063	0.0073	1.44	0.240
			Running	0.019	0.0022	0.43	0.072
			Start (grams)	0.636	0.0737	14.54	2.424
	ULEV	0.10	SAME AS LDT2 LEV				
LDT4	**Tier 1**	0.39	FTP	0.152	0.0177	2.03	0.585
			Running	0.024	0.0029	0.33	0.094
			Start (grams)	1.835	0.2136	24.44	7.061
	LEV	0.195	FTP	0.076	0.0088	1.53	0.293
			Running	0.023	0.0026	0.46	0.087
			Start (grams)	0.770	0.0889	15.45	2.954
	ULEV	0.117	FTP	0.046	0.0053	1.33	0.176
			Running	0.014	0.0016	0.40	0.052
			Start (grams)	0.462	0.0535	13.43	1.773

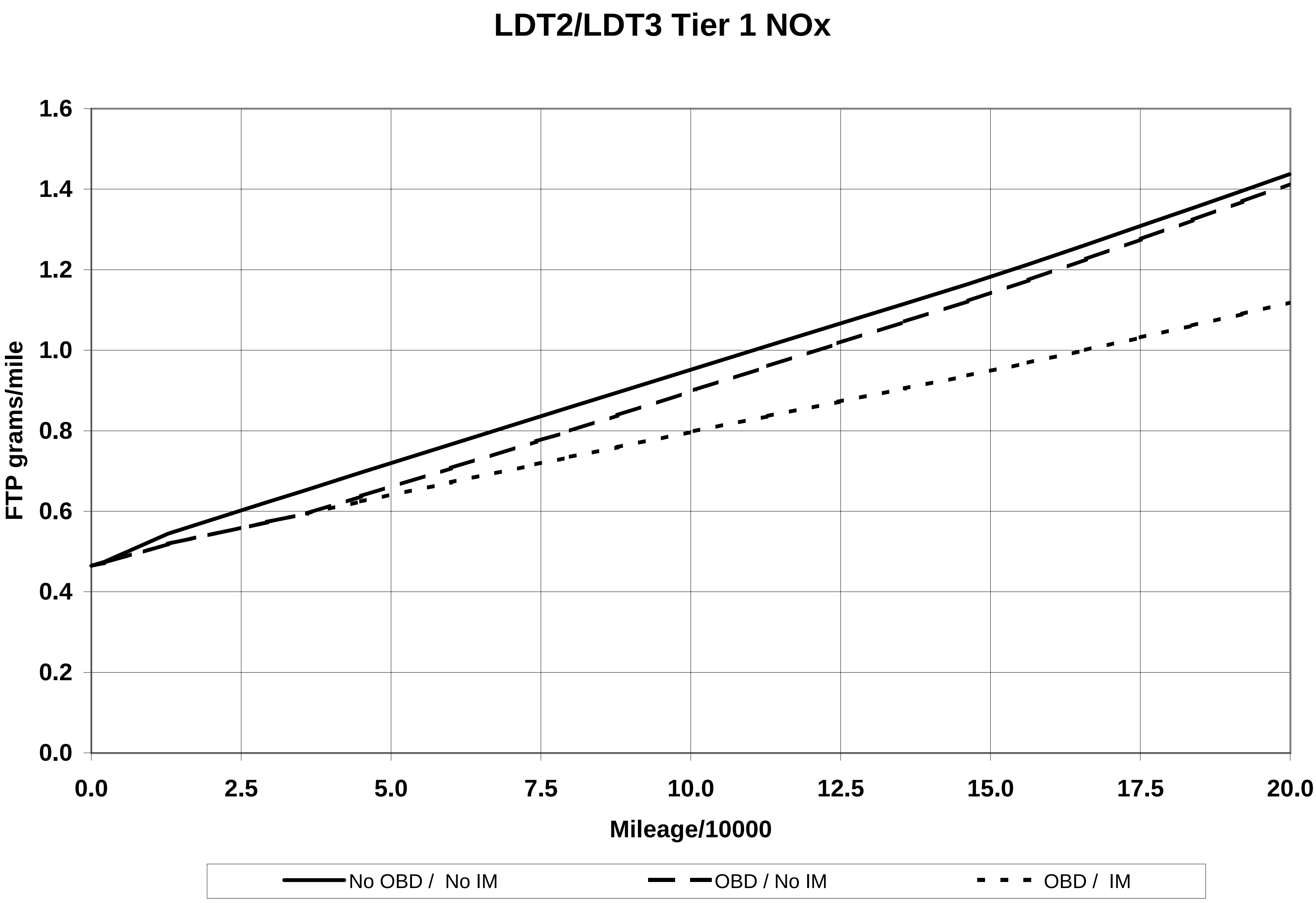
APPENDIX C:
NOx FTP-Based Composite BERs for Tier 1, LEV and ULEV

LDV/LDT1 Tier 1 NOx

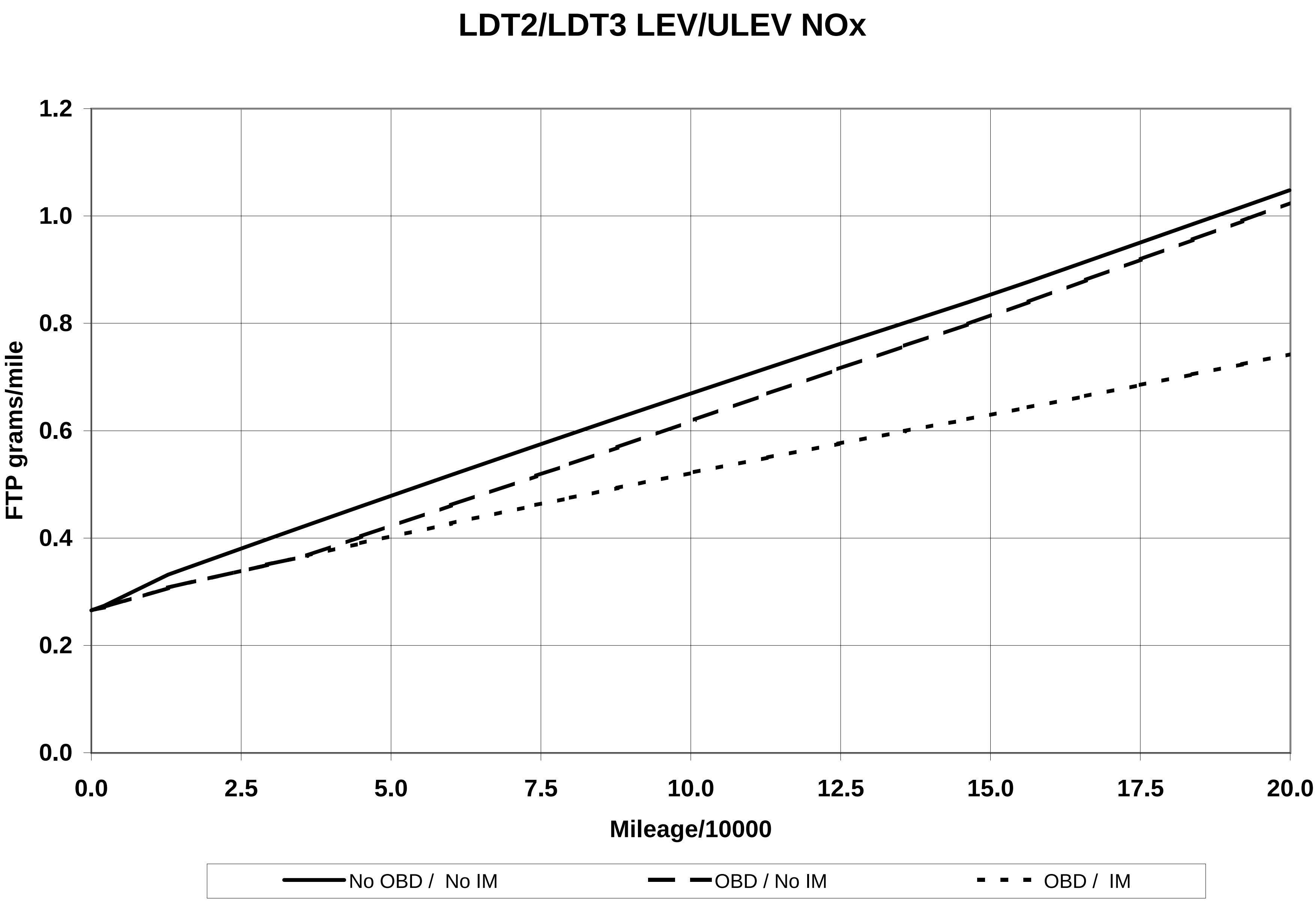


LDV/LDT1 LEV/ULEV NOx

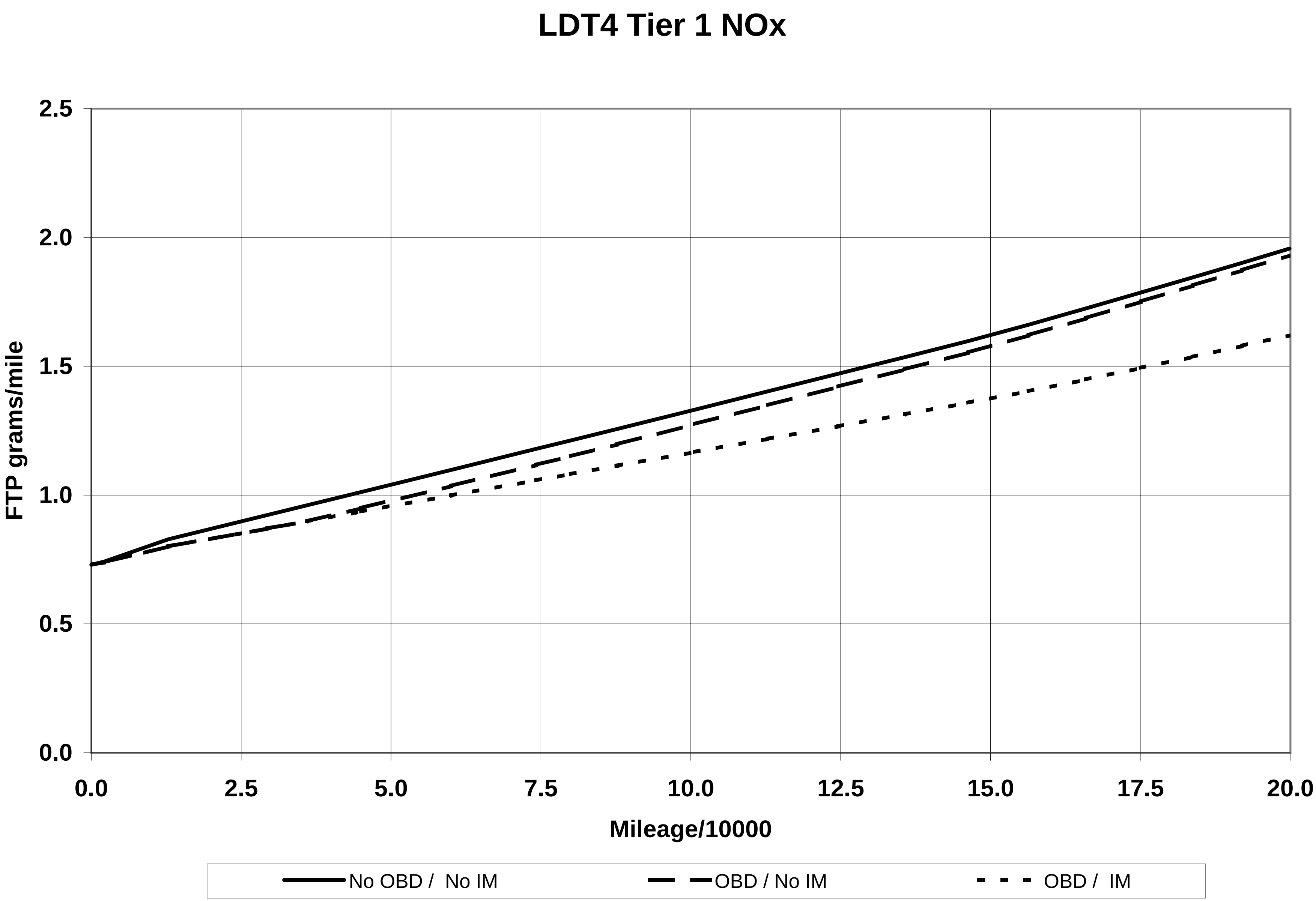


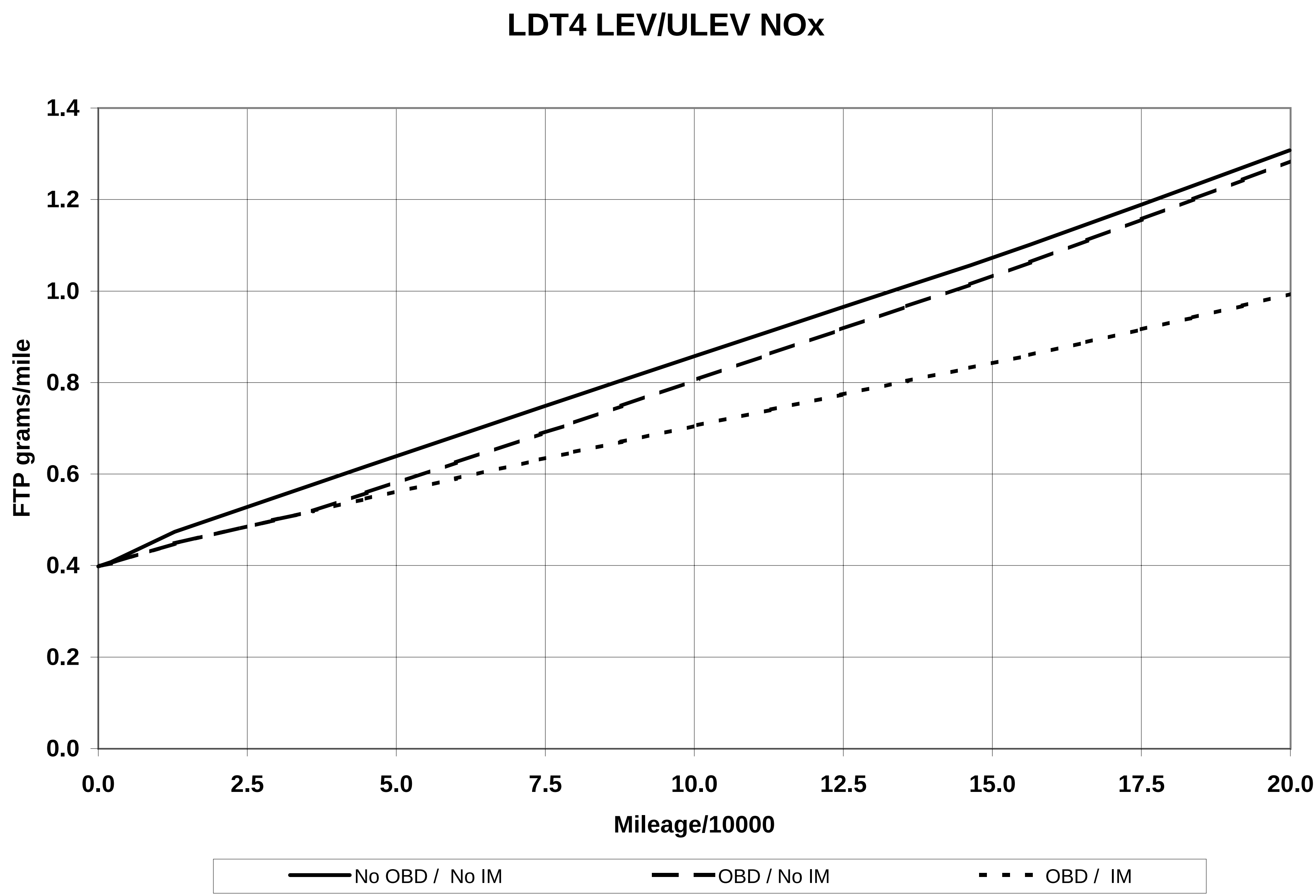


LDT2/LDT3 Tier 1 NOx
FTP grams/mile
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM

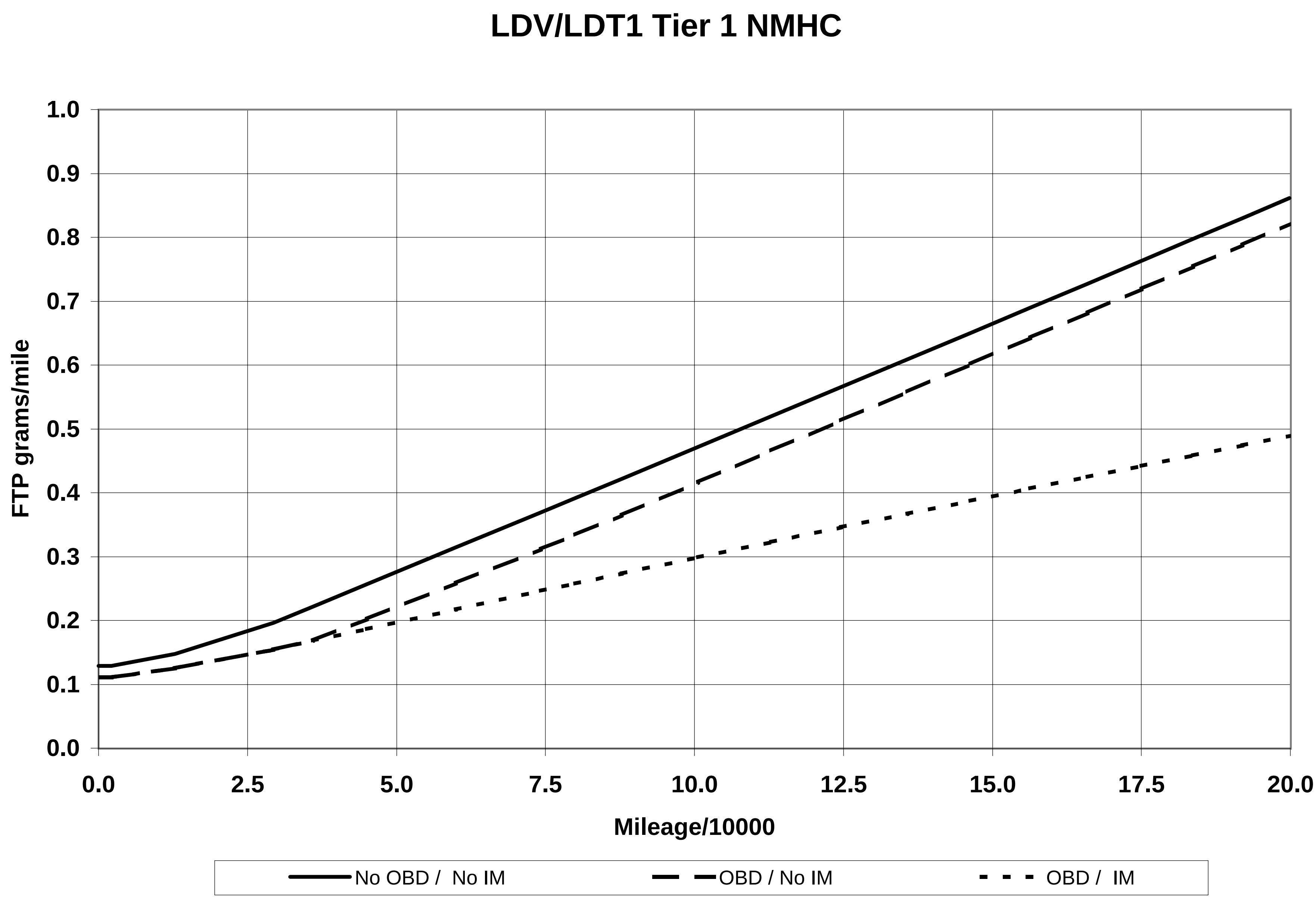


LDT2/LDT3 LEV/ULEV NOx
FTP grams/mile
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM

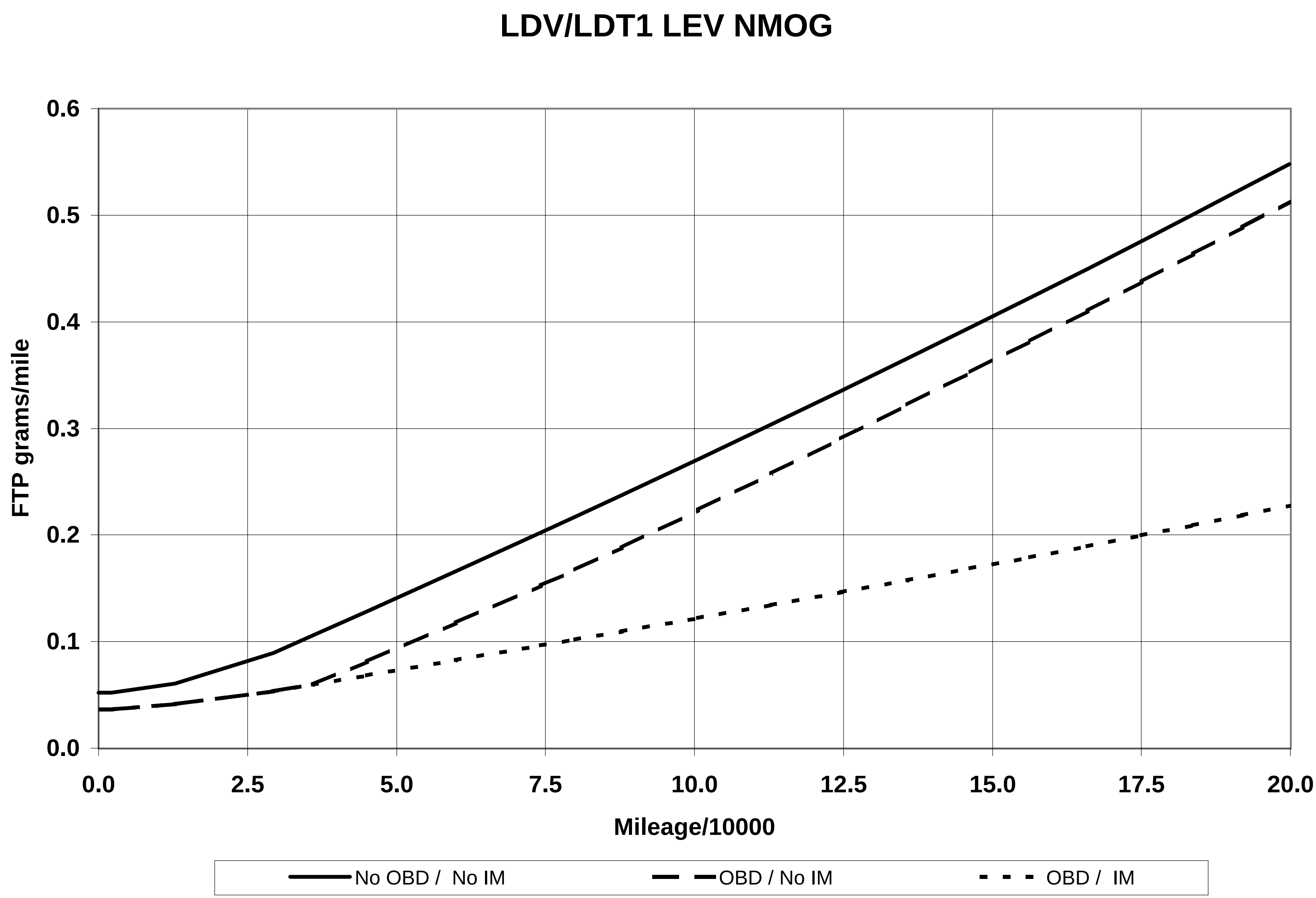

LDT4 Tier 1 NOx
FTP grams/mile
2.5
2.0
1.5
1.0
0.5
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM

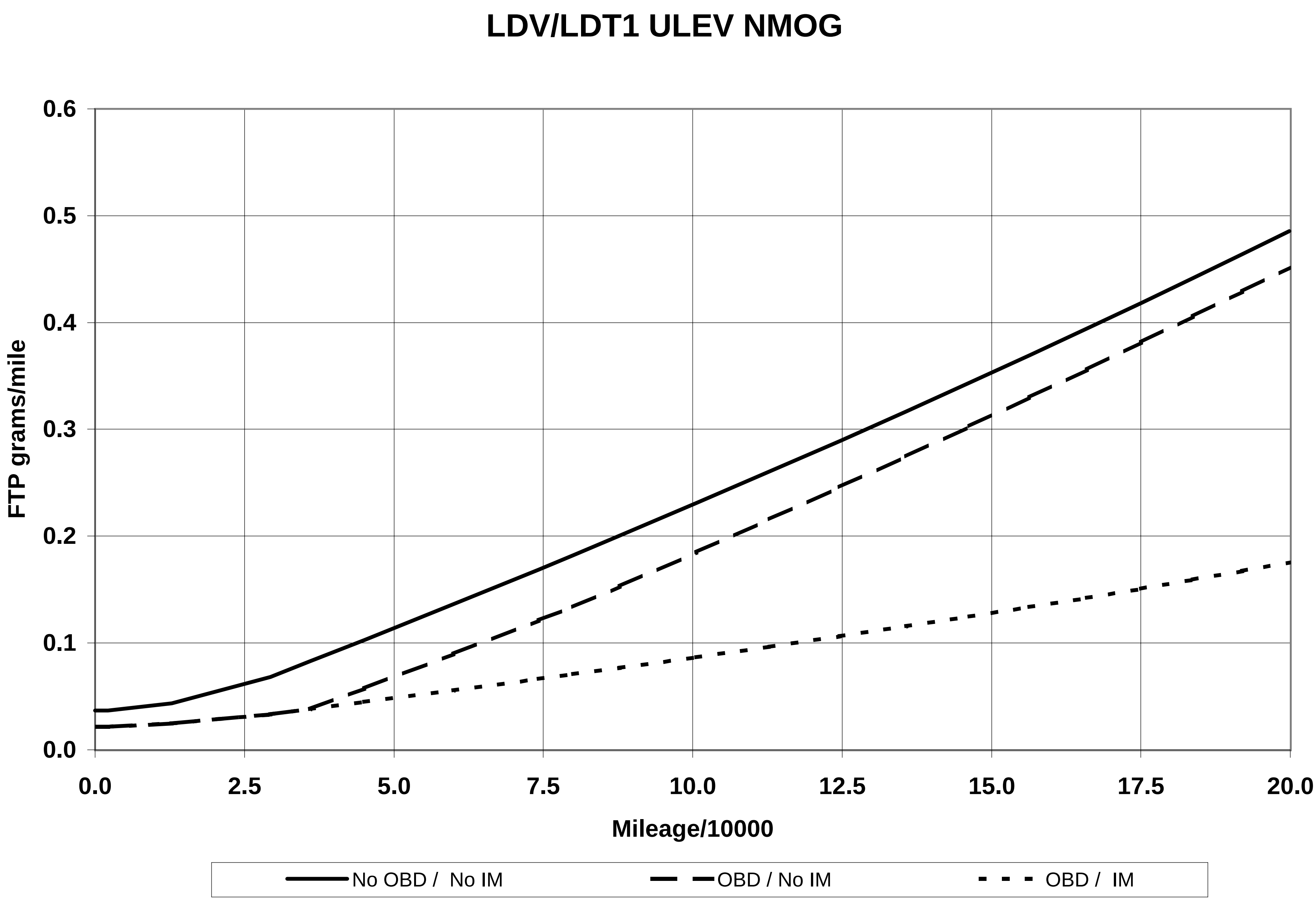

LDT4 LEV/ULEV NOx
FTP grams/mile
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM

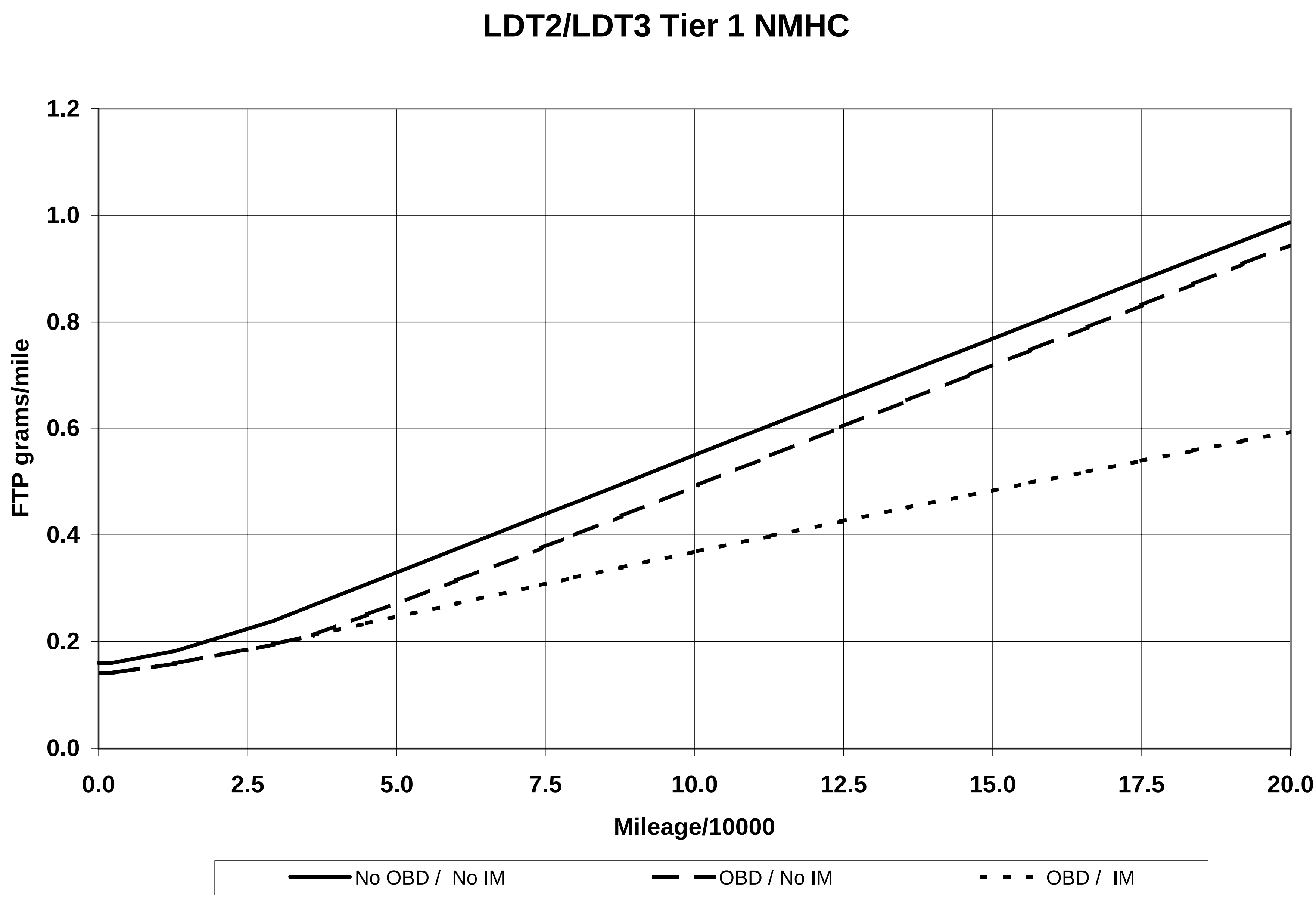
APPENDIX D (Corrected):
NMHC/NMOG FTP-Based Composite BERs for Tier 1, LEV and ULEV

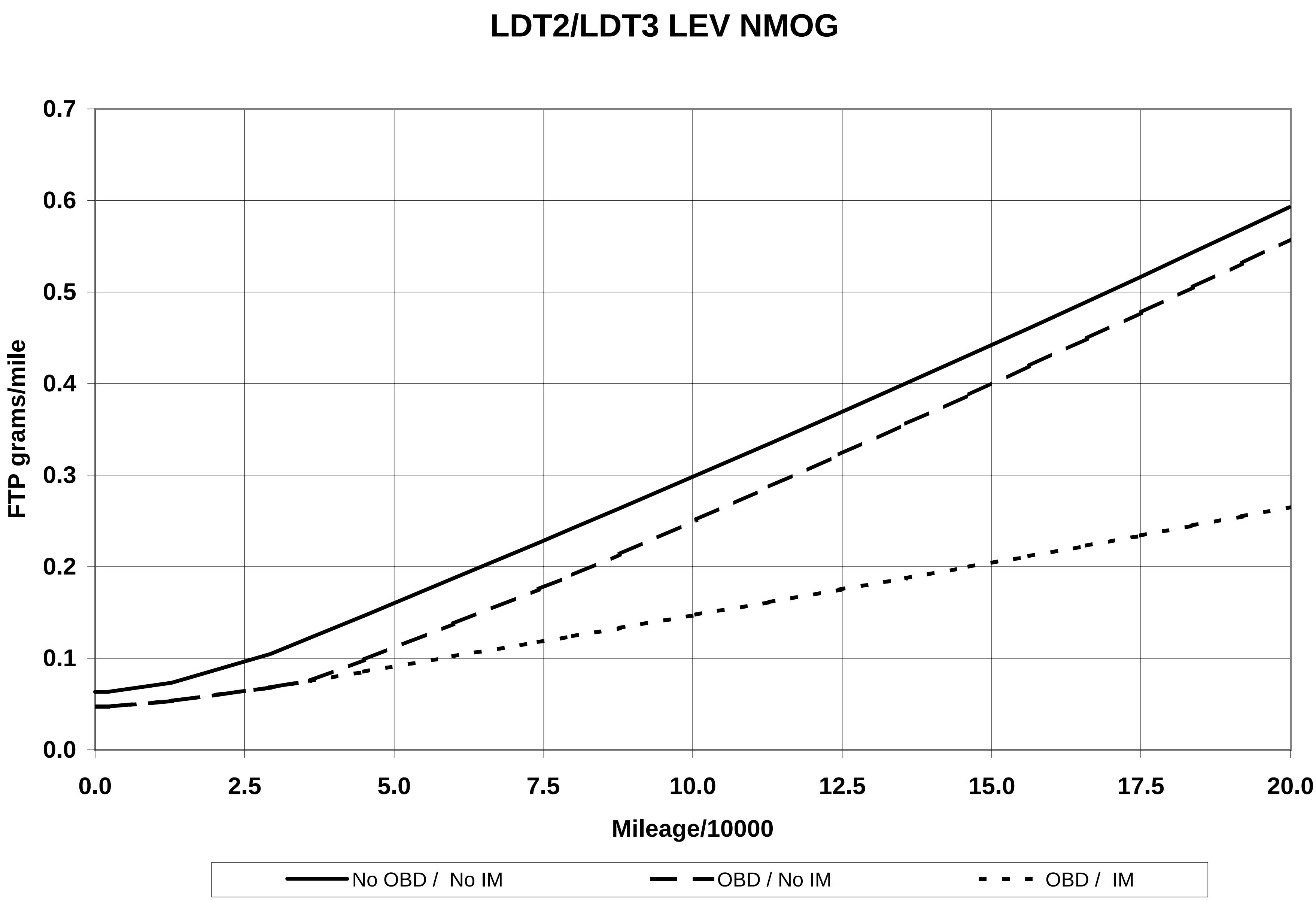


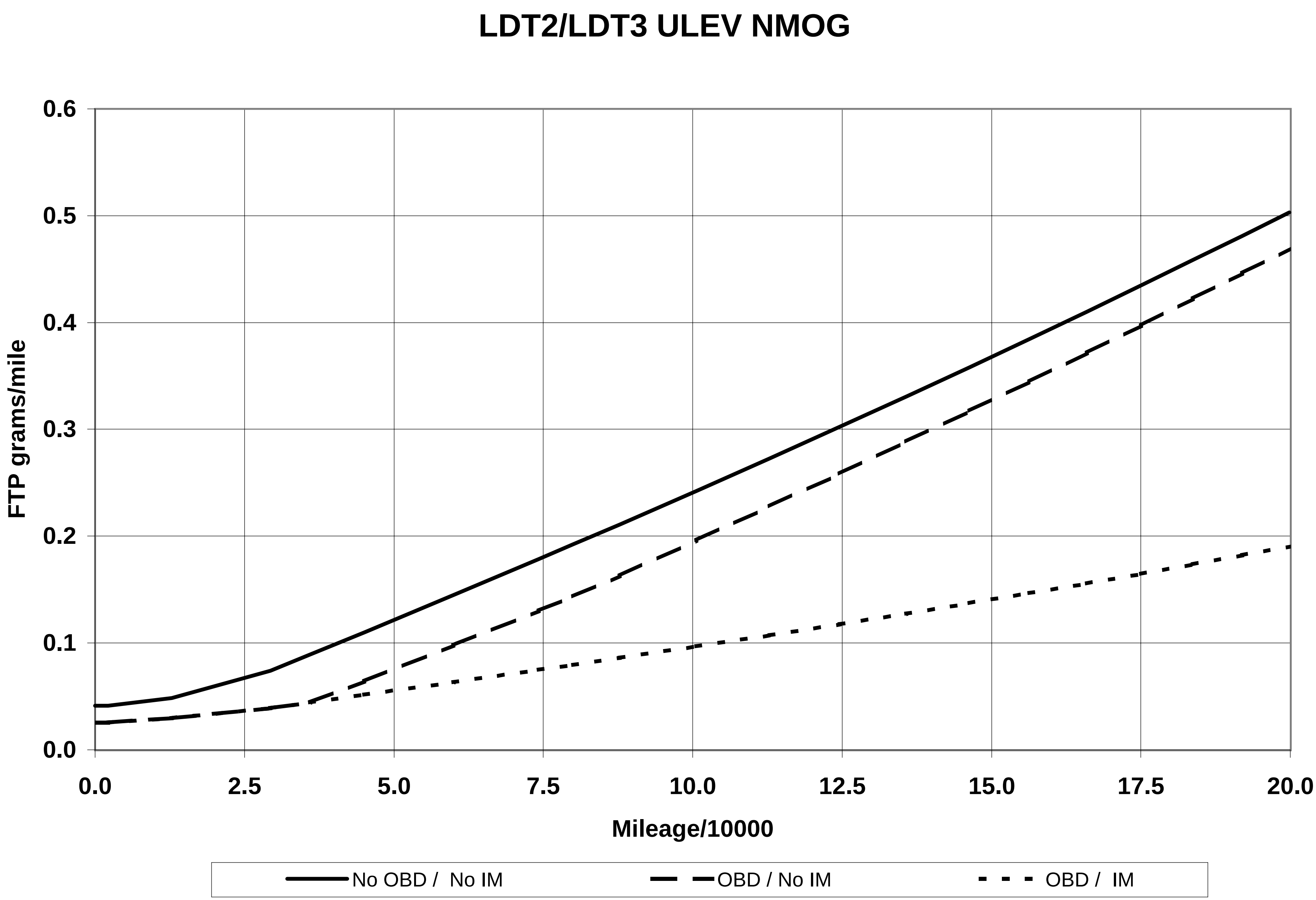
LDV/LDT1 Tier 1 NMHC
FTP grams/mile
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM


LDV/LDT1 LEV NMOG
FTP grams/mile
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM

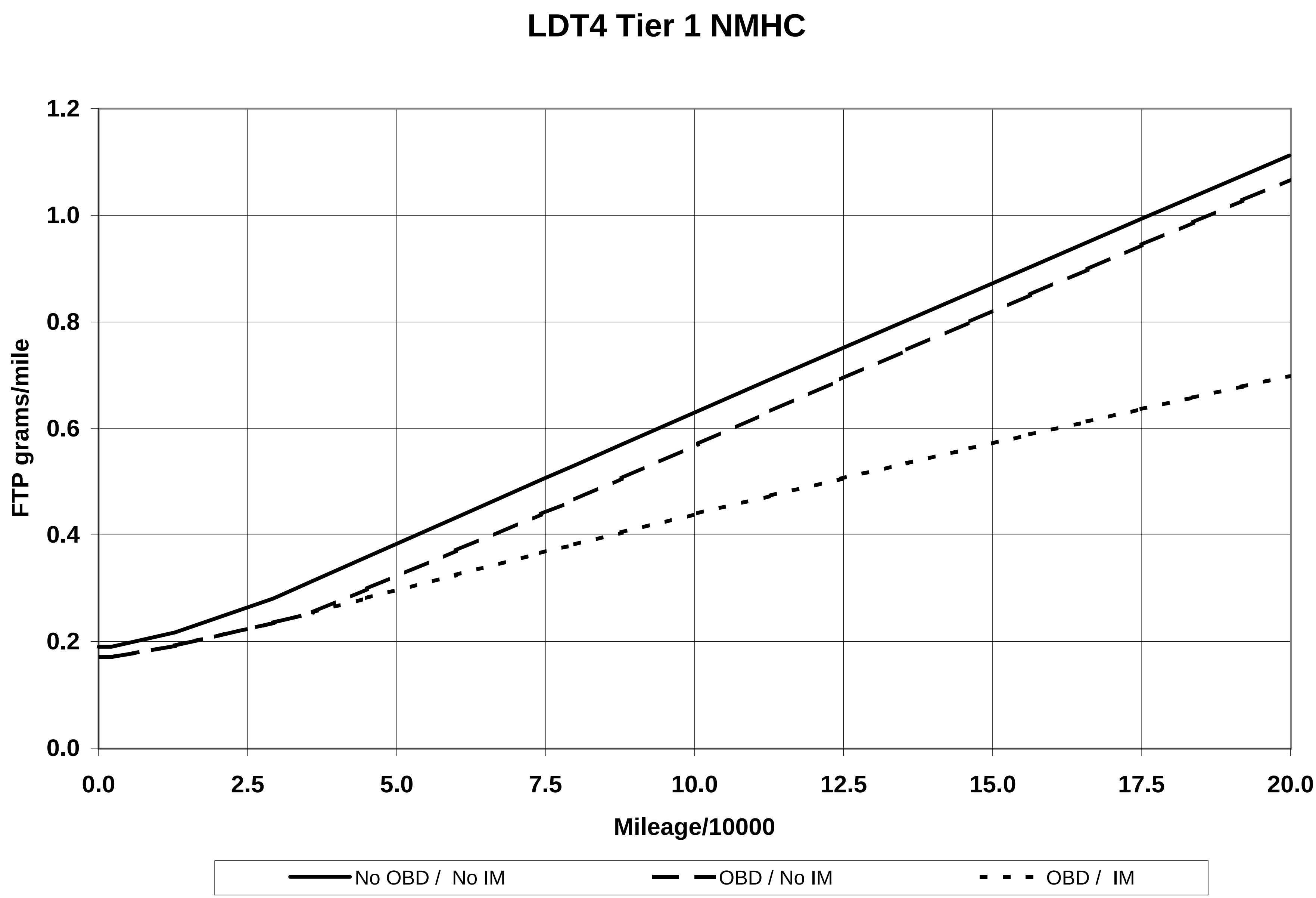

LDV/LDT1 ULEV NMOG
0.6
0.5
0.4
0.3
0.2
0.1
0.0
FTP grams/mile
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM

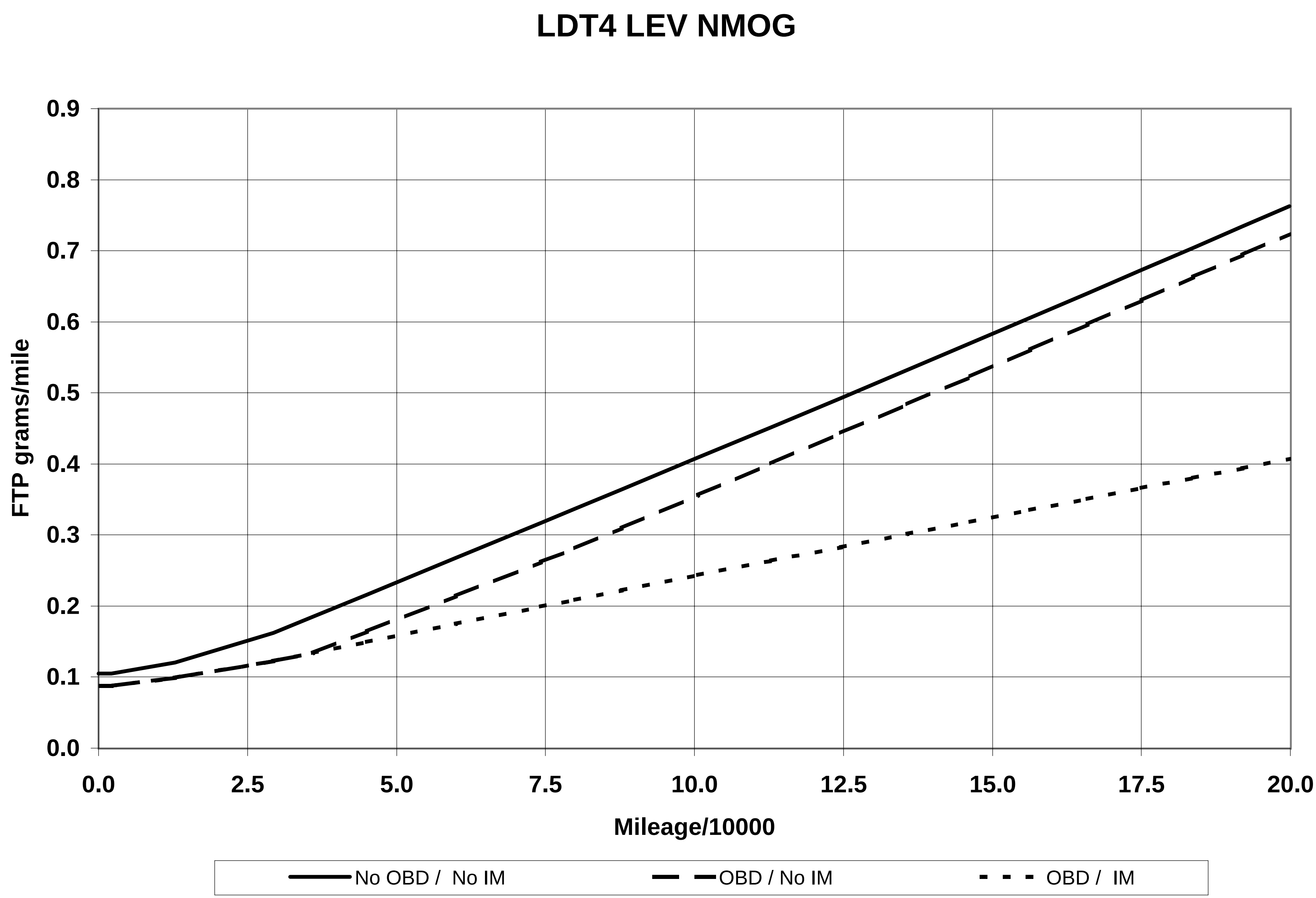

LDT2/LDT3 Tier 1 NMHC
1.2
1.0
0.8
0.6
0.4
0.2
0.0
FTP grams/mile
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM

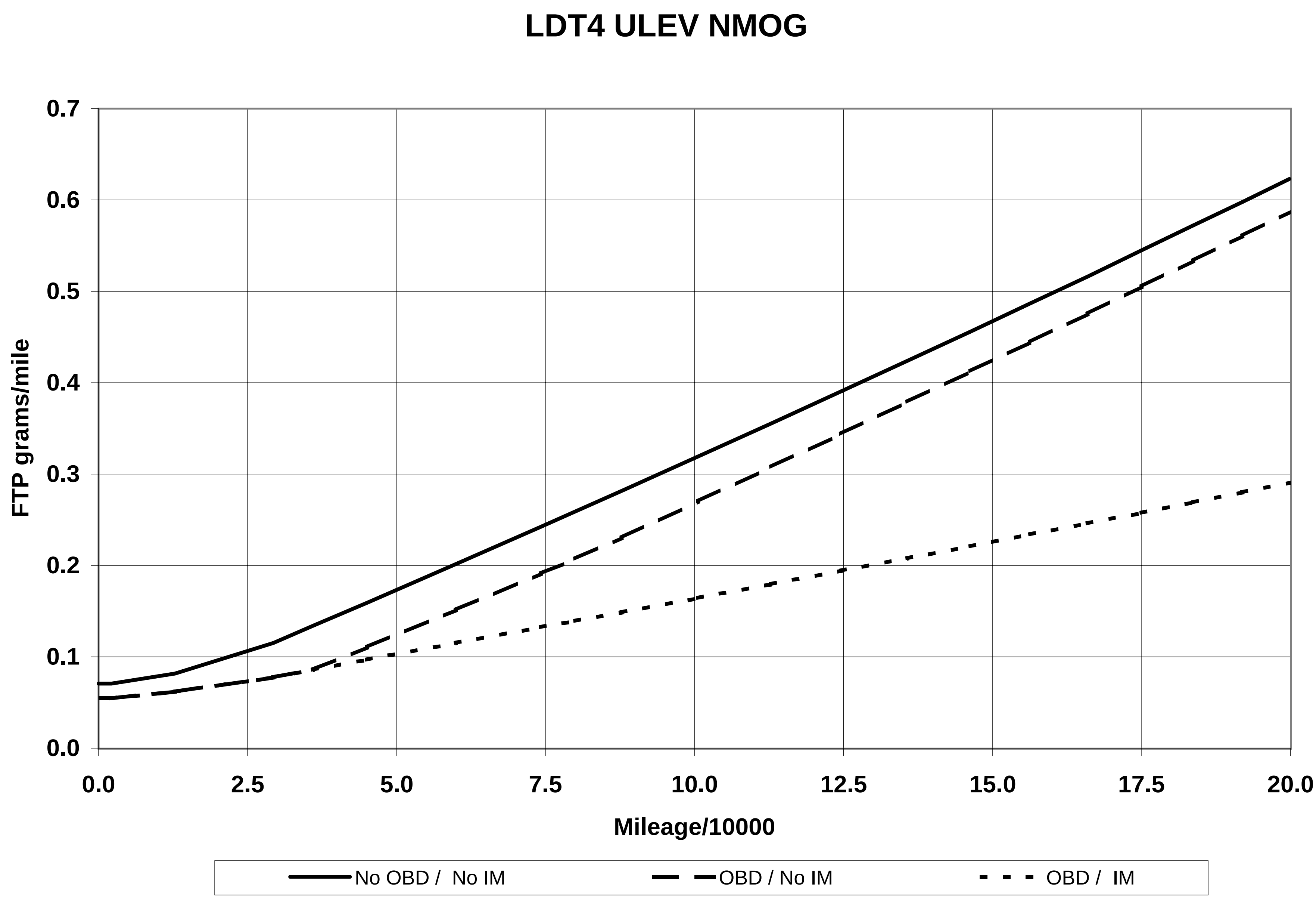

LDT2/LDT3 LEV NMOG
FTP grams/mile
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM



LDT2/LDT3 ULEV NMOG
FTP grams/mile
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM


LDT4 Tier 1 NMHC
FTP grams/mile
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM


LDT4 LEV NMOG
FTP grams/mile
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM


LDT4 ULEV NMOG
FTP grams/mile
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Mileage/10000
No OBD / No IM
OBD / No IM
OBD / IM