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Facility-Specific Speed Correction Factors

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1.0 ABSTRACT AND SUMMARY

Abstract

In MOBILE5, adjustments were made to the basic exhaust emission estimates to account for the effects of area wide average trip speeds using speed correction factors developed from a number of driving cycles with varying average speeds. For MOBILE6 we propose to adjust for differences in driving behavior versus roadway (facility) type and aggressive driving effects as well as average speed. EPA has developed new facility-specific inventory driving cycles, based on real-world driving studies, and tested vehicles using these cycles to address these purposes. This report describes the analysis of the new driving cycle data and presents the resulting speed correction factors proposed for use in MOBILE6.

Summary

Although the adjustments described in this document are called "speed" correction factors, the adjustments include all of the effects on emissions caused by differences in driving behavior, of which average speed is the most obvious and easiest to measure. The speed correction factors described in this document are proposed to be used in MOBILE6 to replace the speed correction factors now used in MOBILE5 for all light duty passenger cars and light duty trucks of all model years and technologies. The speed correction factors for heavy duty vehicles, diesel fueled vehicles and motorcycles from MOBILE5 would be retained for use in MOBILE6. This document also proposes a method for applying the new speed correction factors to future technology vehicles for which no data is yet available.

The new MOBILE6 speed correction factors specifically account for aggressive driving behavior not represented in older driving cycles. They also allow for evaluation of vehicle emissions by roadway type (facility) and by roadway segments (links). There are four roadway types modeled in MOBILE6:

- Freeways
- Arterial/Collectors
- Freeway Ramps
- Local Roadways

The proposed speed correction factors for freeways and arterial/collectors depend on both speed and basic emissions level of the vehicles. The correction factors for freeway ramps and local roadways depend only on emission level and cannot be adjusted for average speeds different than the national average. All speed corrections are based on new driving cycles designed to reflect real-world driving behavior, including the effects of aggressive driving not found in the standard vehicle FTP certification driving cycle (Urban Dynamometer Driving Cycle) and most older driving cycles used in emission testing.

Since the data for this analysis was collected using the new, realistic driving cycles, an emission impact of aggressive driving is included in the effect of the new speed correction factors on emissions. The introduction of the new Supplemental FTP (SFTP) into vehicle emission certification will require the reduction of the emission effects from aggressive driving for future vehicle certification. The impact of the SFTP on emissions will be addressed in a separate document.

Table 16 contains our proposed speed correction factors for freeways. Table 17 contains the proposed speed correction factors for arterial/collector roadways. For MOBILE6, the correction factor for Local Roadways and Freeway Ramps assume a national average speed and will not have an adjustment for local average speeds. The speed correction factors for freeways and arterial/collectors converge below 7.1 mph and at higher speeds, depending on the pollutant and emission level. At those points the freeway and arterial/collector speed correction factors become identical. The speed correction factors for speeds below 7.1 mph will remain the same as in MOBILE5, adjusted to account for the difference between the old and new speed correction factors where they intersect at 7.1 mph.

MOBILE5 did not model average speeds above 65 miles per hour. The new driving cycles also do not address average speeds above 65 miles per hour. EPA will consider whether sufficient information is available to model average speeds above 65 miles per hour in MOBILE6 and will present any proposals for these higher speeds in a separate document. As in MOBILE5, MOBILE6 will not explicitly address average speeds less than 2.5 miles per hour. Idle emissions will be assumed to be the same as the grams per hour emitted at an average speed of 2.5 miles per hour. This “idle” emission rate will be available as an output from MOBILE6.

Table 13 shows the coefficients used to calculate the freeway ramp and local roadway emissions from the basic emission rate. Table 14 and 15 show the additive offsets used to calculate the adjusted basic emission rate which is adjusted by the speed correction factors. Appendix B has an example calculation of the application of speed correction factors to the base emissions calculated by MOBILE6.

Figures 4a through 4c show the effect of emission level on the speed correction factors. Figures 5a through 5c compare the new MOBILE6 speed correction factors with selected MOBILE5 speed correction factors. Care should be taken in interpreting these figures, since there are many differences in how these factors are applied in MOBILE6 as compared to MOBILE5. These figures are discussed in more detail in Chapter 7.

The report is organized into sections which address various aspects of the analysis.

Chapter 2 gives a brief background of the need for new, facility based, speed correction factors.

Chapter 3 discusses the development of the facility cycles and the emission testing sample used in the development of the proposed speed correction factors.

Chapter 4 discusses the statistical analysis of the data sample.

Chapter 5 describes the approach developed to summarize the emissions data.

Chapter 6 uses the emission levels developed in Chapter 5 to develop the proposed speed correction factors for MOBILE6.

Chapter 7 compares the speed correction factors developed in Chapter 6 to the existing speed correction factors in MOBILE5.

Chapter 8 describes how to contact EPA in order to comment on this document.

EPA is requesting that MOBILE model stakeholders and other knowledgeable readers comment on the methodology and validity of the assumptions used to determine the speed correction factors proposed in this document.

2.0 BACKGROUND

EPA's highway vehicle emission factor model, MOBILE, is used for inventory modeling. MOBILE has historically been based on emission testing using the Federal Test Procedure (FTP) used to certify all light duty vehicles sold in the United States. The FTP uses a driving cycle (the Urban Dynamometer Driving Cycle, commonly referred to as the LA4) which simulates urban driving on a laboratory dynamometer. Correction factors for various conditions (e.g., average speed, temperature, fuels) are applied to emissions measured at the FTP "standard" conditions. The speed correction factors were based on test results for vehicles tested on both the LA4 (Urban Dynamometer Driving Cycle) and several other cycles, each having a different average speed. MOBILE6 will address two areas not adequately addressed in previous versions of the model. These are real world driving behavior and the expanded use of transportation models in determination of area-wide inventories.

"Real-World Driving"

The FTP has been used for emissions certification of all light duty vehicles sold in the United States. The Clean Air Act Amendments of 1990 mandated a closer look at "real-world driving" - that is, driving modes that are not covered by the FTP (and the Urban Dynamometer Driving Cycle). EPA organized the Federal Test Procedure Review Project to address this mandate. A new Supplemental FTP (SFTP) rule was finalized in October 1996. This rule specifies the addition of a new certification cycle with more aggressive driving and associated standards.

MOBILE6 must address both the emission impacts of more aggressive driving than is covered in the driving cycles that were used to develop MOBILE5 and the effects of the new SFTP standards on future model year vehicles. A special EPA emission testing project was initiated to address these concerns. The results of that testing are the basis for the analysis in this document.

Transportation Models

The current and older versions of the MOBILE model were developed to estimate area-wide emission inventories using trip-based emission estimates with trip-based adjustments for average speed. Vehicle trips are defined as all driving from key-on to key-off, including a variety of roadways and speeds.

Local officials have begun to integrate transportation models into their regional air quality planning processes. Most transportation models represent the roadway system as a network of "nodes," which are usually intersections, connected by "links," which represent a particular type of roadway or "facility." Transportation models generate link-specific estimates of speed and traffic volume. Transportation planners have begun using MOBILE to generate link-specific emissions estimates for planning purposes.

Recent data from instrumented vehicles and chase car studies show that some types of facility-specific driving contain more frequent and more extreme acceleration and deceleration than others[1]. Different facilities may have similar average speeds, but may differ significantly in the amount of steady cruise. These differences suggest that there is a need to quantify the emission differences (if any) between facilities in order to evaluate facility-specific speed related traffic control measures in inventory modeling.

For example, at an average speed of 25 mph, travel over surface streets is likely have a relatively low level of traffic congestion, but will include many stops for traffic signals. Travel on a freeway at 25 mph may indicate a high congestion level, but may include fewer stops. MOBILE5's trip based emission estimates do not differentiate between roadway types. If these models are used for each roadway separately, they would not account for any differences in emissions resulting from these differences in driving behavior.

Other Approaches

California is also updating it’s highway emission factor model. However, California has taken a different approach to modeling the effects of changes in vehicle speeds. Rather than attempt to discern what the driving behavior is for various facilities at various average speeds, they divide all observed driving into speed bins. Each bin contains “microtrips” with similar average speeds, regardless of the roadway type where the driving was observed. By weighting the results of the various speed bins, any areawide average speed can be modeled. Changes in driving behavior can be modeled by varying the distribution of speeds.

This approach requires areas to evaluate their fleet activity as "trips", where individual vehicles travel over a variety of roadway types at varying speeds to reach a destination. These trips are then used to develop a distribution of average trip speeds. Transportation models generally do not produce trip statistics and transportation planners would need to adjust their models to generate these distributions. Any changes in the roadway system resulting in changes in average speeds on specific roadways will require a change in the full areawide distribution of trip speeds. Evaluation of the emission impact of changes in the specific roadways will require new estimates of the areawide emission levels.

One important advantage of California's approach is the need for fewer driving cycles. Given limited testing budgets, this allows more vehicles to be tested over each cycle, thus increasing the statistical confidence in the emission test results. Development of the driving cycles themselves requires fewer assumptions such as decisions about where and under what conditions the observed driving occurred. The resulting trip-based California driving cycles are also similar in concept to the trip-based Unified Driving Cycle (or LA92), which is used by California as the basis for the highway vehicle emission factors. The approach we have proposed for MOBILE6 requires more driving cycles with more detailed information about driving conditions and location.

The most important disadvantage of California's approach is the dependence on vehicle trip information. Since vehicle trips occur over a variety of roadways at a variety of average speeds, evaluation of trips is most relevant for only areawide emission estimates. The confidence in the estimate of emissions will decrease as the size of the area to be modeled is decreased or if only specific roadways or links are to be modeled. In addition, many transportation planners do not currently generate trip speed distributions and other trip information from their models. This will mean that changes will need to be made in the transportation models in many cases in order to effectively use the California emission factors. In comparison, the approach proposed for MOBILE6 is more compatible with analysis by roadway type and link. Since most transportation models already estimate speeds and miles traveled by link, MOBILE6 will not normally require major changes in the output from existing transportation models. Using MOBILE6, the areawide emissions are still able to be estimated by compiling the results from the four roadway types.

A more detailed description of the California approach or a comparison of the two approaches is beyond the scope of this document. Readers are encouraged to obtain information directly from California to compare with the results documented in this report.

3.0 VEHICLE TESTING

3.1 New Driving Cycles

The basis for the analysis found in this report is a set of vehicles recruited and tested in 1997. The testing included new driving cycles specifically designed to address the effects of in-use driving behavior on emissions. Table 1 gives a brief description of the new cycles that were used in the testing. Collectively, these new driving schedules will be referred to in this document as “facility” cycles. The driving behavior in each driving schedule is selected from data collected from a particular roadway type during periods of various congestion levels. These congestion levels have been roughly grouped into “levels of service” (LOS) using letters A through G, similar to congestion category designations used in transportation models. Briefly, LOS “A” refers to “free flow” (uncongested) situations and the subsequent letters indicate increasing levels of congestion. The definition of these categories is discussed in more detail in a separate EPA report describing the development of the new facility driving cycles[1].

Table 2 compares the new cycles’ statistics to the target population statistics for each cycle. The statistics for each cycle will differ from the statistics of the population of driving which the cycle is designed to simulate (or “target population”). For example, the highest *average* speed of the arterial/collector cycles is 24.8 mph. We know that driving on arterial/collectors can have average speeds higher than that. The *maximum* speed of the arterial/collector cycles is only 58.9 mph, while the maximum speed of the targeted population is 74.9 mph. This is a result of the cycle development process which chooses the best combination of microtrips to match the target population. The microtrip which contains the maximum observed speed may over-represent certain aspects of driving behavior and cannot be used within the confines of a single driving cycle of limited duration.

Each cycle was designed to result in emission levels representative of the emissions we would expect from the driving behavior observed in the target population. Characteristics which were deemed important to the match were specific power, speed, and amount of acceleration, deceleration and idle. The factor which most affects emissions, shown from previous experience in development of the Supplemental FTP, is the power distribution. The average speed or maximum speed of the resulting cycles may not exactly match the target population. More importantly, however, the cycles approximate the power distribution of the target population. We feel that the emissions generated from the new cycles are a true representation of the expected emissions from the driving behavior that was observed in the target population from which the cycle was generated.

In addition to the new cycles described in Table 1, each vehicle was also tested using the following cycles:

- Federal Test Procedure (FTP), with an additional hot running 505 seconds of the LA4 (Urban Dynamometer Driving Cycle).
- California Air Resources Boards (CARB) area-wide Unified Cycle (LA92).
- New York City Cycle (NYCC), a low speed cycle which has previously been used for speed correction factors in the MOBILE model.
- ST01, a cycle based on instrumented vehicle data representing the beginning of trips which is the first 258 seconds of the vehicle certification air conditioning cycle (SC03).

Table 3 shows more information on these additional cycles.

3.2 Sample Selection

The vehicle sample for this analysis came from EPA Emission Factor testing performed at both the Automotive Testing Laboratories, Inc. (ATL), in Ohio and EPA's National Vehicle and Fuels Emission Laboratory (NVFEL), in Ann Arbor, Michigan, in the spring of 1997. All of the vehicles at ATL were recruited at Inspection and Maintenance lanes run by the State of Ohio, and were tested in an as-received condition (without repairs). At the time of this analysis, a total of 62 1983 through 1996 model year vehicles had been recruited and had completed testing in Ohio, and 23 1990 through 1996 model year vehicles recruited and tested in Ann Arbor. The sample of 85 vehicles includes 22 light-duty trucks. Most of the 85 vehicles were fuel injection, with 3 carbureted passenger cars and 4 carbureted light duty trucks.

The vehicles tested at the EPA laboratory were recruited randomly. The vehicles tested at ATL were selected as a stratified random sample, with strata corresponding to IM240 pass or fail outcome determined at state run IM240 inspection stations in Ohio. ATL used the final phase-in cutpoints recommended by EPA for use in I/M programs using the IM240 test procedure to identify vehicles in need of maintenance. Twenty of the vehicles in the ATL sample failed the IM240 test. Proper analysis of the ATL data requires careful weighting of the passing and failing vehicles if emitter status is not considered as a factor in the analysis.

Table 4 shows the mix of EPA vehicle emission certification standards and fuel delivery technology in the sample used in this analysis. Table 5 lists all of the vehicles individually, showing vehicle make and model, odometer mileage, engine size and whether the vehicle passed or failed an IM240 test procedure using final phase-in cutpoints. Table 6 shows the mix of model years and vehicle class (car or truck) in the sample.

3.3 Vehicle Testing

All vehicles were tested in the as-received condition using vehicle certification test fuel. Testing of all cycles were done in random order to reduce any order bias. Vehicles were tested at FTP ambient conditions. Emission results were measured both as composite "bags" and in grams second by second. Only the bag results were used in this analysis.

4.0 STATISTICAL ANALYSES

The purpose of the testing using the new facility cycles was to determine the effects of average speed on emissions using "real world" driving cycles. Separate cycles were developed for freeway and arterial/collector roadways to allow comparison of those two roadway types. The testing program also "over sampled" high emitting vehicles in order to provide a sufficient sample size to allow separate analysis of high emitting vehicles. Although vehicle mileage (or vehicle age) is considered important for estimating emissions, it is not thought that vehicle mileage is a factor in the effect of average speed on emissions. Together, the following testing and vehicle parameters were considered as potentially important in determining the effect of average speed on emissions:

1. Emitter status.
2. Roadway type.
3. Vehicle class.
4. Exhaust Emission Standard.

The data from the vehicles tested using the new facility cycles were evaluated to determine if the effect of the average speed on emissions differed significantly by these parameters. The sections below (Sections 4.1 through 4.4) discuss the statistical results for each parameter evaluated. Section 4.5 discusses the statistical support for the convergence of the freeway and arterial/collector estimates. Section 4.6 summarizes the conclusions derived from the statistical analysis. Chapter 5 describes the final proposed methodology.

Other factors were considered. Although there is a large range of model years (1983 through 1996 model years), the sample size (85 vehicles) was not sufficient for analysis explicitly by model year or age. For the analysis, the difference in model years is assumed to be captured by the difference in emission standards.

Table 7(a-c) shows sample means and standard deviations for the combined dataset for each cycle, stratified into high and normal emitter levels. A vehicle may be a Normal emitter for one pollutant, but considered a High emitter for another. In some cases the sample sizes (Normal and High) do not sum to 85 vehicles. This is because some test results on some vehicles were voided due to errors in the testing or sampling and could not be used. No valid emission test results were eliminated from the analysis.

Figure 1(a-c) graphically shows the effects of average speed on emissions. Each point is the ratio of the mean for the emissions of each of the 14 facility cycles versus mean emissions for the LA4 (Urban Dynamometer Driving Cycle) for the same vehicles. The data show that the high emitting vehicles do not exhibit as much sensitivity to speed, resulting in smaller ratios.

It was expected that as the average speed increases the difference between emissions from cycles representing arterial/collector roadways and emissions from cycles representing freeways would decrease. A special analysis was done to confirm the observed convergence of freeway and arterial/collector roadway emissions versus average speed. This analysis is discussed in Section 4.5 below.

The method of analysis of variance was used to judge the effect of the above parameters on the relation between average speed and emissions. The dependent variables in these analyses were chosen to be the logarithm of grams-per-hour emissions. The grams-per-hour measure is more stable than grams-per-mile, particularly at lower speeds, where very little distance is traveled over a long time. The log transformation yields values that better satisfy the ANOVA test requirements of normally distributed constant-variance errors. In the actual fitting of speed correction factor equations, described in Section 5, gram-per-hour units were used for analysis at average speeds less than 30 mph. However, at high speeds (average speeds above 30 mph), using a linear fit and grams per hour units, when converted back to grams per mile, forces a curve shape which does not match the data trends. For speeds above 30 mph, gram per mile units were used.

Table 8 reports the ANOVA results in terms of p-values associated with tests of the various factors described above. The p-value gives a concise way of judging statistical significance. The p-value of a test is the smallest level of significance at which the null hypothesis can be rejected. In these models, the null hypothesis states that the levels of a given factor, e.g., roadway type, have equal effect on emissions. The level of significance for this test is the probability of Type I error, i.e., of rejecting the null hypothesis when it is true, that is, of falsely concluding that a difference exists. By convention, the level of significance is chosen to be arbitrarily small, typically 0.05, in order to limit the occurrence of Type I error. If p is smaller than the chosen level of significance, the null hypothesis is rejected in favor of the claim that a difference exists.

For example, in comparing the normal and high emitter classes of total hydrocarbons, Table 8 reveals a p-value of 0.000 for the main effect of the emitter class. In graphical terms, the main effect captures the intercept of a line relating (log) emissions to speed. Thus, the small p-value agrees with the rather obvious hypothesis that high emitters have different average emissions than normal emitters. However, for the interaction of emitter class with speed, the p-value is 0.1411, implying that difference in the slopes (the relationship between emissions versus average speed) of the normal and high emitter lines (regressions) is not statistically significant.

Further, more detailed ANOVA results are shown in Appendix A at the end of this report. We now consider the statistical results for the individual factors.

4.1 Emitter Status

The sample was separated into "emitter status groups" based on their Hot Running LA4 exhaust emissions. Hot Running LA4 are emissions that would result from an FTP test which does not include any engine starts. These emissions are intended to be the basic unit of exhaust emissions for use in MOBILE6[1]. The emitter status groups were defined by the following pass/fail cutpoints:

- 0.8 g/mi Total Hydrocarbons (THC)
- 15 g/mi Carbon Monoxide (CO)
- 2.0 g/mi Oxides of Nitrogen (NOx)

These are the final phase-in cutpoints recommended by EPA for use in I/M programs using the IM240 test procedure to identify vehicles in need of maintenance. A vehicle is considered a Normal emitter if its emissions are less than or equal to the cutpoint level for that pollutant. It is considered a High emitter if its emissions exceed the cutpoint level for that pollutant. Once a vehicle is identified by emitter status for a pollutant using the Hot Running LA4 emission results, it is always categorized that way in this analysis, regardless of its emission results on another driving cycle. The cutpoints were not used in combination. A vehicle could be considered as a Normal emitter for the CO analysis even if it were designated as a High emitter for NOx or THC.

Table 8 confirms that the average emissions differ statistically by emitter class. The speed variable also is significant, i.e., emissions vary with average speed. However, except for CO, the emitter class-speed interaction is statistically non-significant.

While it is not always the case that the other factors - roadway type, vehicle type, and emissions standard - interact statistically with emitter class, engineering judgement warrant modeling these factors separately for normal and high emitters. Statistical conclusions for these factors are presented next.

4.2 Roadway Type

For modeling in MOBILE6, four roadway types are considered: arterial/collectors, freeways, freeway ramps and local roads. With arterial/collectors and freeways, the range of average speeds in the facility cycles overlaps at speeds below 30 mph. At higher speeds, only freeway cycles are available. The interaction between roadway type and vehicle type and between roadway type and emission standard was examined.

Figure 2 (a-c) shows the effects of average speed on emissions in terms of the ratio of the means for the emissions versus emissions for the LA4 (Urban Dynamometer Driving Cycle) for normal emitting vehicles. The cycles representing freeway driving and arterial/collector driving are connected with lines to show the difference in these road types versus average speed. The Unified Cycle (LA92), the Area-wide Non-Freeway cycle, Local Roadway cycle and Freeway Ramp cycle results are also shown in the figures. The same vehicles were tested on all cycles, so differences between freeways and arterial/collectors are controlled for the vehicle effect.

The emissions data were compared statistically to determine if there is reason to model arterial/collectors and freeways separately. The ANOVA results appear in Table 8. For all pollutants in the normal emitter class, the main effects are statistically significant. The speed interaction effects also are significant, albeit marginally so for hydrocarbons. Among high emitter vehicles, only NOx exhibits a significant difference between the arterial/collector and freeway road types.

Since only freeway cycles are represented at speeds over 30 mph, no comparisons of roadway type are required. Local roadways and freeway ramps are represented by only a single cycle each and therefore cannot be analyzed for the effect of average speed.

4.3 Vehicle Class

Of the 85 vehicles in the facility cycle sample, 22 are light duty trucks. The high emitters among the trucks number three for NOx, six for CO and 10 for THC/NMHC. In the freeway and arterial/collector roadway categories, for the normal emitters, the ANOVA results for passenger cars versus light duty trucks in Table 8 show significant main effects. However, the interaction with speed effects all are non-significant. For the high emitters, none of the vehicle type comparisons is statistically significant at the 0.05 level.

For the local and freeway ramp driving cycles, the results are mixed for normal emitter vehicles. NOx emissions differ at the 0.05 level on both cycles and CO is significant for the ramp cycle. Among high emitters, vehicle type is not significant for any of the pollutants on either cycle.

4.4 Emission Standard

It was expected that vehicles certified to the new Tier 1 exhaust emission standards would exhibit a different response to average speed than the Tier 0 vehicles. Since the facility cycle sample contains only 12 Tier 1 vehicles, a method was developed for increasing the sample size by reclassifying a portion of the Tier 0 vehicles in the sample. Vehicles were defined as "Clean" Tier 0 vehicles if their emissions were less than 70% of both the NMHC and NOx Tier 1 certification standard as measured on the standard FTP test. The Tier 1 standards are:

o NMHC standard: 0.25 g/mi (< 50,000 miles), 0.31 g/mi (>50,000 miles).
o NOx standard: 0.4 g/mi (< 50,000 miles), 0.6 g/mi (>50,000 miles).

A total of eight clean Tier 0 vehicles were identified by this criterion. One Tier 0 vehicle (number 5016) had low FTP Bag 1 and Bag 3 emissions and technically qualified for reassignment. However, because it had large Bag 2 and IM240 emissions, it was not considered representative of Tier 1 emission behavior and thus retained Tier 0 status under the new definition. The clean Tier 0 vehicles were used both in the analysis of both Tier 0 and Tier 1 emission levels. Table 9 shows the subset of 20 vehicles used to represent Tier 1 emission behavior. Tables 11 (a-d) show the average emissions for each driving cycle in the sample of normal emitting Tier 0 vehicles, high emitting Tier 0 vehicles and the expanded sample of vehicles considered normal emitting Tier 1 vehicles. Figure 3 (a-c) compares the Tier 0 and the expanded Tier 1 sample of vehicles for the difference in the effects of average speed on emissions. Emissions are shown in terms of the ratio of the means for the emissions versus emissions for the LA4 (Urban Dynamometer Driving Cycle).

The ANOVA results in Table 8 compare emissions of the Tier 0 and Tier 1 vehicles for the reallocated sample. On the arterial/collector and freeway cycles, for normal emitters the emissions standard main effect is highly significant for all pollutants, and the interaction with speed is significant for hydrocarbons. (The results are similar for the official emission standard classification.) For the local and freeway ramp facility cycles, all main effects are also significant.

There were no high emitter Tier 1 vehicles for any of the pollutants, so no test of the standard factor can be made for that emitter class.

4.5 Convergence of Freeways and Arterial/Collectors

The data show a statistical difference between the freeway and arterial/collector cycles below 30 mph, where the data overlaps. However, there are no arterial/collector cycles above 24.8 mph and there are no freeway cycles below 13.1 mph. If the speed correction factors for both of these roadway types are to cover the entire spectrum of average speeds available in the MOBILE6 model (0 to 65 mph), then some assumptions about the effect of average speed on emissions will need to be made for the speeds outside the typical range for these roadways.

Based on the facility cycle emission testing results, it appears that as average speed increases there is a decrease in the difference between emission results for arterial/collector cycles and freeway cycles at the same average speed. This suggests, that above a certain average speed, the same relationship between average speed and emissions can be used for both freeways and arterial/collector roadways.

Support for the hypothesis that mean gram-per-hour emissions of arterial and highway driving converge in the neighborhood of 30 mph can be found in the data from tests on the cycles that represent these two forms of driving. Consider the following model of emissions:

$$Y = b_0 + b_1X + b_2{*}D + b_3X{*}D$$

where Y is emissions (in grams/hour) of a given pollutant; X is average speed of the cycle tested; and D is a dummy variable representing road type (D = 0 for arterial, D = 1 for highway). This equation effectively models two lines. When D = 0, the function estimates emissions versus speed for arterials, with slope b_1 and intercept b_0. When D = 1, the line represents highway emissions with slope $(b_1 + b_3)$ and intercept $(b_0 + b_2)$.

This model is useful for examining differences between arterial and freeway emissions. The basic question of whether the linear functions differ is answered by testing the coefficients of terms involving variable D. If both these coefficients (b_2 and b_3) are zero, then the road types are judged to be the same. For the 85 car sample, tests of this hypothesis are rejected for all categories of emission standard and emission level.

Given that arterial and highway speed-emissions lines are significantly different, we now ask if they differ at a chosen speed, e.g., 30 miles per hour. This is answered by constructing an appropriate function of the linear model described above. When X = 30, the function becomes:

$$Y = b_0 + b_1*30 \quad \text{for arterials}$$

$$Y = b_0 + b_1*30 + b_2*1 + b_3*1*30$$

$$= (b_0 + b_2) + (b_1 + b_3)*30 \quad \text{for highways}$$

The two functions are identical when the linear combination $b_2 + b_3*30$ equals zero. This hypothesis can be tested using the ESTIMATE feature of the SAS GLM procedure.

Table 10 presents results of these tests for Tier 0 normal and high emitters, and for Tier 1 normal emitters. At the five percent level, a significant difference is found in only in one case, for Tier 0 normal CO emissions. This gives strong support for the claim that arterial/collector roadway and freeway emissions are similar at speeds around 30 mph, even though their relationship at average speeds below 30 mph is different. Based on this convergence, we propose that the relationship between average speed and emissions for arterial/collector roadways and freeways should be the same at average speeds above 30 mph.

4.6 Summary

The statistical analysis of the important parameters resulted in the following decisions about how the data would be grouped for the MOBILE6 analysis:

Roadway Type

There will be different equations for the two roadway types (freeways and arterial/collectors) for CO and NOx emission at both High and Normal emitter groups. There will be different equations for the two roadway types for THC and NMHC emissions only for normal emitting vehicles. Since the equations converge, there will be only one equation for all roadway types and pollutants at average speeds above about 30 mph. The exact average speed where the equations converge varies. For high emitting Tier 0 vehicles there will be no difference between the two roadway types for THC and NMHC emissions at any average speed.

Vehicle Class

There will not be different equations for vehicle class (car versus truck). The equations will depend on emission level (below), which will adequately cover any emission standard differences between cars and trucks. Splitting the data by both emission standard (below) and vehicle class would make sample sizes much too small for any meaningful results.

Emission Standard

There will be separate equations for Tier 0 and Tier 1 emission standard vehicles for normal emission levels. There are no high emitting Tier 1 vehicles in the sample.

Emission Levels

The Tier 0 emission standard data will be further separated by emitter status (Normal and High) for all pollutants with separate speed equations for each. For the purpose of analysis, this effectively results in three samples of vehicles representing three distinct emission levels:

- Level 1 : Tier 1 (Normal emitter)
- Level 2 : Tier 0 (Normal emitter)
- Level 3 : Tier 0 (High emitter)

5.0 EMISSION LEVEL CALCULATION

Once the appropriate aggregations for the existing data were determined as described in the previous section, least square linear regressions were fit to the emission results versus average speed. This was done in a "multi-linear" fashion, rather than using a single line or using another non-linear curve shape. Attempts to fit non-linear curves to the total data sample resulted in unacceptably high error coefficients. A linear fit of smaller groupings of the data provided a closer fit to the data. A separate linear regression was done for different groupings of cycles based on ranges of average speeds. Together, these lines will define the change in emissions of the sample over the entire range of average speeds.

5.1 Freeway Versus Arterial/Collector Effects

As discussed in the previous section, the data show a statistical difference between the freeway and arterial/collector cycles below 30 mph, where the data overlap. However, there are no arterial/collector cycles above 24.8 mph and there are no freeway cycles below 13.1 mph. If the speed correction factors for both of these roadway types are to cover the entire spectrum of average speeds available in the MOBILE6 model (0 to 65 mph), then some assumptions about the effect of average speed on emissions will need to be made for the speeds outside the range for which we have data.

Logically, both curves will converge at idle (zero mph). Idling emissions should not depend on roadway type. Also, it is logical to assume that driving which has a high average speed must consist almost entirely of cruise with little stopping or idle, regardless of roadway type. This suggests a model where freeways and arterial/collector roadways have different emissions at normal arterial/collector average speeds, but have the same emissions at extremely low speeds (and idle) and at higher speeds. Based on this model, we have defined the following speed/facility segments:

- o High Speeds (above about 30 mph) for both freeways and arterial/collectors.
- o Intermediate Speed Freeways (from 13.1 to about 30 mph) for freeways.
- o Low Speed Freeways (from 7.1 to 13.1 mph) for freeways.

- o Arterial/Collectors (from 7.1 to about 30 mph) for arterial/collectors.
- o Extremely Low Speed and Idle (less than 7.1 mph) for both freeways and arterial/collectors.

We propose to use a combined emission estimate for both arterial/collector and freeway facilities for THC and NMHC at the highest emission level. This will mean that, at high emitting THC and NMHC emission levels, that there will be no emission difference between the two facility types. There would still be separate freeway and arterial/collector estimates for CO and NOx emissions at high emitting levels.

5.1.1 High Speeds

A regression was done of emissions versus average speed for the three emission standard/emitter groups described above for the four freeway cycles with an average speed above 30 mph (Freeway at 30.5 mph, Freeway at 52.9 mph, Freeway at 59.7 mph and Freeway at 63.2 mph) in grams per mile for each pollutant. Tables 12a, 12b, 12c and 12d show the results of those regressions. All of the slope coefficients of the regressions are statistically significant, meaning that the increase or decrease in emissions versus average speed is different than zero. These regressions will be used to estimate the emissions of vehicles on both freeway and arterial/collector roadways at average speeds above the point where the equations converge.

5.1.2 Intermediate Speed Freeways

A regression was done of emissions versus average speed for each of the emission standard/emitter groups described above for the four freeway cycles representing freeway driving in the most congested conditions (Freeway at 13.1 mph, Freeway at 18.6 mph and Freeway at 30.5 mph) in grams per hour for each pollutant. Tables 12a, 12b, 12c and 12d show the results of those regressions. These regressions will be used to estimate the emissions of vehicles on freeways between average speeds of 13.1 mph and about 30 mph. Note that the freeway cycle at 30.5 mph was included in both the intermediate speed freeway and high speed estimates. It is expected that the two regressions should converge at about this average speed.

5.1.3 Low Speed Freeways

None of the existing facility cycles for freeway driving have an average speed below 13.1 mph. It will be assumed that at speeds lower than 7.1 mph (the average speed of the New York City Cycle) the effect of average speed on emissions will be the same for freeways and arterial/collector roadways. The emissions of freeway driving for average speeds between 13.1 mph and 7.1 mph will be calculated by linear interpolation between these emission levels in grams per hour. Tables 12a, 12b, 12c and 12d show the resulting equations representing this interpolation. Most freeway travel will occur at average speeds well above this range.

5.1.4 Arterial/Collectors

The freeway cycle at 30.5 mph (already included in the freeway estimate) was included in the arterial/collector roadway estimates as well. It was shown that the two regressions should converge at about this average speed. The New York City Cycle was also included in the arterial/collector roadway estimates. The New York City Cycle was not derived from the same chase car or instrumented data used to develop the other facility cycles. However, the New York City Cycle was originally developed as a speed correction cycle and, as shown in Table 3, does contain acceleration rates higher than the contained in the LA4 (Urban Dynamometer Driving Schedule). It was deemed that the New York City Cycle was representative of “real world” driving and could be included in the analysis as another facility cycle.

A regression was done of emissions versus average speed for each of the emission standard/emitter groups described above for the arterial/collector cycles (Arterial/Collector at 11.6 mph, Arterial/Collector at 19.2 mph, Arterial/Collector at 24.8 mph) in grams per hour for each pollutant. Included in that regression was data from the New York City Cycle (with and average speed of 7.1 mph) and the Freeway at 30.5 mph cycle for the same vehicles.

Tables 12a, 12b, 12c and 12d show the results of those regressions. These regressions will be used to estimate the emissions of vehicles on arterial/collector roadways in this range of average speeds.

5.1.5 Extremely Low Speeds and Idle

No data was collected for the vehicles in the sample at speeds lower than 7.1 mph (the average speed of the New York City Cycle). In this range the model will assume that the effect of average speed on emissions will be the same for freeways and arterial/collector roadways. Since the MOBILE5 model already has estimates for the effect of average speed on vehicles at speeds from 2.5 to 7.1 mph, and since there is no need to differentiate this effect by facility type, the existing speed correction factors in MOBILE5 will be used for this range of average speeds for both freeways and arterial/collectors.

The MOBILE5 speed correction factors do not match the new proposed speed correction factors at 7.1 mph. This discontinuity will be resolved by adding the difference in the two estimates to values calculated using the old MOBILE5 speed correction factors. As in MOBILE5, emissions at idle will be assumed to be the same (in grams per hour) as the emissions at 2.5 mph (the lowest average speed modeled).

5.2 Local Roadways and Freeway Ramps

There is only one cycle each to represent driving on local roadways and freeway ramps. As a result, these cycles are not included in the analysis of emissions versus average speed. However, the data from these cycles were separated using the same sample splits by emission standard (Tier 0 versus Tier 1) and emitter status (Normal versus High) as are used for the freeway and arterial/collectors. The average emission levels were analyzed as a linear function of the base emission rate (hot running LA4 emissions). These regressions will be used to estimate the emission levels for these roadway types as a function of the base emission rate calculated in MOBILE6. The coefficients for these regressions are shown in Table 13.

5.3 Special Cases

Ideally, the equations above would define a rational, smooth relationship for emissions versus average speed for the range of 0 to 65 mph for each pollutant based on the available data. However due to vagaries of using real-world data and the use of a multi-linear modeling approach, some of the equations resulting from the general approach will cause small discontinuities in the overall relationship. For example, the intermediate speed freeway emission level for NOx (computed in gram per hour) does not intersect with the high speed freeway emission level estimate (computed in grams per mile) at any speed. These discontinuities, when examined, do not cast doubt on the overall relationship, but will require special handling to be coded mathematically. A single smooth curve could be fit to the data over all speeds. This would generate different and more difficult problems, however, such as an unacceptably poor fit in certain speed ranges. For MOBILE6, some basic “rules” will be used to assure that there are no abrupt or counter-intuitive changes in emissions versus average speed.

1) If at 30.5 mph, the emission estimate for the intermediate speed freeway equation is still higher than the emissions for freeways calculated using the high speed equation, the emission value calculated for 30.5 mph using the intermediate speed freeway equation will be used for speeds greater than 30.5 mph until the value for the high speed equation for that speed exceeds the intermediate speed freeway value. This rule keeps the intermediate speed freeway value from increasing beyond the emission level calculated at 30.5 mph, which is the highest average speed data point used in the regression (no extrapolations).

2) When calculating the emissions of an arterial/collector roadway, the arterial/collector estimate for emissions will be used unless the estimate for freeways at that same speed are higher than the arterial/collector estimate. This rule defines at what average speed the arterial/collector and freeway emission estimates will converge. Above that speed the arterial/collector and freeway emission estimates will be assumed to be the same. All of the MOBILE6 arterial/collector equations intersect with the freeway estimate between 24 and 34 mph.

6.0 SPEED CORRECTION FACTORS

Using the methods in the previous section, the emission data can be described as a series of continuous, smooth functions for the two roadway types (freeways and arterial/collectors) by emission levels for all pollutants over the entire range of average speeds in MOBILE6 (2.5 to 65 mph). This generalized relationship between emissions and average speed for any emission level is referred to in the model as speed correction factors. These speed correction factors are the values which will be stored and used in MOBILE6 to adjust the basic exhaust emission estimate for average speed. Freeway ramps and local roadways, however, have only a single cycle and cannot vary by average speed. MOBILE6 must also estimate speed effects for groups of vehicles with basic emission rates that differ from those in the data sample.

6.1 Basic Modeling Approach

The basic exhaust emission rate generated by MOBILE6 will be based on a hot running LA4 emission estimate with an average speed of 19.6 mph. In MOBILE6 Freeway Ramp and Local Roadway emissions do not depend on speed and can be determined directly from the basic exhaust emission rate. For freeways and arterial/collector roadways, the adjustment to account for the average speed and facility type includes an multiplicative part and a additive part. The multiplicative part accounts primarily for the difference in emissions due to changes in average speed. The additive part accounts primarily for the difference between the basic emission rate, based on the running emissions for the LA4 cycle, and the running emissions on the facility at the same average speed. In MOBILE6, we propose that the basic emission rate be adjusted using the following general method:

$$\text{Adjusted BER} = (\text{BER} + \text{EO}) * \text{SCF} + \text{AEO}$$

Where:

BER = Basic Emission Rate (running emissions for the LA4 cycle).

EO = Emission Offset (a function of BER emissions)

SCF = Multiplicative Speed Correction Factor (a function of speed and emissions).

AEO = Arterial/Collector Emission Offset (a function of speed and emissions).

For freeways, the AEO would be zero, since it only applies to arterial/collector roadways. Using the above equation, with a BER identical to the average hot running LA4 emissions of each sample of vehicles in each of the three emission level groupings described in Section 4.6, the estimate of emissions at any speed for each facility will match the average emission level predicted by the regression equations from the facility cycle data from that vehicle sample. For cases where the BER is not identical to the average hot running LA4 emissions of any of the facility cycle sample emission level groupings, the EO will still be calculated as a function of the BER, however the SCF and AEO adjustments will be interpolated using the three emission level sample estimates. The interpolation would be determined by the emission level of the sum of the BER and the EO. There are five cases:

- o If the emissions are between the Level 1 and the Level 2 emission levels, the SCF and AEO factors would be interpolated between those two curves.

- o If the emissions were between the Level 2 and the Level 3 emission levels, the SCF and AEO factors would be interpolated between those two curves.

- o If the emissions were equal to the Level 2 emission level, the Level 2 SCF and AEO factors would be used.

- o If the emissions were equal to or above Level 3 emission level, the Level 3 SCF and AEO factors would be used.

- o If the emissions were equal to or below Level 1 emission level, the Level 1 SCF and AEO factors would be adjusted proportionally to the change in the BER and accounting for differences in the emission standards. This will be discussed in Section 6.4 below.

In this way, an emission offsets and an effect of average speed can be calculated for any basic exhaust emission rate for any average speed allowed in MOBILE6 for each facility type.

6.2 Emission Offsets

In order to appropriately apply the multiplicative (proportional) speed correction factors (SCF) of the form described in Section 6.1, first the basic exhaust running emission rate (BER) must be adjusted to match the emissions observed on the freeway cycles at the same speed as the BER (19.6 mph). All other speed adjustments are applied to this new, adjusted BER emission level.

6.2.1 Freeway Emission Offset Calculation

The emission offset is simple in concept. It is simply the difference between the average emissions of vehicles from the Hot Running LA4 cycle (the basis of the BER) and the predicted average emissions of the same vehicles from the regressions using the freeway cycles from Section 5.0 above.

Emission Offset = Freeway Cycle at 19.6 mph - Hot Running LA4 Cycle

The emission offset (EO) is calculated for each of the three emission levels (see Section 4.0). Table 14 shows the emission offsets calculated for the three emission levels. As described in Section 6.1, the EO values can be adjusted to reflect any BER emission levels greater than Level 1 directly by interpolation. Emission levels less than Level 1 (Tier 1) are discussed in Section 6.4 below.

6.2.2 Arterial/Collector Emission Offset Calculation

Arterial/collector cycles have higher emissions than freeway cycles at the same average speed. For MOBILE6, we propose to account for this difference as an additional emission offset effect, beyond that already accounted for by the freeway emissions estimate. Since the difference between the emissions of arterial/collector cycles and freeway cycles varies with average speed, this additional emission offset effect will be dependent on average speed.

AEO at X mph = Arterial/Collector emissions at X mph - Freeway emissions at X mph

The arterial/collector emission offset (AEO) is calculated for each of the three emission levels (see Section 4.0). Table 15 shows the arterial/collector emission offsets calculated for the three emission levels at each speed. As described in Section 6.1, the AEO values can be adjusted to reflect any BER emission levels greater than Level 1 directly by interpolation. Emission levels less than Level 1 (Tier 1) are discussed in Section 6.4 below. The AEO is always zero below 7.1 mph and above about 30 mph where arterial/collector and freeway estimates are identical. The AEO is also zero for Level 3 THC and NMHC emissions, since the freeway and arterial/collector emission estimates are the same for this emission level/pollutant.

6.3 Calculating Speed Correction Factors

As discussed in Section 6.2, for MOBILE6 we propose to adjust the basic exhaust emission rates (BER) by first adding an emission value (emission offset, EO) to adjust the BER to the level of the freeway emissions. This EO value will be a function of the basic exhaust emission rate. An additional offset (the Arterial/Collector Emission Offset (AEO)) is added to the freeway emission level to account for arterial/collector driving effects. The speed correction factors are applied to the sum of the BER and the EO.

As the data has shown, the effect of average speed on emissions depends on emission level. Therefore, the appropriate form for speed correction would be a multiplicative adjustment, making the change in emissions due to change in average speed proportional to the basic exhaust emission rate.

For MOBILE6, the speed correction factor (SCF) is defined as the ratio of the predicted emissions at any average speed to the predicted emissions at 19.6 mph for freeways for the same vehicle. The freeway emission levels are defined for all average speeds from 2.5 to 65 mph. Using the emission level equations described in Section 5, a set of SCFs will be determined for each speed in increments of 5 mph beginning at 5 mph through 65 mph and at 2.5 mph for each of the three emission levels within MOBILE6. These increments correspond to the proposed increments of average speed for the VMT distribution for freeways and arterial/collector roadways which we propose as input to MOBILE6. We propose to have MOBILE6 calculate these speed correction factors directly from the emission levels, rather than store the resultant speed correction factors themselves. Table 16 shows the freeway SCF sets for the three emission levels. These SCF sets are shown graphically in Figures 5a, 5b, 5c and 5d. Table 16 shows the freeway emissions at 19.6 mph for each emission level. Table 17 shows the arterial/collector SCF sets for the three emission levels.

Speed correction factors for emission levels below Level 1 (Tier 1) must account for the effects of more stringent emission standards. This is discussed in Section 6.4 below.

6.4 Effect of the NLEV Standards and the Supplemental FTP

Starting in the 2001 model year, light-duty vehicles will be certified for sale using a new test procedure, referred to as the Supplemental Federal Test Procedure (SFTP). Vehicles certified using this test procedure will have lower emissions during typical driving than vehicles certified using the current test procedures, primarily by requiring reductions in emissions during hard accelerations and with accessory loads, like air conditioning. These vehicles will also have to meet tighter National Low Emission Vehicle (NLEV) emission standards. The effects of speed (including aggressive driving) on NLEV may differ from current vehicles. However, speed corrections for NLEVs cannot be determined directly from the available NLEV emission data. Not enough data on in-use NLEV vehicles is available yet.

The basic exhaust emission rates and emission offsets for NLEV will differ from Tier 1 vehicles in several ways. In addition to lower exhaust emission standards, the emission offsets for normal emitting NLEV vehicles will be affected by the SFTP. Although high emitting NLEV standard vehicles will have basic exhaust running emission rate (BER) emissions higher than Level 1 (average emissions based on the sample of normal emitting Tier 1 vehicles), the effect of the SFTP will likely reduce the offset for these vehicles as well. The amount of this reduction will be addressed in a separate document describing the effects of the SFTP. It is sufficient to know here that a separate set of emission offsets will be used for NLEV vehicles which reflect the effect of the SFTP.

In addition to the adjustments to the EO and AEO, the multiplicative speed correction factors (SCF) for Level 1 (Tier 1) will also be adjusted to account for the change in emission standards for basic exhaust running emission rates less than Level 1. Using the multiplicative Level 1 SCF without adjustment would assume that the change in standards had affected all types of driving behavior emission effects proportionally. If we compare the Tier 1 SCFs to the Tier 0 normal SCFs (as in Figures 5a-d), the effect appears to increase as emission levels decrease. It is likely that NLEV standard vehicles should be more sensitive to changes in average speed than Tier 1 vehicles.

An alternative to using the Tier 1 multiplicative SCFs would be to use the same change in emissions observed in Tier 1 vehicles versus speed (additively) to represent the effects of speed for NLEV standard vehicles. This additive approach would match the trend in SCFs, but assumes that there is no effect from new standards on the emission effects from changes in average speed. It is likely that NLEV standard vehicles are less sensitive to changes in average speed than estimated by the additive approach.

The two alternatives (multiplicative and additive) discussed above can be summarized as the following two sets of equations:

$$SCF_{mult} = SCF_{Tier1}$$

$$BER_{speed} = BER * SCF_{mult}$$

and

$$SCF_{add} = (SCF_{Tier1} - 1.0) * \text{Tier 1 Sample Average Emission Level}$$

$$BER_{speed} = BER + SCF_{add}$$

where

BER_{speed} is the speed corrected basic emission rate.
SCF_{mult} is the speed correction factor assuming a multiplicative adjustment.
SCF_{add} is the speed correction factor assuming an additive adjustment.
SCF_{Tier1} is the speed correction factor for Tier 1 vehicles at a given speed.
BER is the NLEV basic emission rate, unadjusted for speed.

Rather than choose between the additive and multiplicative approaches described above for NLEV standard vehicles, we propose to choose SCF values that lie between these two estimates. These SCFs would be used for all NLEV standard vehicles, and other vehicles with emission standard levels less than Tier 1, regardless of emission level. We strongly encourage readers to comment on this issue and propose alternate solutions to selecting SCFs for NLEV standard vehicles.

6.5 Application in MOBILE6

We propose to apply the speed corrections described in this document to gasoline fueled, light-duty vehicles (cars and light trucks) of all model years and technologies. The speed correction factor would be applied to the basic exhaust hot running emission rates, adjusted to freeway emission levels at 19.6 mph. Additional adjustment would be made to the freeway emission estimate between 7.1 and about 30 mph to account for arterial/collector roadways. MOBILE6 would continue to use the existing speed correction factors and methodology found in MOBILE5 for diesel vehicles, gasoline fueled heavy-duty vehicles and motorcycles. Heavy-duty diesel vehicles will also be adjusted for NOx excess emissions separately from the MOBILE6 speed correction factors.

In MOBILE6, the daily average emission rate will be calculated by VMT weighting an emission estimate for each hour of the day. Within each hour of the day, there will be a distribution of speeds for freeways and arterial/collectors, either a default national average or a user supplied distribution. The speed correction would be applied to the estimate of Normal and High emitters within each model year separately. Older (pre-1981) model year gasoline fueled, light-duty vehicles will have only composite (combined Normal and High) basic exhaust emission rates. In these cases the speed correction will be applied to the composite basic exhaust emission rates (including both Normal and High emitters). Speed correction factors will not be applied to the effects of engine start on emissions estimated by MOBILE6.

The speed distribution in MOBILE6 will consist of average speed "bins" from 5 to 65 mph in 5 mph increments and for 2.5 mph (14 speed bins) representing the distribution of average speeds within each hour. Each hour of the day will have an estimate of the distribution of vehicle miles traveled (VMT) on freeways, ramps, local and arterial/collector roadways. These distributions will be used to weight together the emission estimates in each speed bin to give an hourly emission estimate. Freeway Ramps and Local Roadways will have hourly emission estimates and VMT estimates, but will not have speed distributions. The hourly emission estimates will be weighted by the hourly VMT distribution separately for each facility. Finally, the VMT distribution between facilities will be used to combine the results into an area-wide running exhaust emission estimate. Emissions due to engine start within each hour will be calculated separately. In summary, MOBILE6 will:

- Determine the basic running exhaust emission rate (BER).
- For each hour, correct the BER for temperature and fuel effects.
- Using the corrected BER, calculate the emissions for Freeway Ramps, Local Roadways and for the 14 speed bins for freeways and arterial/collectors using the appropriate emission offsets and speed correction factors described in this document.
- Using the speed distributions, weight the freeways, ramps, local and arterial/collector speed bin results to get hourly emissions.
- Using the hourly VMT distributions, weight together the hourly facility results to get daily emissions by facility.
- Using the facility VMT distribution, weight the daily facility emissions to get the area-wide running exhaust emission estimate.
- Combine the running exhaust emission estimate with the engine start emissions to get the composite exhaust emission rate.

Appendix B shows an example calculation.

The national average default factors proposed to be used in MOBILE6 for VMT weighting the speed-corrected, facility-type emissions into a single area-wide running emissions rate is described in a report prepared for EPA by Systems Applications International[3]. This report also contains the default distributions of average speeds on each facility over the day. All of these default values can be overridden by the user with local information using methods described in a separate guidance document[4].

The operating mode inputs used in MOBILE5 will not be needed for MOBILE6. Instead, MOBILE6 uses values for the number of engine starts, the distribution of soak times between engine starts, the mileage accumulation rates and the distribution of these factors over the day[5]. These values are used to determine the weighting of the running exhaust emissions with the effects of engine starts to calculate a composite exhaust emission factor. Although MOBILE6 contains default values, these default values will normally be overridden by user supplied local information.

Similarly, once the composite running and engine start emissions are calculated, the composite exhaust HC emissions can be combined with the calculated non-exhaust HC emissions. The reader should refer to the reports regarding the non-exhaust emission estimates and their associated activity for more details on how these values are calculated.

7.0 COMPARISON TO MOBILE5

Figures 6a, 6b, and 6c show the proposed MOBILE6 speed correction factors (SCFs) for freeways compared to selected speed correction factors used in MOBILE5. This comparison cannot be made clearly, since the two versions of the model use very different approaches.

- The proposed MOBILE6 SCFs depend on emission level and the MOBILE5 SCFs do not.
- The MOBILE5 SCFs are applied to a composite exhaust emission rate, including engine start emissions. The MOBILE6 SCFs will only be applied to the hot running exhaust emissions, before the effects of engine start are added.
- The MOBILE6 SCFs are intended to estimate the effects on freeways excluding ramp activity, but the MOBILE5 SCFs are a composite of all roadway types.
- The MOBILE6 SCFs include the effect of additional aggressive driving effects on emissions missing from the MOBILE5 SCFs.

The overall shape of the MOBILE5 and MOBILE6 SCFs is similar. The MOBILE6 SCFs are flatter at speeds greater than 55 mph than in MOBILE5, especially for CO and NOx. This may be due largely to the fact that the old speed cycles above 48 mph all started from idle (zero mph) and accelerated to a speed higher than the average speed of the cycle. This extra acceleration, which is not generally found on cruising vehicles on limited access freeways, adds to the power demand, therefore likely increasing emissions in the old high speed cycles relative to lower speed cycles. The acceleration to reach freeway speeds is now contained in the separate ramp cycle. This additional ramp cycle will allow this effect to be weighted appropriately with freeway driving. The effect from starting and ending at idle is less pronounced in the lower speed cycles since they inherently have a higher percentage of driving at idle.

In Figure 6a (THC), the MOBILE6 SCF for the lowest emission level (based Tier 1 vehicles) has a positive slope beyond about 30 mph, indicating increasing THC emissions with increasing average speed. However, as shown in Figure 4a, Tier 1 vehicles are much cleaner at all speeds than the normal emitting Tier 0 vehicles. The shape of the THC MOBILE6 SCFs for the higher emission levels (based on Tier 0 vehicles, Normal and High) is very close to the shape of MOBILE5 SCFs.

For higher average speeds (above 19.6 mph) the proposed MOBILE6 SCFs for CO emissions (Figure 6b) have a strongly positive slope at lower emission levels (based on Tier 0 Normals and Tier 1 vehicles). This is very different from the SCFs used in MOBILE5. The proposed MOBILE6 SCFs for THC/NMHC emissions for Tier 0 Normal vehicles have a negative slope. However CO emissions are more sensitive to aggressive driving than THC/NMHC emissions, which may explain the difference in the trends.

The proposed MOBILE6 SCFs for NOx emissions (Figure 6c) for the higher emission levels (based on Tier 0 vehicles) have a slight upward trend at higher speeds, similar to the MOBILE5 trends. The lowest emission level SCFs (based on Tier 1 vehicles) has a steep slope, similar to the oldest MOBILE5 SCF. All of the proposed MOBILE6 SCFs tend to rise as average speeds decrease, which is expected with more accelerations and decelerations (stop and go driving) present in the driving patterns. However, the MOBILE6 SCFs rise much more steeply and to higher levels than the MOBILE5 SCFs.

Since the Freeway Ramp and Local Roadway emissions are estimated directly from the basic exhaust emission rate (based on the hot running LA4 emissions), they cannot be compared to the speed correction factor used in MOBILE5. When MOBILE6 is nearer completion, it will be possible to create a composite result containing a weighted sum of all of the roadway types in MOBILE6 that can be more fairly compared to MOBILE5 results.

8.0 COMMENTS

EPA is requesting that MOBILE model stakeholders and other knowledgeable readers comment on the methodology and validity of the assumptions used to determine the speed correction factors proposed in this document. Comments should clearly distinguish between recommendations for clearly defined improvements that can be readily made in the short term based on data reasonably at hand to EPA and improvements that are long term, exploratory or dependent on data not currently available to EPA. The schedule for MOBILE6 will not allow for the serious consideration of proposed long term improvements. However, these long term comments will be considered for future data collection and data analysis. General areas for review include:

- Report clarity;
- Overall methodology
- Appropriateness of data sets selected;

- Statistical approaches used;
- Empirical relationships selected;
- Appropriateness of the conclusions;
- Recommendations for alternate data sources or methods.

Comments on this report and its proposed use in MOBILE6 may be submitted electronically to:

mobile@epa.gov

or by fax to:

(734) 214-4939

or by mail to:

MOBILE6 Review Comments
2000 Traverwood
US EPA Assessment and Modeling Division
Ann Arbor MI 48105

Electronic submission of comments is preferred. All comments may be made public. In your comments, please note clearly the document that you are commenting on. Please be sure to include your name, address, affiliation, and any other pertinent information.

References

1. Carlson, T.R., et al., “Development of Speed Correction Cycles,” MOBILE6 Stakeholder Review Document (M6.SPD.001). Prepared for EPA by Sierra Research, Inc., 1997.

2. Brzezinski, D.J., et al., “Coefficients for the Determination of Engine Start and Running Emissions From FTP Bag Emissions,” MOBILE6 Stakeholder Review Document (M6.STE.002), 1997.

3. “Development of Methodology for Estimating VMT Weighting by Facility Type,” MOBILE6 Stakeholder Review Document (M6.SPD.003) EPA420-P-99-006. Prepared for EPA by Systems Applications International, Inc., 1998.

4. “Guidance for the Development of Facility Type VMT and Speed Distributions,” MOBILE6 Stakeholder Review Document (M6.SPD.004) EPA420-P-99-004. Prepared for EPA by Systems Applications International, Inc., 1998.

5. Glover, E.L., et al., “Soak Length Activity Factors for Start Emissions,” MOBILE6 Stakeholder Review Document (M6.FLT.003),

Tables

Table 1

New Facility-Specific/Area-Wide Speed Correction Cycle Statistics

Cycle*	Average Speed (mph)	Maximum Speed (mph)	Maximum Accel Rate (mph/s)	Length (seconds)	Length (miles)
Freeway, High Speed	63.2	74.7	2.7	610	10.72
Freeway, LOS A-C	59.7	73.1	3.4	516	8.55
Freeway, LOS D	52.9	70.6	2.3	406	5.96
Freeway, LOS E	30.5	63.0	5.3	456	3.86
Freeway, LOS F	18.6	49.9	6.9	442	2.29
Freeway, LOS “G”	13.1	35.7	3.8	390	1.42
Freeway Ramps	34.6	60.2	5.7	266	2.56
Arterial/Collectors LOS A-B	24.8	58.9	5.0	737	5.07
Arterial/Collectors LOS C-D	19.2	49.5	5.7	629	3.36
Arterial/Collectors LOS E-F	11.6	39.9	5.8	504	1.62
Local Roadways	12.9	38.3	3.7	525	1.87
Non-Freeway Area-Wide Urban Travel	19.4	52.3	6.4	1,348	7.25

* LOS (level of service) refers to roadway congestion categories. See Section 4.6.

Table 2

Comparison of Key Representativeness Statistics For Facility-Specific Cycle Schedules Versus Total Vehicle Observations

Driving Cycle	Mean Speed (mph)		Maximum Speed (mph)		Maximum Accel Rate (mph/sec)		Total SAFD Difference (%)	High-Power Difference (%)
	Cyc.	Obs.	Cyc.	Obs.	Cyc.	Obs.		
Freeway High-Speed	63.2	62.7	74.7	80.9	2.7	5.8	9.41	0.16
Freeway LOS A-C	59.7	59.2	73.1	83.2	3.4	6.8	12.12	0.39
Freeway LOS D	52.9	52.0	70.6	75.8	2.3	6.1	15.10	0.35
Freeway LOS E	30.5	32.1	63.0	71.3	5.3	8.5	25.17	0.18
Freeway LOS F	18.6	19.9	49.9	69.5	6.9	9.6	23.83	0.06
Freeway LOS G	13.1	14.4	35.7	49.1	3.8	5.7	18.80	0.10
Freeway Ramp	34.6	35.4	60.2	79.1	5.7	9.3	42.74	0.99
Arterial LOS A-B	24.8	25.2	58.9	74.9	5.0	14.9	17.04	0.40
Arterial LOS C-D	19.2	18.9	49.5	71.3	5.7	10.4	16.86	0.21
Arterial LOS E-F	11.6	12.0	39.9	56.8	5.8	10.2	17.86	0.24
Local Roadways	12.8	14.6	38.3	62.7	3.7	12.5	21.80	0.11
Unified Cycle	24.6	26.3	67.2	80.3	6.9	10.4	30.27	0.19

Table 3

Statistics for Additional Tested Cycles

Cycle	Average Speed (mph)	Maximum Speed (mph)	Maximum Accel Rate (mph/s)	Length (seconds)	Length (miles)
LA4 (Urban Dynamometer Driving Cycle)	19.6	56.7	3.3	1368	7.45
Running 505 (First 505 seconds of the Urban Dynamometer Driving Cycle)	25.6	56.7	3.3	505	3.59
Unified Cycle (LA92)	24.6	67.2	6.9	1435	9.81
ST01 (Engine Start Cycle)	20.2	41.0	5.1	248	1.39
New York City Cycle (NYCC)	7.1	27.7	6.0	600	1.18

Table 4

Distribution of the Vehicle Sample
By Emission Standard and Technology

Fuel Delivery	TIER 0 Emission Standard	TIER 1 Emission Standard	Total Sample
Carburetor	7	--	7
Throttle Body FI	27	1	28
Multi-Port FI	39	11	50
Total Sample	73	12	85

Table 5

Vehicle Sample Description

Site	Veh. No.	Veh. Class	VIN	Mod. Yr.	Make	Mod.	Std.	Miles	Eng. Size	Fuel Inj.	IM240
E.LIB	5001	LDV	1G4AH51R7J6401871	88	BUICK	CENT	Tier 0	129,698	2.5	TBI	PASS
E.LIB	5002	LDV	1G3NL54UXKM283722	89	OLDSMOBILE	CUTL	Tier 0	61,956	2.5	TBI	FAIL
E.LIB	5003	LDV	2FACP74F3MX162914	91	FORD	CROW	Tier 0	53,003	5.0	PFI	PASS
E.LIB	5005	LDV	1G1JC14GOM7126454	91	CHEVROLET	CAVA	Tier 0	54,658	2.2	TBI	PASS
E.LIB	5006	LDV	1G1JC111XK7150483	89	CHEVROLET	CAVA	Tier 0	107,611	2.0	TBI	PASS
E.LIB	5007	LDV	1G3HY54C9JW312653	88	OLDSMOBILE	DELT	Tier 0	101,534	3.8	PFI	PASS
E.LIB	5008	LDV	1FACP57U5NG145893	92	FORD	TAUR	Tier 0	74,078	3.0	PFI	PASS
E.LIB	5009	LDV	1G2WP14T6KF307905	89	PONTIAC	GRAN	Tier 0	155,181	3.1	PFI	FAIL
E.LIB	5010	LDV	4T1SK12E9PU184046	93	TOYOTA	CAMR	Tier 0	29,392	2.2	TBI	PASS
E.LIB	5011	LDV	2C1MS2468P6704533	93	GEO	METR	Tier 0	105,445	1.0	TBI	PASS
E.LIB	5012	LDV	1G2NV54D9JC821314	88	PONTIAC	GRAN	Tier 0	89,764	2.3	TBI	PASS
E.LIB	5013	LDV	1G2NE5434PC795009	93	PONTIAC	GRAN	Tier 0	72,348	2.3	PFI	PASS
E.LIB	5014	LDV	1G6CD53B7M4272204	91	CADILLAC	SEDA	Tier 0	51,707	4.9	TBI	FAIL
E.LIB	5015	LDV	1G2NE5438PC758996	93	PONTIAC	GRAN	Tier 0	58,538	2.3	PFI	PASS
E.LIB	5016	LDV	1G4HR54C5KH488839	89	BUICK	LESA	Tier 0	65,212	3.8	TBI	FAIL
E.LIB	5017	LDV	WVWEB5159MK012875	91	VW	CABR	Tier 0	67,496	1.8	TBI	PASS
E.LIB	5018	LDV	1B3ES27C9SD221573	95	DODGE	NEON	Tier 1	20,855	2.0	TBI	PASS
E.LIB	5019	LDV	1G1FP23TXLL111092	90	CHEVROLET	CAMA	Tier 0	71,258	3.1	PFI	FAIL
E.LIB	5020	LDV	1FACP5245NG196687	92	FORD	TAUR	Tier 0	84,148	3.8	TBI	PASS
E.LIB	5021	LDV	1B3ES67C2SD188892	95	DODGE	NEON	Tier 1	28,525	2.0	PFI	PASS
E.LIB	5022	LDV	1G1JC1112KJ207455	89	CHEVROLET	CAVA	Tier 0	110,929	2.0	TBI	PASS
E.LIB	5023	LDV	1FAPP36X6JK249611	88	FORD	TEMP	Tier 0	107,979	2.3	PFI	PASS
E.LIB	5024	LDV	2FAPP36X8MB116542	91	FORD	TEMP	Tier 0	97,522	2.3	PFI	FAIL
E.LIB	5025	LDT1	1N6SD16S6MC351945	91	NISSAN	HARD	Tier 0	103,346	2.4	PFI	PASS
E.LIB	5026	LDV	1MEBM50U3KG663746	89	MERCURY	SABL	Tier 0	107,075	3.0	PFI	FAIL
E.LIB	5027	LDV	JE3CU14A1NU003588	92	EAGLE	SUMM	Tier 0	129,457	1.5	PFI	FAIL
E.LIB	5028	LDV	1YVGE22A8P5138202	93	MAZDA	626	Tier 0	103,171	12	PFI	FAIL
E.LIB	5029	LDT1	1P4FH4430KX568849	89	PLYMOUTH	VOYA	Tier 0	118,586	3.0	PFI	PASS
E.LIB	5030	LDV	1FABP29D9GA165884	86	FORD	TAUR	Tier 0	50,755	2.5	TBI	FAIL
E.LIB	5031	LDV	JT2SV24E8J3189405	88	TOYOTA	CAMR	Tier 0	197,090	2.0	PFI	FAIL
E.LIB	5032	LDV	1MEBP923XFA603099	85	MERCURY	COUG	Tier 0	113,584	14	TBI	FAIL
E.LIB	5033	LDT1	1GCBS14E3H2170996	87	CHEVROLET	S10	Tier 0	128,681	2.5	TBI	PASS
E.LIB	5034	LDT1	1GCBS14A3F2156946	85	CHEVROLET	S10	Tier 0	89,435	1.9	NO	PASS
E.LIB	5035	LDV	1FABP37X6HK239681	87	FORD	TEMP	Tier 0	118,148	2.5	TBI	FAIL
E.LIB	5036	LDV	JN1HM05S8HX081093	87	NISSAN	STAN	Tier 0	58,173	2.0	PFI	PASS
E.LIB	5037	LDV	1P3BP49CXDF305484	83	PLYMOUTH	RELI	Tier 0	94,399	2.2	NO	FAIL
E.LIB	5038	LDV	2G1WL52M2T9212643	96	CHEVROLET	LUMI	Tier 1	16,557	3.1	PFI	PASS
E.LIB	5039	LDV	1HGED3554JA017137	88	HONDA	CIVI	Tier 0	184,457	1.5	TBI	FAIL
E.LIB	5040	LDV	2HGED6359KH534893	89	HONDA	CIVI	Tier 0	161,598	12	TBI	PASS
E.LIB	5041	LDV	JT2EL32G3H0076681	87	TOYOTA	TERC	Tier 0	136,654	1.5	NO	PASS
E.LIB	5042	LDT1	1GCDM15NXFB180388	85	CHEVROLET	ASTR	Tier 0	179,855	4.3	NO	FAIL
E.LIB	5043	LDV	2HGED6349KH537915	89	HONDA	CIVI	Tier 0	122,821	1.5	TBI	PASS
E.LIB	5044	LDT1	1GTBS14E5J2520442	88	CHEVROLET	S15	Tier 0	115,693	2.5	TBI	FAIL

Table 5

Vehicle Sample Description

E.LIB	5045	LDV	1G2WH54T6PF250844	93	PONTIAC	GRAN	Tier 0	85,789	3.4	PFI	FAIL
E.LIB	5046	LDT1	1FTCR1056FUD20466	85	FORD	RANG	Tier 0	56,488	2.8	NO	FAIL
E.LIB	5047	LDT1	1FTDE14N8MHB05052	91	FORD	ECON	Tier 0	79,573	5.8	PFI	FAIL
E.LIB	5048	LDT1	1FTCR10A2KUB93426	89	FORD	RANG	Tier 0	123,419	2.3	TBI	PASS
E.LIB	5049	LDV	2G1AW19X5G1258479	86	CHEVROLET	CELE	Tier 0	131,601	2.8	NO	PASS
E.LIB	5050	LDT1	1FDDE14F9FHA59240	85	FORD	ECON	Tier 0	86,203	5.8	NO	PASS
E.LIB	5051	LDV	1G1JF11W1K7156403	89	CHEVROLET	CAVA	Tier 0	123,581	3.1	PFI	PASS
E.LIB	5052	LDV	1G1JC14GXM7146551	91	CHEVROLET	CAVA	Tier 0	90,945	2.2	TBI	PASS
E.LIB	5053	LDT2	1FDEE14N0MHB15171	91	FORD	E150	Tier 0	97,531	5.8	PFI	FAIL
E.LIB	5054	LDV	1FAPP1282MW314230	91	FORD	ESCO	Tier 0	105,861	1.8	PFI	FAIL
E.LIB	5055	LDT1	2P4GH25K6MR240965	91	PLYMOUTH	VOYA	Tier 0	72,032	2.5	TBI	PASS
E.LIB	5056	LDT1	1GNDM15Z4MB190115	91	CHEVROLET	ASTR	Tier 0	90,880	4.3	TBI	PASS
E.LIB	5057	LDV	1G1LT53T9PY237873	93	CHEVROLET	CORS	Tier 0	41,766	3.4	PFI	PASS
E.LIB	5058	LDT1	1GCCS19Z5P0178401	93	CHEVROLET	S10	Tier 0	48,578	4.3	TBI	PASS
E.LIB	5059	LDV	4T1SK11E4PU252562	93	TOYOTA	CAMR	Tier 0	67,344	2.2	PFI	PASS
E.LIB	5060	LDV	1HGCB7658PA075439	93	HONDA	ACCO	Tier 0	61,163	2.2	PFI	PASS
E.LIB	5061	LDV	JN1HJ01P0LT397615	90	NISSAN	MAXI	Tier 0	120,786	3.0	PFI	PASS
E.LIB	5062	LDV	JE3CA11A7PU098450	93	EAGLE	SUMM	Tier 0	52,447	1.5	PFI	PASS
E.LIB	5063	LDV	1G2WJ52M7TF204255	96	PONTIAC	GRAN	Tier 1	20,451	3.1	PFI	PASS
AA	5213	LDV	JT2AE94A5N0273089	92	TOYOTA	CORO	Tier 0	77,310	1.6	PFI	NULL
AA	5217	LDV	1HGCD5632TA260884	96	HONDA	ACCO	Tier 1	7,573	2.2	PFI	NULL
AA	5218	LDV	1G8ZF5498NZ175489	92	SATURN	SL	Tier 0	89,995	1.9	TBI	NULL
AA	5219	LDV	1G1LW13T4NY109988	92	CHEVROLET	BERR	Tier 0	94,316	3.1	PFI	NULL
AA	5220	LDT2	1FTEF14N3RLB27661	94	FORD	F150	Tier 0	97,629	5.8	PFI	NULL
AA	5221	LDT2	1FTEF1549TLB25543	96	FORD	F150	Tier 1	12,877	4.9	PFI	NULL
AA	5222	LDV	JM1BG2263N0464490	92	MAZDA	PROT	Tier 0	10,727	1.8	PFI	NULL
AA	5223	LDV	2G1WL52M2T9212643	96	CHEVROLET	LUMI	Tier 1	17,233	3.1	PFI	NULL
AA	5224	LDV	1G1JC5447N7116728	92	CHEVROLET	CAVA	Tier 0	90,196	2.2	PFI	NULL
AA	5225	LDT1	1FTCR10A9TPB08548	96	FORD	RANG	Tier 1	10,064	2.3	PFI	NULL
AA	5227	LDT2	1GNEV16K9LF116974	90	CHEVROLET	SURB	Tier 0	97,658	5.7	TBI	NULL
AA	5228	LDV	2C3ED56F7RH211101	94	CHRYSLER	LHS	Tier 0	59,937	3.5	PFI	NULL
AA	5229	LDV	1HGEJ8142TL073569	96	HONDA	CIVI	Tier 1	9,433	1.6	PFI	NULL
AA	5230	LDT1	1GNDM19WXRB229457	94	CHEVROLET	ASTR	Tier 0	77,178	4.3	PFI	NULL
AA	5231	LDV	1G8ZK5570RZ145840	94	SATURN	SL	Tier 0	25,930	1.9	PFI	NULL
AA	5232	LDV	KMHJF22M5RU669848	94	HYUNDAI	ELAN	Tier 0	57,960	1.8	PFI	NULL
AA	5233	LDT1	1GNDU06D3NT126706	92	CHEVROLET	LUMI	Tier 0	33,872	3.1	PFI	NULL
AA	5234	LDV	1FARP15J9RW262996	94	FORD	ESCO	Tier 1	51,168	1.9	PFI	NULL
AA	5235	LDT1	2P4FH5532LR534285	90	PLYMOUTH	VOYA	Tier 0	98,530	3.0	PFI	NULL
AA	5237	LDV	2G1WN54X7N9117726	92	CHEVROLET	LUMI	Tier 0	16,133	3.4	PFI	NULL
AA	5239	LDT1	1GMDU06LXRT234029	94	PONTIAC	TRAN	Tier 1	68,305	3.8	PFI	NULL
AA	5240	LDV	4T1BF12K3TU871236	96	TOYOTA	CAMR	Tier 1	18,992	3.0	PFI	NULL
AA	5241	LDV	1B3XC56R3LD749334	90	DODGE	DYNA	Tier 0	6,813	3.3	PFI	NULL

Table 6

Distribution of Vehicle Sample
By Vehicle Class and Model Year

Model Year	Passenger Car	Light-Duty Truck (0-6000 GVW)	Light-Duty Truck (6000-8500 GVW)	Total
1983	1	--	--	1
1985	1	4	--	5
1986	2	--	--	2
1987	3	1	--	4
1988	6	1	--	7
1989	9	2	--	11
1990	3	1	1	5
1991	7	4	1	12
1992	9	1	--	10
1993	10	1	--	11
1994	4	2	1	7
1995	2	--	--	2
1996	6	1	1	8
TOTAL	63	18	4	85

Table 7a Facility-Specific/Area-Wide Speed Correction Cycles Test Results Total Hydrocarbons (THC)						
Cycle	Normal Emitters			High Emitters		
	N	Mean (g/mile)	STD	N	Mean (g/mile)	STD
Freeway at 63.2 mph	61	0.15	0.19	24	1.80	1.66
Freeway at 59.7 mph	61	0.16	0.17	24	1.77	1.69
Freeway at 52.9 mph	61	0.14	0.17	24	1.70	1.38
Freeway at 30.5 mph	61	0.21	0.26	24	2.52	2.12
Freeway at 18.6 mph	61	0.25	0.30	24	3.67	3.75
Freeway at 13.1 mph	61	0.27	0.33	24	4.13	4.06
Freeway Ramps (34.6 mph)	61	0.34	0.46	24	3.04	2.21
Arterial/Collectors at 24.8 mph	61	0.22	0.26	24	3.03	3.07
Arterial/Collectors at 19.2 mph	61	0.26	0.32	24	3.97	4.79
Arterial/Collectors at 11.6 mph	61	0.45	0.84	24	5.15	5.63
Local Roadways (12.9 mph)	61	0.28	0.34	24	4.48	5.07
Non-Freeway Area-Wide Urban Travel (19.4 mph)	60*	0.26	0.31	24	3.57	3.06
FTP (19.6 mph)	61	0.38	0.27	24	3.49	2.77
Running 505 (25.6 mph)	61	0.17	0.23	24	2.57	2.51
Unified Cycle (24.6 mph)	60*	0.24	0.27	24	3.16	3.33
ST01(20.2 mph)	61	2.32	2.29	23*	6.88	5.36
NYCC (7.1 mph)	61	0.62	1.09	24	7.31	7.82

* Test not done

Table 7b **Facility-Specific/Area-Wide Speed Correction Cycles Test Results** **Carbon Monoxide (CO)**						
	Normal Emitters			High Emitters		
Cycle	N	Mean (g/mile)	STD	N	Mean (g/mile)	STD
Freeway at 63.2 mph	70	6.96	7.71	15	66.76	52.09
Freeway at 59.7 mph	70	6.96	6.12	15	65.63	54.63
Freeway at 52.9 mph	70	5.53	5.33	15	54.45	41.82
Freeway at 30.5 mph	70	4.48	4.01	15	66.38	43.18
Freeway at 18.6 mph	70	5.19	4.90	15	74.39	63.48
Freeway at 13.1 mph	70	4.79	4.45	15	82.09	77.01
Freeway Ramps (34.6 mph)	70	10.06	10.79	15	84.02	57.32
Arterial/Collectors at 24.8 mph	70	4.28	3.87	15	75.24	59.12
Arterial/Collectors at 19.2 mph	70	5.22	5.01	15	80.79	62.65
Arterial/Collectors at 11.6 mph	70	5.94	5.65	15	116.57	94.9
Local Roadways (12.9 mph)	70	4.23	4.14	15	92.41	87.81
Non-Freeway Area-Wide Urban Travel (19.4 mph)	69*	4.80	4.62	15	86.63	62.32
FTP (19.6 mph)	70	5.05	3.70	15	79.92	56.89
Running 505 (25.6 mph)	70	3.04	2.75	15	74.04	57.5
Unified Cycle (24.6 mph)	69*	5.93	5.34	15	77.94	58.19
ST01 (20.2 mph)	70	24.55	16.54	14*	111.2	70.30
NYCC (7.1 mph)	70	7.88	8.12	15	158.04	136.34

* Test not done

Table 7c
Facility-Specific/Area-Wide Speed Correction Cycles Test Results
Nitrogen Oxides (NOx)

Cycle	Normal Emitters			High Emitters		
	N	Mean (g/mile)	STD	N	Mean (g/mile)	STD
Freeway at 63.2 mph	72	0.77	0.71	13	3.35	1.07
Freeway at 59.7 mph	72	0.74	0.65	13	3.27	1.02
Freeway at 52.9 mph	72	0.70	0.60	13	3.20	0.97
Freeway at 30.5 mph	72	0.63	0.54	13	3.15	1.00
Freeway at 18.6 mph	72	0.72	0.59	13	3.73	1.34
Freeway at 13.1 mph	72	0.51	0.39	13	2.81	0.99
Freeway Ramps (34.6 mph)	72	0.98	0.81	13	4.00	1.43
Arterial/Collectors at 24.8 mph	72	0.68	0.55	13	3.47	1.07
Arterial/Collectors at 19.2 mph	72	0.79	0.66	13	3.77	1.46
Arterial/Collectors at 11.6 mph	72	0.96	0.78	13	4.44	1.84
Local Roadways (12.9 mph)	72	0.73	0.63	13	3.74	1.46
Non-Freeway Area-Wide Urban Travel (19.4 mph)	71*	0.71	0.57	13	3.56	1.18
FTP (19.6 mph)	72	0.70	0.53	13	3.25	1.04
Running 505 (25.6 mph)	72	0.59	0.50	13	3.67	1.13
Unified Cycle (24.6 mph)	71*	0.84	0.66	13	3.83	1.23
ST01 (20.2 mph)	72	1.85	1.11	12*	3.78	1.34
NYCC (7.1 mph)	72	0.95	0.69	13	4.07	1.45

* Test not done

Table 8
Analysis of Variance Results (ANOVA P-Values)

	Factor*	THC	CO	NOx	NMHC
All Roadways	Speed	0.0000	0.0000	0.0000	0.0001
	Emitter Class	0.0000	0.0000	0.0000	0.0000
	Speed*Emitter Class	0.1411	0.0152	0.9894	0.1271
======================= Normal Emitters ========================					
	Factor*	THC	CO	NOx	NMHC
Arterial/Collector and Freeway	Roadway Type**	0.0046	0.0006	0.0000	0.0050
	Speed*Roadway Type**	0.0354	0.0020	0.0000	0.0440
	Vehicle Class	0.0016	0.0031	0.0012	0.0404
	Speed*Vehicle Class	0.1754	0.8680	0.5723	0.1802
	Standard***	0.0000	0.0000	0.0000	0.0000
	Speed*Standard***	0.0002	0.0576	0.6491	0.0001
Local Roadway	Vehicle Class	0.0830	0.4038	0.0124	0.5008
	Standard***	0.0000	0.0000	0.0028	0.0000
Freeway Ramp	Vehicle Class	0.2922	0.0443	0.0018	0.7707
	Standard***	0.0003	0.0002	0.0000	0.0007
======================= High Emitters ========================					
	Factor*	THC	CO	NOx	NMHC
Arterial/Collector and Freeway	Roadway Type**	0.1236	0.3307	0.0000	0.1307
	Speed*Roadway Type**	0.1176	0.6233	0.0000	0.1203
	Vehicle Class	0.5942	0.8984	0.3961	0.5693
	Speed*Vehicle Class	0.0641	0.0241	0.9560	0.0699
Local Roadway	Vehicle Class	0.8787	0.5511	0.6093	0.8821
Freeway Ramp	Vehicle Class	0.3701	0.1471	0.6942	0.4075

* All emissions in Log (gram/hour) space.
** Freeways versus Arterial/Collectors limited to speeds < 30 mph, including a vehicle term.
*** There are no Tier 1 High emitters in sample. Some low emitting Tier 0 vehicles are considered both as Tier 0 and as Tier 1 vehicles (see text).

Table 8
Analyses of Variance Results (ANOVA p values)

Factor*	THC	NMHC	CO	NOx
Emitter Level	.0000	.0000	.0000	.0000
	Normal Emitters Only			
Roadway type**	.0006	.0003	.0206	.0000
Vehicle Class	.0001	.0004	.0001	.0001
Standard***	.0001	.0001	.0001	.0001
Local/Vehicle Class	.0476	.1490	.0325	.2753
Local/Standard	.0001	.0001	.0001	.0001
Ramp/Vehicle Class	.0396	.0983	.0107	.0871
Ramp/Standard	.0001	.0001	.0001	.0001
	High Emitters Only			
Roadway type**	.3094	.3281	.0318	.0000
Vehicle Class	.067	.067	.0004	.144
Standard***	NA	NA	NA	NA

* All emissions in Log (gram/hour) space.

** Freeways versus Arterial/Collectors limited to speeds < 30 mph, including a vehicle term.

*** There were no Tier 1 High emitters in sample. Some low emitting Tier 0 vehicles were considered both as Tier 0 and as Tier 1 vehicles (see text).

Table 9
Description of Sample Vehicles Used for Tier 1 Analysis

Veh No.	Test Site	Tier Std.	Mileage	FTP NMHC	FTP NOx	Veh Class	Model Yr.	Eng. Size	Fuel Inj.	IM240 Status	VIN
5007	E.LIB	0	101536	0.13	0.23	LDV	88	3.80	PFI	PASS	1G3HY5C9JW312653
5010	E.LIB	0	29392	0.12	0.21	LDV	93	2.20	TBI	PASS	4T1SK12E9PU18406
5013	E.LIB	0	72348	0.08	0.18	LDV	93	2.30	PFI	PASS	1G2NE5438PC758996
5015	E.LIB	0	58538	0.07	0.41	LDV	93	2.30	PFI	PASS	1G2NE5438PC758996
5017	E.LIB	0	67496	0.15	0.13	LDV	91	1.80	TBI	PASS	WVWEB5159MK012875
5018	E.LIB	1	20855	0.12	0.10	LDV	95	2.00	TBI	PASS	1B3ES27C9SD221573
5021	E.LIB	1	28525	0.12	0.10	LDV	95	2.00	PFI	PASS	1B3ES67C2SD188892
5038	E.LIB	1	16557	0.12	0.34	LDV	96	3.10	PFI	PASS	2GIWL52M2T9212643
5059	E.LIB	0	6734	0.13	0.28	LDV	93	2.20	PFI	PASS	4T1SK11E4PU252562
5060	E.LIB	0	61163	0.11	0.27	LDV	93	2.20	PFI	PASS	1HGCB7658PA075439
5063	E.LIB	1	20451	0.16	0.26	LDV	96	3.10	PFI	PASS	1G2WJ52M7TF204255
5217	AA	1	7573	0.09	0.20	LDV	96	2.20	PFI	NULL	1HGCD5632TA260884
5218	AA	0	89995	0.19	0.39	LDV	92	1.90	PFI	NULL	1G8ZF5498NZI75489
5221	AA	1	12877	0.10	0.53	LDT2	96	4.90	PFI	NULL	1TEF1549TLB25543
5223	AA	1	17233	0.21	0.49	LDV	96	3.10	PFI	NULL	2G1WL52M2T9212643
5225	AA	1	10064	0.12	0.40	LDT1	96	2.20	PFI	NULL	1FTCR10A9TPB08548
5229	AA	1	9433	0.17	0.10	LDV	96	1.60	PFI	NULL	1HGEJ8142TL073569
5234	AA	1	51168	0.15	0.26	LDV	94	1.90	PFI	NULL	1FARP15J9RW262996
5239	AA	1	68305	0.19	0.71	LDT1	94	3.80	PFI	NULL	1GMDU06LXRT234029
5240	AA	1	18992	0.21	0.31	LDV	96	3.00	PFI	NULL	4T1BF12K3TU871236

Table 10
Tests of Convergence in Arterial and Freeway Estimates at 30 mph

Tier 0 Normal Emitter Sample				
Parameter	Estimate	T for H0: Parameter = 0	p value Pr > | T |	Standard Error of the Estimate
THC	0.18089092	1.84	0.0670	0.09840365
NMHC	0.15532642	1.83	0.0688	0.08503405
CO	1.63652794	2.96	0.0033	0.55229111
NOx	0.05946957	1.24	0.2160	0.04797825
Tier 0 High Emitter Sample				
Parameter	Estimate	T for H0: Parameter = 0	p value Pr > | T |	Standard Error of the Estimate
THC	0.95357931	1.52	0.1304	0.62676490
NMHC	0.84766279	1.58	0.1161	0.53612496
CO	24.7784634	1.48	0.1430	16.7645083
NOx	-0.00945343	-0.04	0.9705	0.25464544
Tier 1 Normal Emitter Sample				
Parameter	Estimate	T for H0: Parameter = 0	p value Pr > | T |	Standard Error of the Estimate
THC	0.01509669	1.15	0.2534	0.01310665
NMHC	0.00615421	0.71	0.4813	0.00869272
CO	0.25453921	0.83	0.4114	0.30796933
NOx	0.04101364	1.20	0.2350	0.03423678

Table 11a
Average Emissions by Emission Standard and Emission Level
Total Hydrocarbons (THC)

Cycle	Tier 1*			Tier 0 Normal			Tier 0 High		
	N	Mean (g/mi)	Std. Dev.	N	Mean (g/mi)	Std. Dev.	N	Mean (g/mi)	Std. Dev.
Freeway at 63.2 mph	20	0.050	0.032	49	0.183	0.200	24	1.798	1.656
Freeway at 59.7 mph	20	0.066	0.038	49	0.187	0.180	24	1.771	1.688
Freeway at 52.9 mph	20	0.035	0.019	49	0.171	0.178	24	1.702	1.384
Freeway at 30.5 mph	20	0.038	0.031	49	0.253	0.272	24	2.523	2.124
Freeway at 18.6 mph	20	0.044	0.036	49	0.305	0.318	24	3.672	3.745
Freeway at 13.1 mph	20	0.046	0.040	49	0.330	0.341	24	4.127	4.063
Freeway Ramps (34.6 mph)	20	0.083	0.080	49	0.408	0.488	24	3.036	2.205
Arterial/Collectors at 24.8 mph	20	0.044	0.035	49	0.262	0.278	24	3.028	3.072
Arterial/Collectors at 19.2 mph	20	0.060	0.054	49	0.318	0.341	24	3.970	4.794
Arterial/Collectors at 11.6 mph	20	0.063	0.045	49	0.551	0.917	24	5.155	5.630
NYCC (7.1 mph)	20	0.122	0.111	49	0.744	1.183	24	7.306	7.824
Local Roadways (12.9 mph)	20	0.053	0.056	49	0.336	0.360	24	4.478	5.075
Non-Freeway Areawide Urban Travel (19.4 mph)	19	0.057	0.047	49	0.311	0.325	24	3.571	3.060
Hot Running LA4 (19.6 mph)	20	0.036	0.019	49	0.199	0.201	24	3.175	2.945
Unified Cycle (24.6 mph)	19	0.060	0.049	48	0.282	0.287	24	3.158	3.328

Table 11b Average Emissions by Emission Standard and Emission Level Carbon Monoxide (CO)									
Cycle	Tier 1			Tier 0 Normal			Tier 0 High		
	N	Mean (g/mi)	Std. Dev.	N	Mean (g/mi)	Std. Dev.	N	Mean (g/mi)	Std. Dev.
Freeway at 63.2 mph	20	1.862	1.765	58	8.157	7.945	15	66.763	52.094
Freeway at 59.7 mph	20	3.045	1.446	58	7.755	6.410	15	65.632	54.628
Freeway at 52.9 mph	20	1.381	1.179	58	6.449	5.403	15	54.448	41.822
Freeway at 30.5 mph	20	1.305	1.636	58	5.218	3.998	15	66.377	43.185
Freeway at 18.6 mph	20	1.513	1.570	58	5.978	4.997	15	74.390	63.484
Freeway at 13.1 mph	20	1.264	1.564	58	5.596	4.464	15	82.087	77.005
Freeway Ramps (34.6 mph)	20	2.803	2.651	58	11.665	11.170	15	84.016	57.322
Arterial/Collectors at 24.8 mph	20	1.271	1.215	58	4.934	3.921	15	75.235	59.118
Arterial/Collectors at 19.2 mph	20	1.562	1.638	58	6.052	5.103	15	80.793	62.646
Arterial/Collectors at 11.6 mph	20	1.538	1.699	58	6.902	5.727	15	116.569	94.897
NYCC (7.1 mph)	20	2.652	3.068	58	9.061	8.384	15	158.041	136.341
Local Roadways (12.9 mph)	20	1.249	1.727	58	4.924	4.212	15	92.412	87.806
Non-Freeway Areawide Urban Travel (19.4 mph)	19	1.357	1.580	58	5.497	4.696	15	86.628	62.322
Hot Running LA4 (19.6 mph)	20	0.892	0.846	58	3.569	2.997	15	82.194	64.114
Unified Cycle (24.6 mph)	19	1.892	2.104	57	6.855	5.394	15	77.941	58.194

Table 11c Average Emissions by Emission Standard and Emission Level Oxides of Nitrogen (NOx)									
Cycle	Tier 1			Tier 0 Normal			Tier 0 High		
	N	Mean (g/mi)	Std. Dev.	N	Mean (g/mi)	Std. Dev.	N	Mean (g/mi)	Std. Dev.
Freeway at 63.2 mph	20	0.331	0.353	60	0.840	0.736	13	3.354	1.069
Freeway at 59.7 mph	20	0.340	0.287	60	0.806	0.674	13	3.270	1.021
Freeway at 52.9 mph	20	0.241	0.164	60	0.789	0.619	13	3.200	0.970
Freeway at 30.5 mph	20	0.234	0.158	60	0.709	0.558	13	3.155	0.996
Freeway at 18.6 mph	20	0.231	0.168	60	0.817	0.591	13	3.727	1.339
Freeway at 13.1 mph	20	0.187	0.143	60	0.585	0.386	13	2.805	0.995
Freeway Ramps (34.6 mph)	20	0.324	0.222	60	1.106	0.823	13	3.998	1.435
Arterial/Collectors at 24.8 mph	20	0.233	0.163	60	0.769	0.559	13	3.473	1.068
Arterial/Collectors at 19.2 mph	20	0.376	0.476	60	0.905	0.660	13	3.774	1.461
Arterial/Collectors at 11.6 mph	20	0.416	0.605	60	1.093	0.777	13	4.435	1.841
NYCC (7.1 mph)	20	0.353	0.292	60	1.093	0.672	13	4.072	1.455
Local Roadways (12.9 mph)	20	0.311	0.426	60	0.830	0.637	13	3.735	1.463
Non-Freeway Areawide Urban Travel (19.4 mph)	19	0.253	0.159	60	0.796	0.583	13	3.561	1.179
Hot Running LA4 (19.6 mph)	20	0.191	0.123	60	0.591	0.457	13	3.245	1.045
Unified Cycle (24.6 mph)	19	0.357	0.255	59	0.943	0.678	13	3.830	1.230

Table 11d Average Emissions by Emission Standard and Emission Level Non-Methane Hydrocarbons (NMHC)									
Cycle	Tier 1			Tier 0 Normal			Tier 0 High		
	N	Mean (g/mi)	Std. Dev.	N	Mean (g/mi)	Std. Dev.	N	Mean (g/mi)	Std. Dev.
Freeway at 63.2 mph	19	0.038	0.023	49	0.148	0.177	24	1.633	1.524
Freeway at 59.7 mph	20	0.052	0.035	49	0.154	0.162	24	1.601	1.518
Freeway at 52.9 mph	19	0.026	0.015	48	0.140	0.159	24	1.537	1.231
Freeway at 30.5 mph	19	0.025	0.020	49	0.207	0.246	24	2.290	1.847
Freeway at 18.6 mph	16	0.031	0.031	48	0.250	0.288	24	3.347	3.295
Freeway at 13.1 mph	17	0.027	0.022	49	0.259	0.310	24	3.740	3.463
Freeway Ramps (34.6 mph)	18	0.068	0.069	47	0.357	0.444	24	2.767	1.957
Arterial/Collectors at 24.8 mph	20	0.029	0.028	49	0.214	0.252	24	2.737	2.672
Arterial/Collectors at 19.2 mph	18	0.042	0.041	48	0.264	0.304	24	3.616	4.291
Arterial/Collectors at 11.6 mph	20	0.034	0.022	49	0.458	0.805	24	4.665	4.888
NYCC (7.1 mph)	19	0.082	0.089	49	0.622	1.024	24	6.571	6.609
Local Roadways (12.9 mph)	17	0.038	0.045	48	0.280	0.334	24	4.059	4.426
Non-Freeway Areawide Urban Travel (19.4 mph)	18	0.038	0.033	49	0.257	0.301	24	3.245	2.635
Hot Running LA4 (19.6 mph)	20	0.020	0.009	49	0.157	0.176	24	2.945	2.770
Unified Cycle (24.6 mph)	19	0.041	0.039	48	0.232	0.265	24	2.860	2.930

Table 12a
Regressions of Emissions Versus Average Speed
Total Hydrocarbons (THC)

Emissions = Constant + a*(Average Speed)

Roadway Type	Emission Level	Speed Data Range (mph)	Constant (p value)	a (p value)	Units
Freeway	1 (Tier 1)	7.1 - 13.1	1.034*	-0.032*	grams per hour
Freeway	1 (Tier 1)	13.1 - 30.5	0.202 (.4780)	0.032 (.0175)	grams per hour
Freeway	1 (Tier 1)	30.5 - 63.2	0.019 (.2157)	0.001 (.0533)	grams per mile
Freeway	2 (Tier 0 Normal)	7.1 - 13.1	6.672*	-0.170*	grams per hour
Freeway	2 (Tier 0 Normal)	13.1 - 30.5	1.933 (.2284)	0.192 (.0094)	grams per hour
Freeway	2 (Tier 0 Normal)	30.5 - 63.2	0.315 (.0000)	-0.00226 (.0570)	grams per mile
Freeway	3 (Tier 0 High)	7.1 - 13.1	44.558** (.0013)	1.202** (.0908)	grams per hour
Freeway	3 (Tier 0 High)	13.1 - 30.5	44.558** (.0013)	1.202** (.0908)	grams per hour
Freeway	3 (Tier 0 High)	30.5 - 63.2	3.193 (.0000)	-0.024 (.0836)	grams per mile
Arterial/ Collector	1 (Tier 1)	7.1 - 24.8	0.690 (.0009)	0.017 (.0958)	grams per hour
Arterial/ Collector	2 (Tier 0 Normal)	7.1 - 24.8	4.891 (.0001)	0.081 (.1930)	grams per hour
Arterial/ Collector	3 (Tier 0 High)	7.1 - 24.8	44.558** (.0013)	1.202** (.0908)	grams per hour

* The values are calculated based on the NYCC at 7.1 mph and Freeway at 13.1 mph cycles.
** Freeway and Arterial/Collector cycles were combined.

Table 12b
Regressions of Emissions Versus Average Speed
Carbon Monoxide (CO)

Emissions = Constant + a*(Average Speed)

Roadway Type	Emission Level	Speed Data Range (mph)	Constant (p value)	a (p value)	Units
Freeway	1 (Tier 1)	7.1 - 13.1	14.730*	0.280*	grams per hour
Freeway	1 (Tier 1)	13.1 - 30.5	1.655 (.9045)	1.278 (.0454)	grams per hour
Freeway	1 (Tier 1)	30.5 - 63.2	0.246 (.7436)	0.032 (.0263)	grams per mile
Freeway	2 (Tier 0 Normal)	7.1 - 13.1	46.679*	2.390*	grams per hour
Freeway	2 (Tier 0 Normal)	13.1 - 30.5	15.273 (.4824)	4.788 (.0000)	grams per hour
Freeway	2 (Tier 0 Normal)	30.5 - 63.2	2.398 (.1526)	0.0872 (.0060)	grams per mile
Freeway	3 (Tier 0 High)	7.1 - 13.1	1206.641*	-9.747*	grams per hour
Freeway	3 (Tier 0 High)	13.1 - 30.5	365.822 (.4888)	54.438 (.0275)	grams per hour
Freeway	3 (Tier 0 High)	30.5 - 63.2	64.691 (.0147)	-0.0269 (.9559)	grams per mile
Arterial/ Collector	1 (Tier 1)	7.1 - 24.8	10.036 (.1950)	0.941 (.0138)	grams per hour
Arterial/ Collector	2 (Tier 0 Normal)	7.1 - 24.8	36.128 (.0054)	3.877 (.0000)	grams per hour
Arterial/ Collector	3 (Tier 0 High)	7.1 - 24.8	863.64 (.0114)	38.563 (.0202)	grams per hour

* The values are calculated based on the NYCC at 7.1 mph and Freeway at 13.1 mph cycles.

Table 12c
Regressions of Emissions Versus Average Speed
Oxides of Nitrogen (NOx)

Emissions = Constant + a*(Average Speed)

Roadway Type	Emission Level	Speed Data Range (mph)	Constant (p value)	a (p value)	Units
Freeway	1 (Tier 1)	7.1 - 13.1	4.625*	-0.154*	grams per hour
Freeway	1 (Tier 1)	13.1 - 30.5	-0.855 (.5289)	0.264 (.0001)	grams per hour
Freeway	1 (Tier 1)	30.5 - 63.2	0.126 (.2886)	0.0031 (.1667)	grams per mile
Freeway	2 (Tier 0 Normal)	7.1 - 13.1	8.291*	0.121*	grams per hour
Freeway	2 (Tier 0 Normal)	13.1 - 30.5	-0.957 (.7262)	0.761 (.0000)	grams per hour
Freeway	2 (Tier 0 Normal)	30.5 - 63.2	0.594 (.0008)	0.00373 (.2575)	grams per mile
Freeway	3 (Tier 0 High)	7.1 - 13.1	24.889*	1.364*	grams per hour
Freeway	3 (Tier 0 High)	13.1 - 30.5	0.423 (.9717)	3.232 (.0000)	grams per hour
Freeway	3 (Tier 0 High)	30.5 - 63.2	2.980 (.0000)	0.00512 (.6389)	grams per mile
Arterial/ Collector	1 (Tier 1)	7.1 - 24.8	2.325 (.1066)	0.170 (.0167)	grams per hour
Arterial/ Collector	2 (Tier 0 Normal)	7.1 - 24.8	5.123 (.0027)	0.567 (.0000)	grams per hour
Arterial/ Collector	3 (Tier 0 High)	7.1 - 24.8	14.609 (.0471)	2.812 (.0000)	grams per hour

* The values are calculated based on the NYCC at 7.1 mph and Freeway at 13.1 mph cycles.

Table 12d
Regressions of Emissions Versus Average Speed
Non-Methane Hydrocarbons (NMHC)

Emissions = Constant + a*(Average Speed)

Roadway Type	Emission Level	Speed Data Range (mph)	Constant (p value)	a (p value)	Units
Freeway	1 (Tier 1)	7.1 - 13.1	0.685*	-0.028*	grams per hour
Freeway	1 (Tier 1)	13.1 - 30.5	0.00266 (.9892)	0.0236 (.0105)	grams per hour
Freeway	1 (Tier 1)	30.5 - 63.2	0.00475 (.6971)	0.000592 (.0115)	grams per mile
Freeway	2 (Tier 0 Normal)	7.1 - 13.1	5.796*	-0.176*	grams per hour
Freeway	2 (Tier 0 Normal)	13.1 - 30.5	1.328 (.3602)	0.165 (.0131)	grams per hour
Freeway	2 (Tier 0 Normal)	30.5 - 63.2	0.259 (.0000)	-0.00189 (.0773)	grams per mile
Freeway	3 (Tier 0 High)	7.1 - 13.1	40.178*	1.103*	grams per hour
Freeway	3 (Tier 0 High)	13.1 - 30.5	37.404 (.0580)	1.107 (.2142)	grams per hour
Freeway	3 (Tier 0 High)	30.5 - 63.2	2.899 (.0000)	-0.022 (.0773)	grams per mile
Arterial/ Collector	1 (Tier 1)	7.1 - 24.8	0.399 (.0082)	0.0118 (.1048)	grams per hour
Arterial/ Collector	2 (Tier 0 Normal)	7.1 - 24.8	4.111 (.0003)	0.0617 (.2612)	grams per hour
Arterial/ Collector	3 (Tier 0 High)	7.1 - 24.8	42.589 (.0023)	1.017 (.1299)	grams per hour

* The values are calculated based on the NYCC at 7.1 mph and Freeway at 13.1 mph cycles.

Table 13
Freeway Ramp and Local Roadway Emissions
As a Function of Hot Running LA4 Emissions
In Grams/Hour

Emissions (g/hr) = Constant + a*(LA4) + b*($LA4^2$)
where LA4 is the hot running LA4 emissions in g/hr

Roadway Type	Pollutant	Constant (p value)	a (p value)	b (p value)	R^2
Freeway Ramp (34.6 mph)	THC	4.560 (.0302)	2.046 (.0000)	-0.00356 (.0000)	0.934
Freeway Ramp (34.6 mph)	CO	224.333 (.0010)	2.040 (.0000)	-0.000145 (.0074)	0.848
Freeway Ramp (34.6 mph)	NOx	5.353 (.1103)	2.863 (.0000)	-.0101 (.0019)	0.866
Freeway Ramp (34.6 mph)	NMHC	4.368 (.0193)	2.014 (.0000)	-0.00387 (.0000)	0.934
Local Roadways (12.9 mph)	THC	-0.479 (.8627)	1.045 (.0000)	-0.000724 (.3090)	0.765
Local Roadways (12.9 mph)	CO	13.795 (.7042)	0.721 (.0000)	0.000 (.9600)	0.803
Local Roadways (12.9 mph)	NOx	1.870 (.0424)	0.701 (.0000)	0.000609 (.4803)	0.919
Local Roadways (12.9 mph)	NMHC	-0.896 (.7115)	1.135 (.0000)	-0.00161 (.0201)	0.764

Table 14
Emission Offset

(Predicted Freeway Emissions - Average Hot Running LA4 Emissions)

	Level 1 (Tier 1) (grams per mile)			Level 2 (Tier 0) (grams per mile)			Level 3 (High Emitters) (grams per mile)		
	Fwy	LA4	Offset	Fwy	LA4	Offset	Fwy	LA4	Offset
THC	0.042	0.036	0.006	0.290	0.199	0.091	3.476	3.175	0.301
CO	1.363	0.892	0.471	5.567	3.569	1.998	73.102	82.194	-9.092
NOx	0.220	0.191	0.029	0.712	0.591	0.121	3.253	3.245	0.008
NMHC	0.024	0.020	0.004	0.233	0.157	0.076	3.153	2.945	0.208

Table 15
Arterial/Collector Emission Offsets

(Predicted Arterial/Collector Emissions - Predicted Freeway Emissions)

Pollutant	Average Speed* (miles per hour)	Level 1 (grams per mile)	Level 2 (grams per mile)	Level 3 (grams per mile)
THC	10	0.014	0.073	0
	15	0.018	0.086	0
	20	0.009	0.037	0
	25	0.005	0.007	0
	30	0.001	0	0
CO	10	0.192	0.431	14.010
	15	0.222	0.479	17.313
	20	0.082	0.131	9.016
	25	0	0	4.038
	30	0	0	0.719
NOx	10	0.094	0.171	0.420
	15	0.118	0.211	0.526
	20	0.065	0.110	0.290
	25	0.033	0.049	0.148
	30	0.012	0.009	0.053
NMHC	10	0.012	0.069	0
	15	0.015	0.082	0
	20	0.008	0.035	0
	25	0.004	0.008	0
	30	0.001	0	0

* Arterial/Collector Emission Offsets below 10 mph and over 30 mph are zero.

Table 16
Speed Correction Factors
For Freeways
By Emission Level*

Avg. Speed (mph)	Total Hydrocarbons (THC)			Carbon Monoxide (CO)			Oxides of Nitrogen (NOx)			Non-Methane HC (NMHC)		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
7.1	2.71	2.65	2.15	1.73	1.61	2.19	2.26	1.81	1.50	2.87	2.75	2.14
10	1.71	1.71	1.63	1.29	1.27	1.52	1.40	1.28	1.18	1.69	1.73	1.62
15	1.08	1.10	1.20	1.02	1.04	1.08	0.94	0.98	1.00	1.00	1.09	1.20
19.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.00	0.99	0.99	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	0.99
25	0.95	0.93	0.86	0.99	0.97	0.94	1.04	1.01	1.00	1.00	0.94	0.86
30	0.91	0.88	0.77	0.98	0.95	0.91	1.07	1.02	1.00	1.00	0.90	0.77
35	0.91	0.81	0.68	1.00	0.98	0.87	1.07	1.02	1.00	1.07	0.83	0.68
40	0.97	0.77	0.64	1.12	1.06	0.87	1.14	1.04	1.00	1.20	0.79	0.64
45	1.04	0.73	0.61	1.24	1.14	0.87	1.21	1.07	1.00	1.32	0.74	0.61
50	1.10	0.69	0.57	1.36	1.21	0.87	1.28	1.09	1.00	1.45	0.70	0.57
55	1.17	0.65	0.54	1.47	1.29	0.86	1.35	1.12	1.00	1.57	0.66	0.54
60	1.24	0.61	0.50	1.59	1.37	0.86	1.42	1.15	1.01	1.70	0.62	0.50
65	1.30	0.57	0.47	1.71	1.45	0.86	1.49	1.17	1.02	1.82	0.58	0.47

* Emission levels shown as Fwy emissions in Table 14. See Section 4.6.

Table 17
Speed Correction Factors
For Arterial/Collector Roadways
By Emission Level*

Avg. Speed (mph)	Total Hydrocarbons (THC)			Carbon Monoxide (CO)			Oxides of Nitrogen (NOx)			Non-Methane HC (NMHC)		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
7.1	2.71	2.65	2.15	1.73	1.61	2.19	2.26	1.81	1.50	2.87	2.75	2.14
10	2.04	1.96	1.63	1.43	1.35	1.71	1.82	1.52	1.31	2.18	2.03	1.62
15	1.49	1.40	1.20	1.18	1.13	1.32	1.47	1.28	1.16	1.62	1.44	1.20
20	1.22	1.12	0.99	1.06	1.02	1.12	1.30	1.16	1.09	1.34	1.15	0.99
25	1.05	0.95	0.86	0.99	0.97	1.00	1.19	1.08	1.04	1.17	0.97	0.86
30	0.95	0.88	0.77	0.98	0.95	0.92	1.12	1.04	1.01	1.06	0.90	0.77
35	0.91	0.81	0.68	1.00	0.98	0.87	1.07	1.02	1.00	1.07	0.83	0.68
40	0.97	0.77	0.64	1.12	1.06	0.87	1.14	1.04	1.00	1.20	0.79	0.64
45	1.04	0.73	0.61	1.24	1.14	0.87	1.21	1.07	1.00	1.32	0.74	0.61
50	1.10	0.69	0.57	1.36	1.21	0.87	1.28	1.09	1.00	1.45	0.70	0.57
55	1.17	0.65	0.54	1.47	1.29	0.86	1.35	1.12	1.00	1.57	0.66	0.54
60	1.24	0.61	0.50	1.59	1.37	0.86	1.42	1.15	1.01	1.70	0.62	0.50
65	1.30	0.57	0.47	1.71	1.45	0.86	1.49	1.17	1.02	1.82	0.58	0.47

* Emission levels shown as Fwy emissions in Table 14. See Section 4.6.

Figures

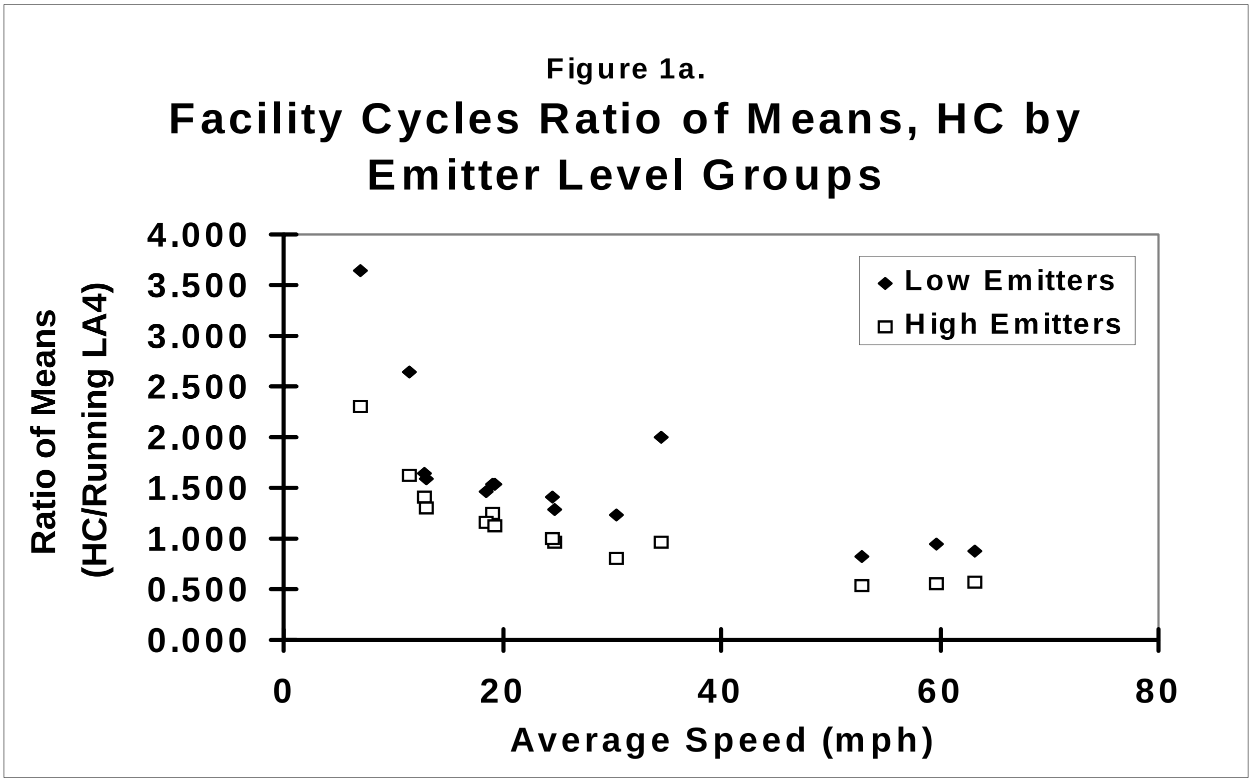


Figure 1a.
Facility Cycles Ratio of Means, HC by Emitter Level Groups
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Ratio of Means (HC/Running LA4)
Low Emitters
High Emitters
0
20
40
60
80
Average Speed (mph)

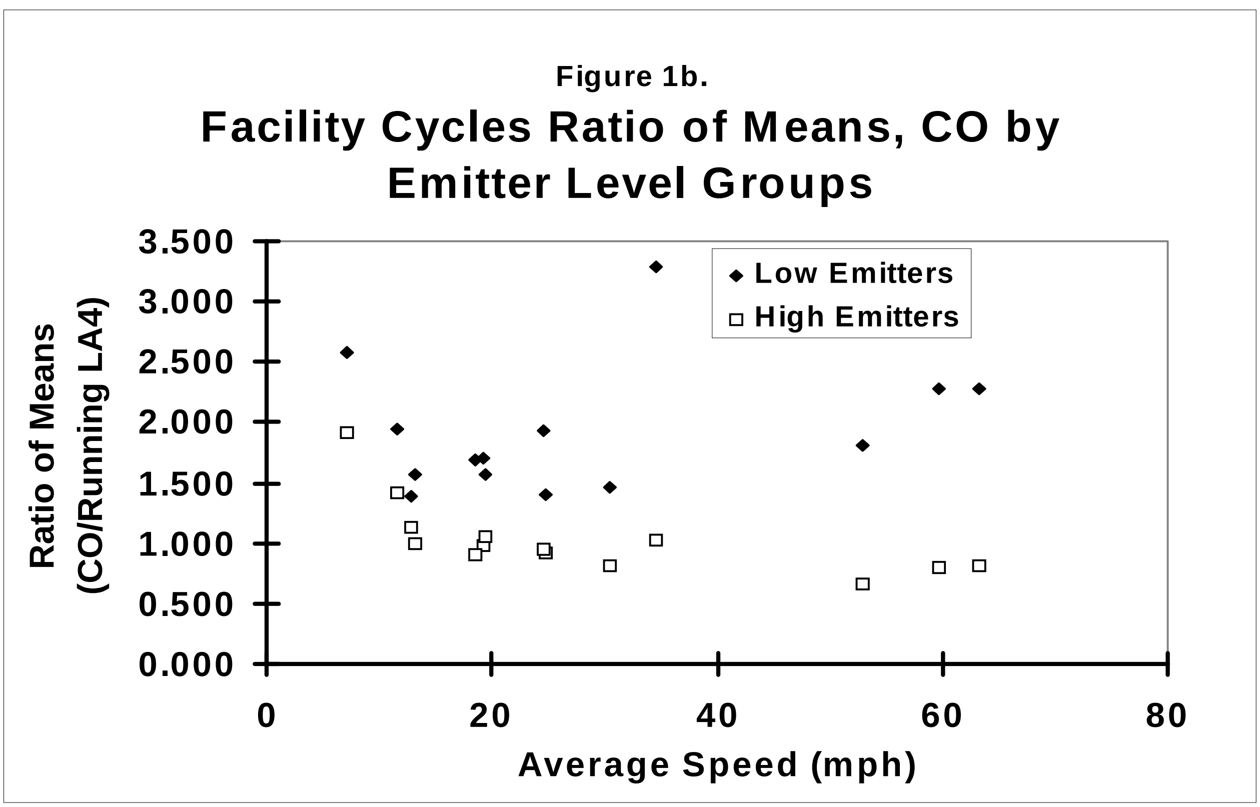


Figure 1b.
Facility Cycles Ratio of Means, CO by Emitter Level Groups
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Ratio of Means (CO/Running LA4)
Low Emitters
High Emitters
0
20
40
60
80
Average Speed (mph)

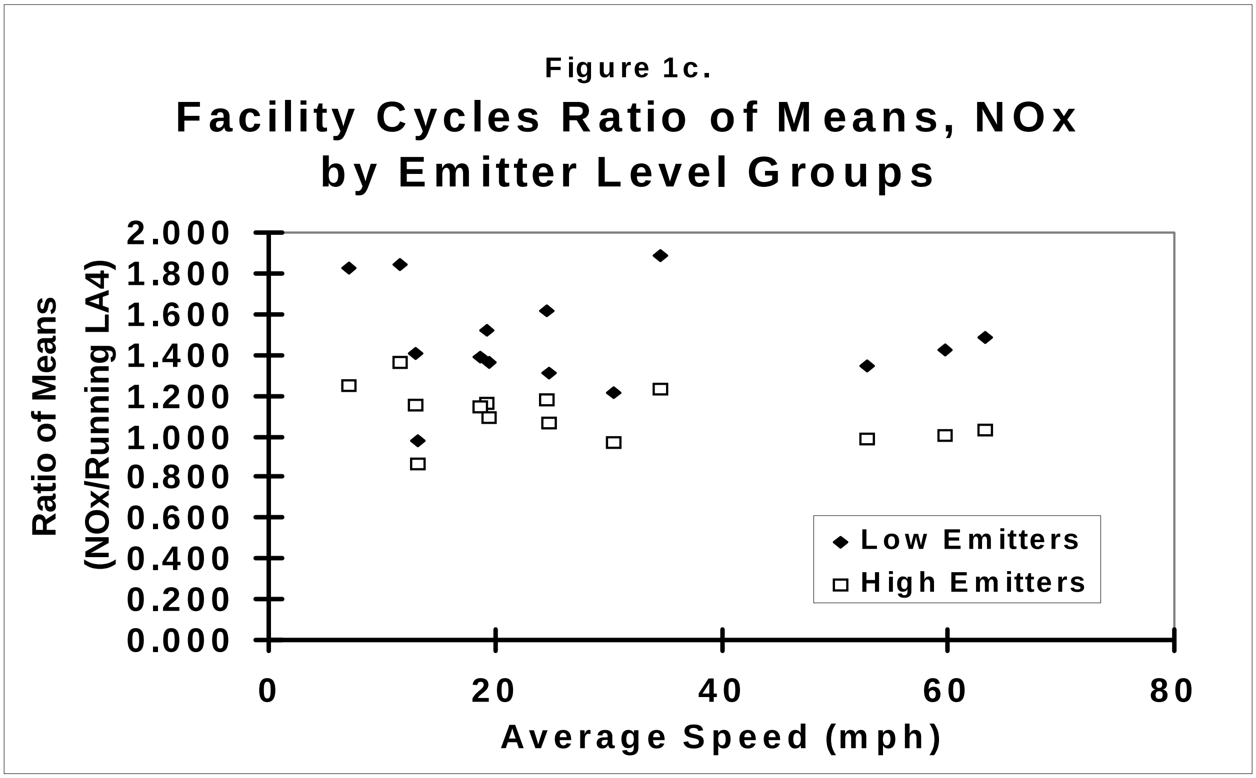


Figure 1c.
Facility Cycles Ratio of Means, NOx
by Emitter Level Groups
Ratio of Means
(NOx/Running LA4)
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
20
40
60
80
Average Speed (mph)
Low Emitters
High Emitters

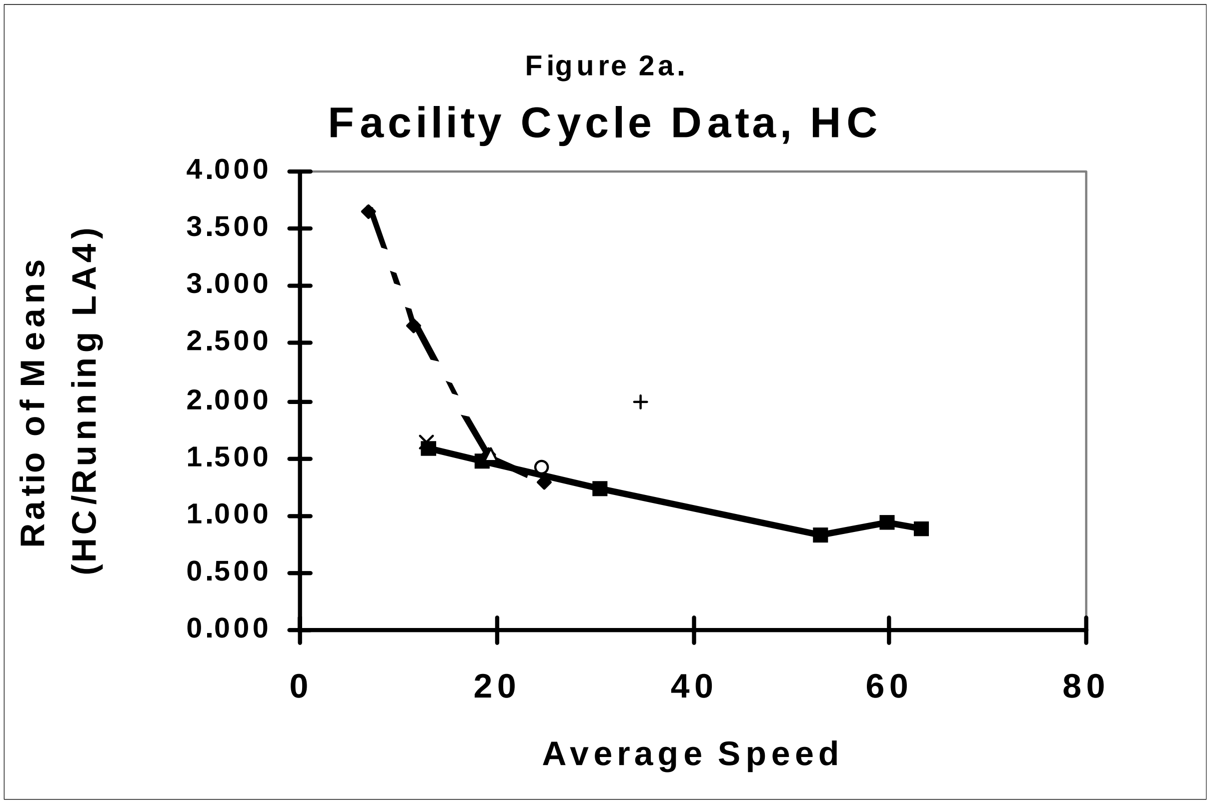
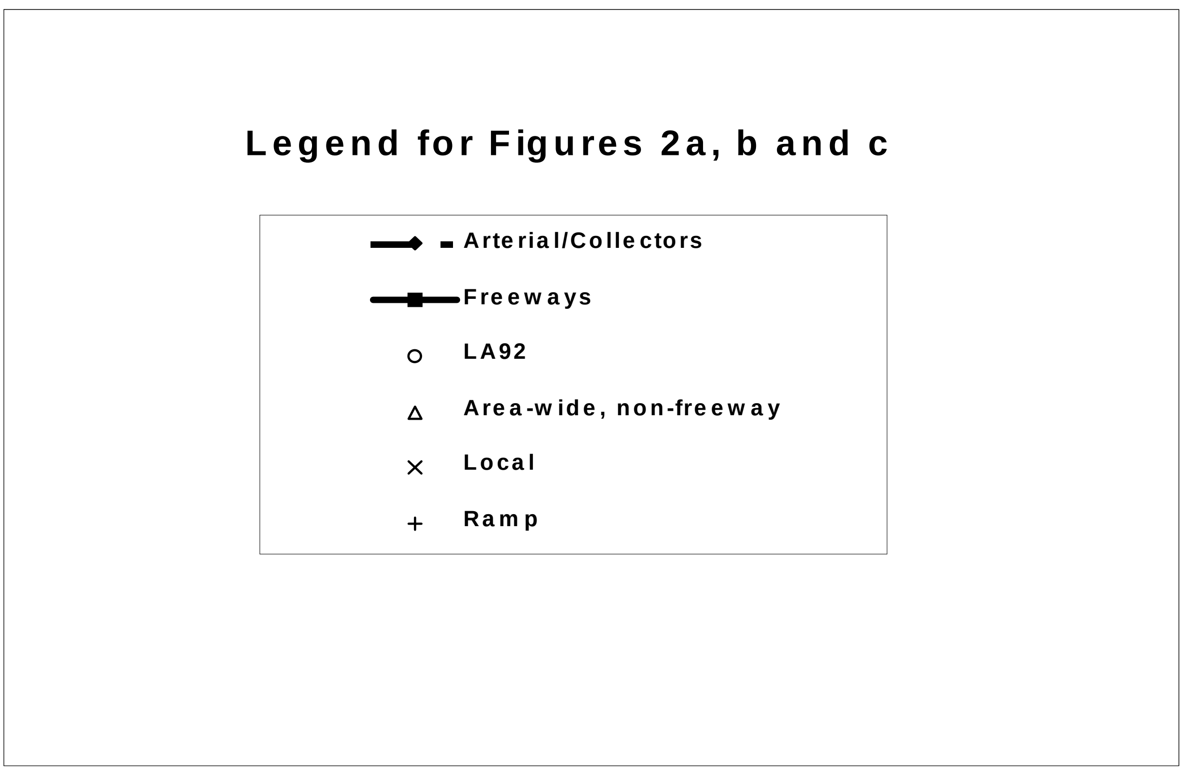


Figure 2a.
Facility Cycle Data, HC
Ratio of Means
(HC/Running LA4)
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
0
20
40
60
80
Average Speed


Legend for Figures 2a, b and c
Arterial/Collectors
Freeways
LA92
Area-wide, non-freeway
Local
Ramp

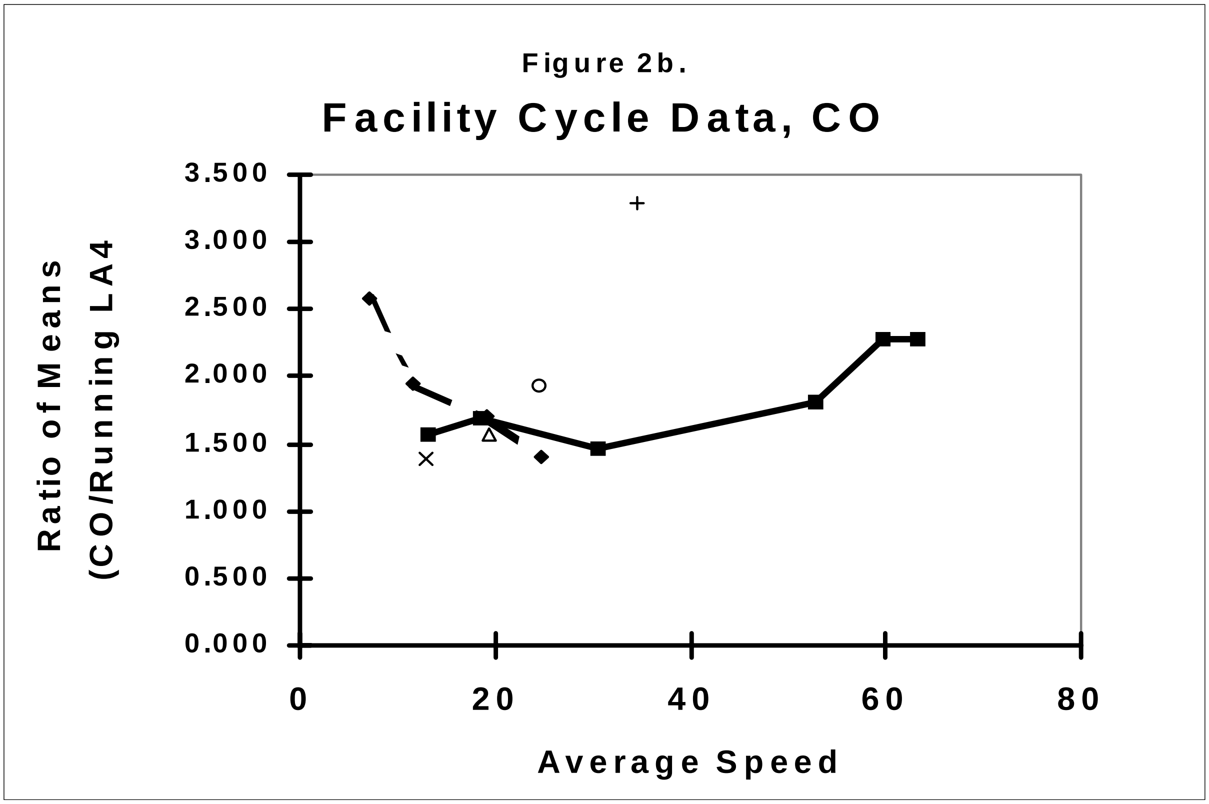


Figure 2b.
Facility Cycle Data, CO
Ratio of Means
(CO/Running LA4
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
0
20
40
60
80
Average Speed

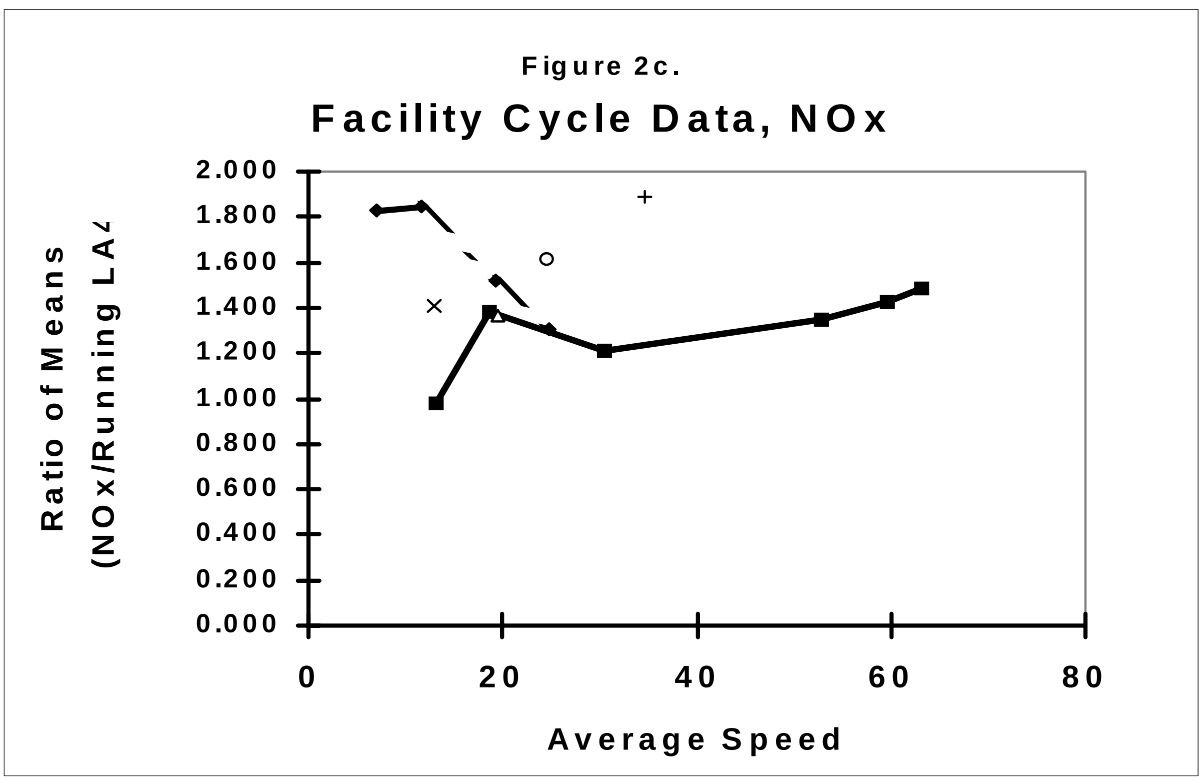
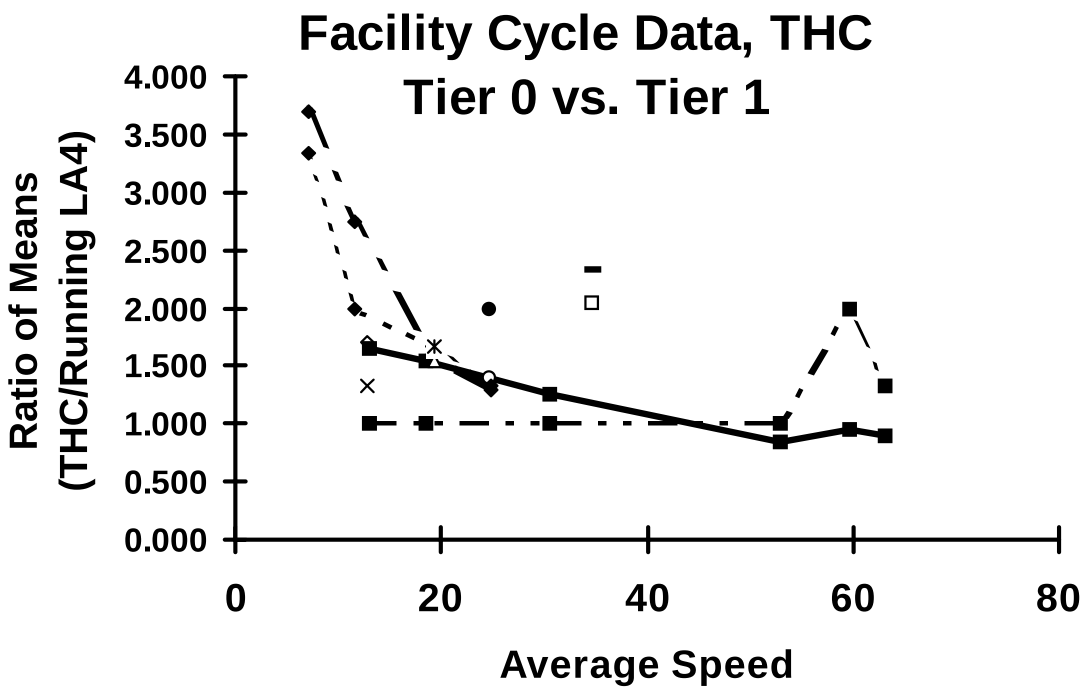
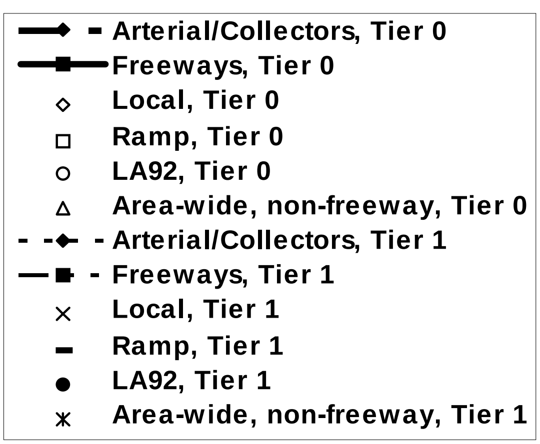


Figure 2c.
Facility Cycle Data, NOx
Ratio of Means
(NOx/Running LA4
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
20
40
60
80
Average Speed

Figure 3a.



Legend for Figures 3a, 3b and 3c



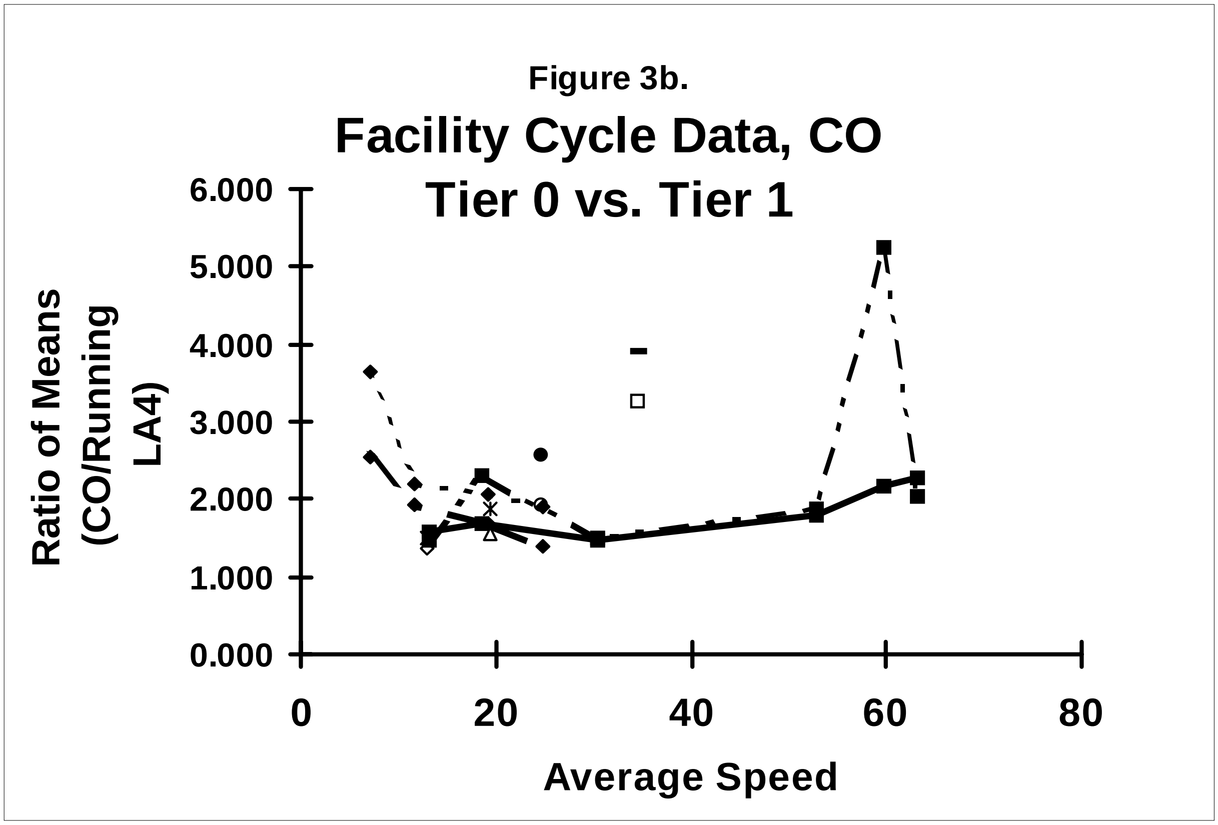


Figure 3b.
Facility Cycle Data, CO
Tier 0 vs. Tier 1
Ratio of Means (CO/Running LA4)
6.000
5.000
4.000
3.000
2.000
1.000
0.000
0
20
40
60
80
Average Speed

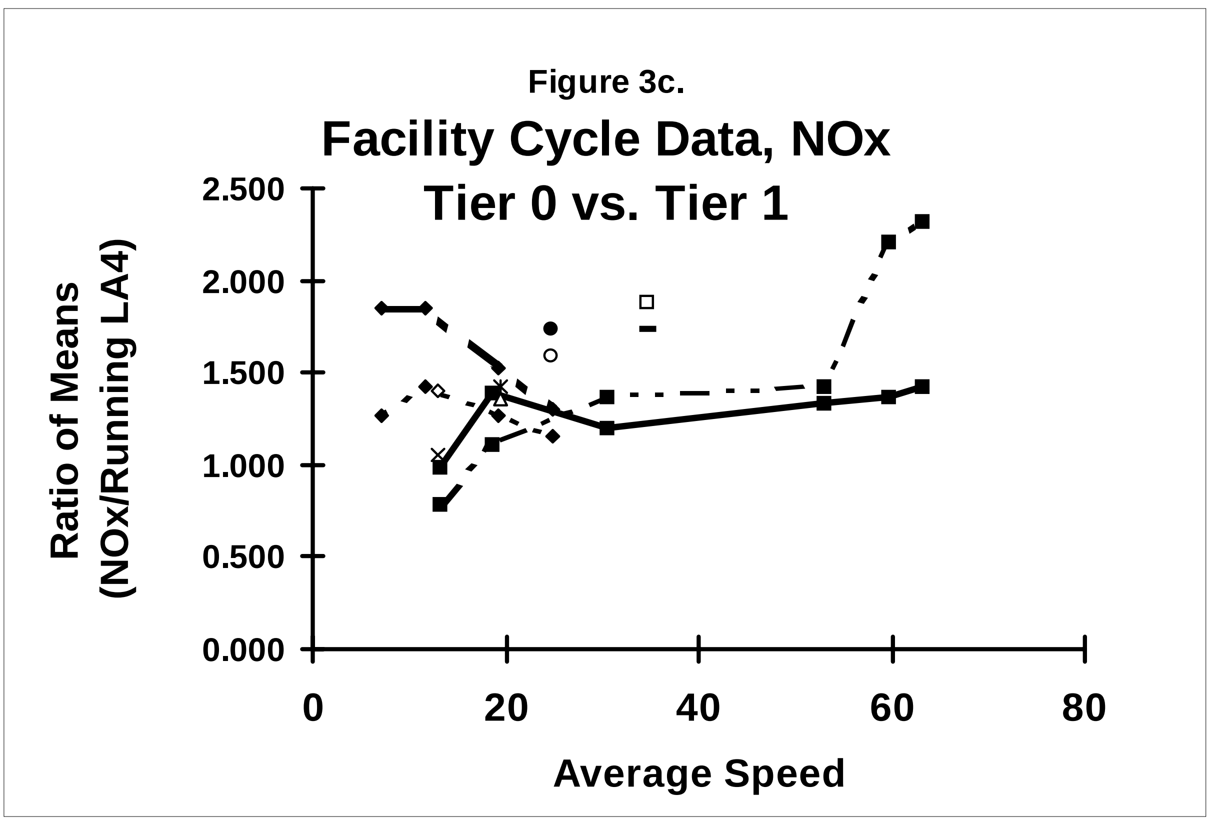


Figure 3c.
Facility Cycle Data, NOx
Tier 0 vs. Tier 1
Ratio of Means (NOx/Running LA4)
2.500
2.000
1.500
1.000
0.500
0.000
0
20
40
60
80
Average Speed

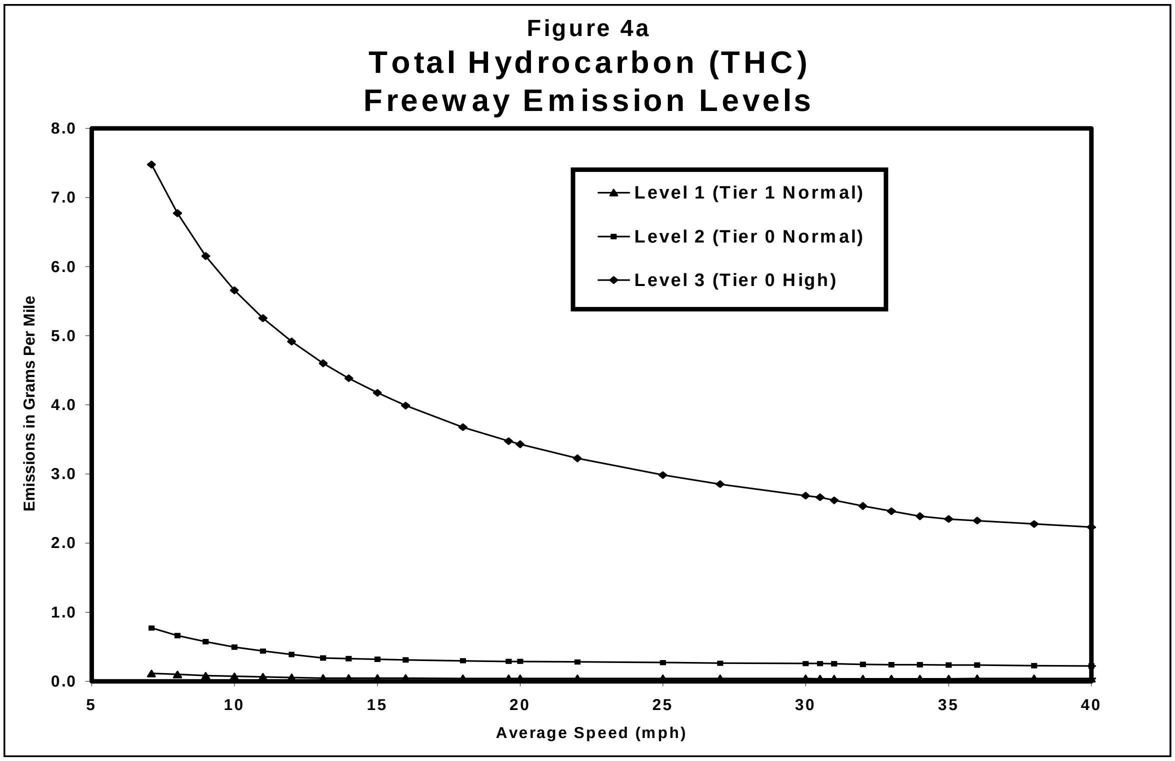


Figure 4a
Total Hydrocarbon (THC)
Freeway Emission Levels
Level 1 (Tier 1 Normal)
Level 2 (Tier 0 Normal)
Level 3 (Tier 0 High)
Emissions in Grams Per Mile
Average Speed (mph)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
5
10
15
20
25
30
35
40

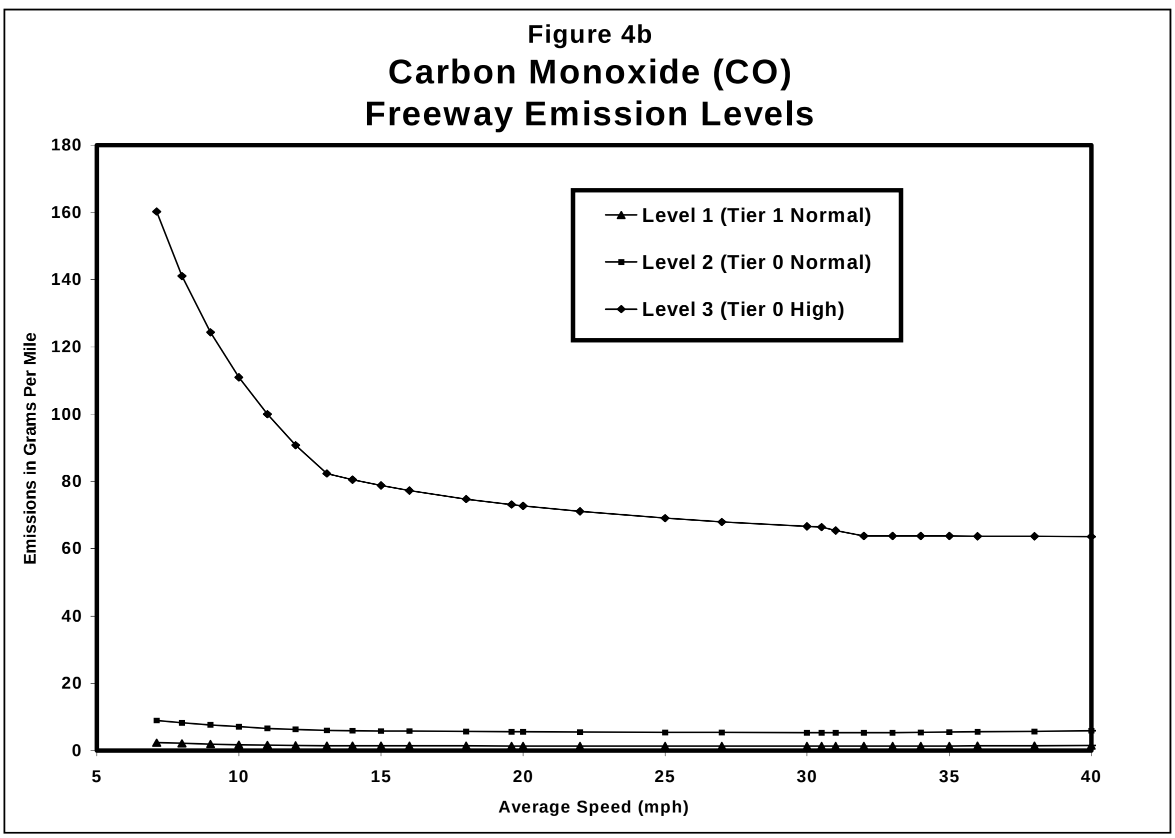


Figure 4b
Carbon Monoxide (CO)
Freeway Emission Levels
Level 1 (Tier 1 Normal)
Level 2 (Tier 0 Normal)
Level 3 (Tier 0 High)
Emissions in Grams Per Mile
Average Speed (mph)
0
20
40
60
80
100
120
140
160
180
5
10
15
20
25
30
35
40

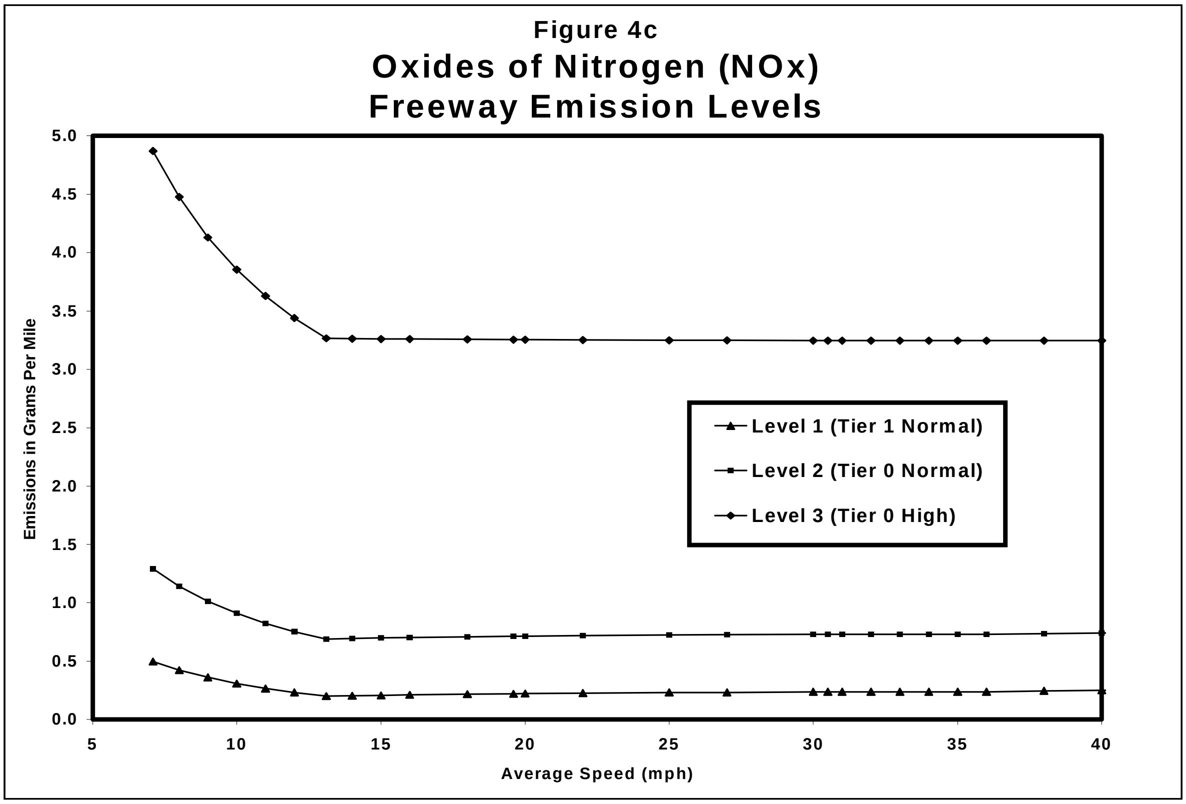


Figure 4c
Oxides of Nitrogen (NOx)
Freeway Emission Levels
Emissions in Grams Per Mile
Average Speed (mph)
Level 1 (Tier 1 Normal)
Level 2 (Tier 0 Normal)
Level 3 (Tier 0 High)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5
10
15
20
25
30
35
40

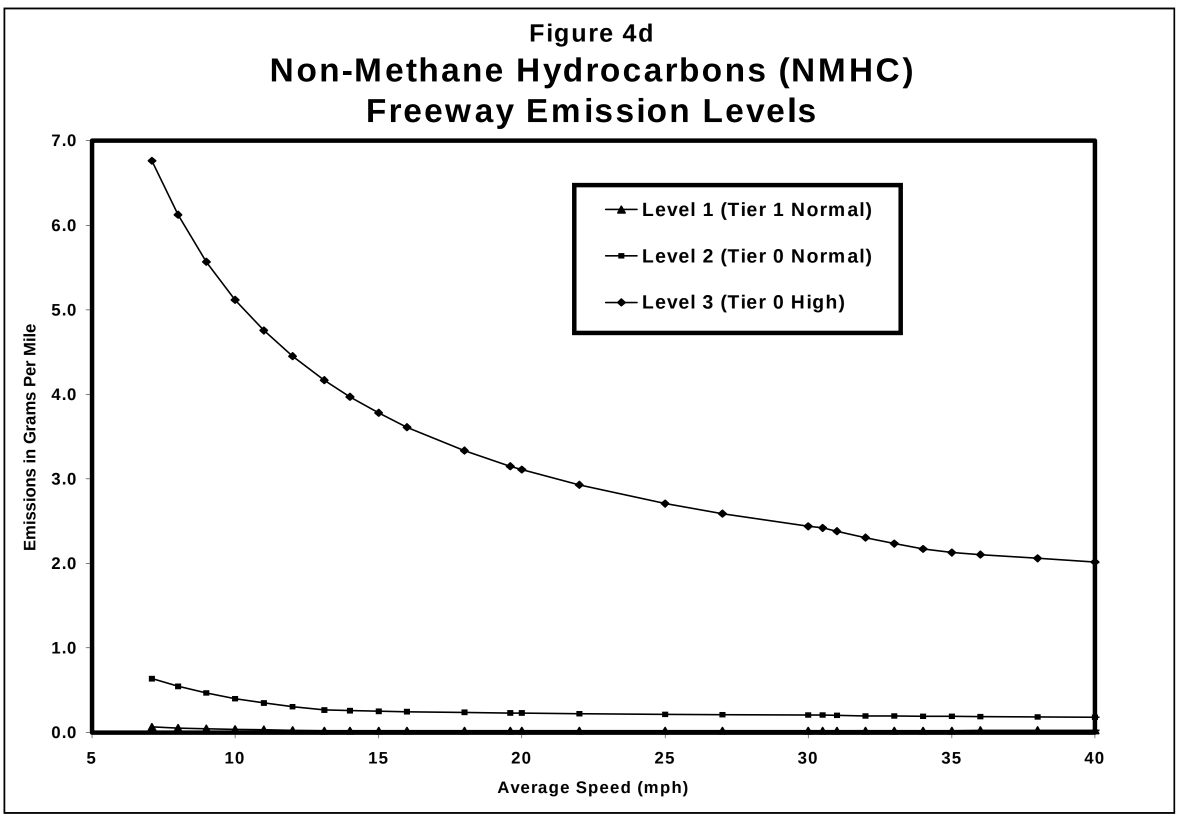


Figure 4d
Non-Methane Hydrocarbons (NMHC)
Freeway Emission Levels
Emissions in Grams Per Mile
Average Speed (mph)
Level 1 (Tier 1 Normal)
Level 2 (Tier 0 Normal)
Level 3 (Tier 0 High)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
5
10
15
20
25
30
35
40

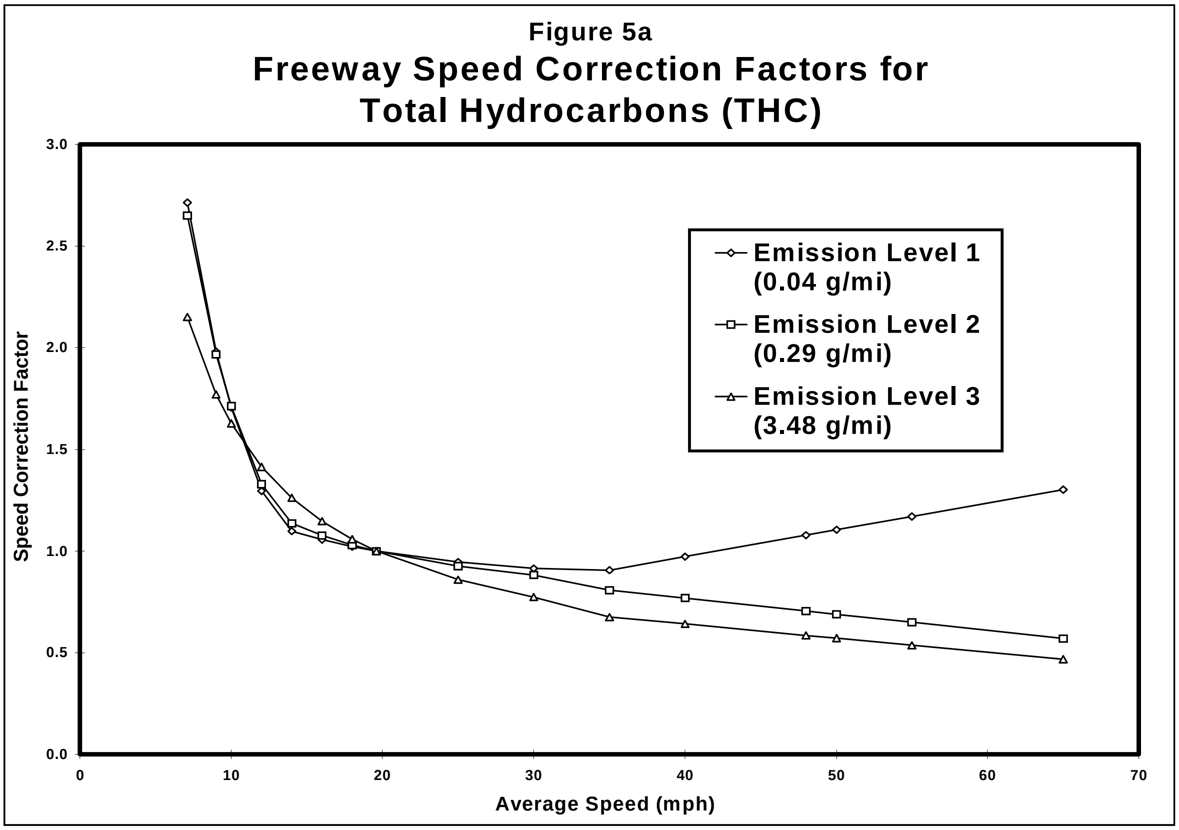


Figure 5a
Freeway Speed Correction Factors for
Total Hydrocarbons (THC)
Speed Correction Factor
Average Speed (mph)
Emission Level 1
(0.04 g/mi)
Emission Level 2
(0.29 g/mi)
Emission Level 3
(3.48 g/mi)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
10
20
30
40
50
60
70

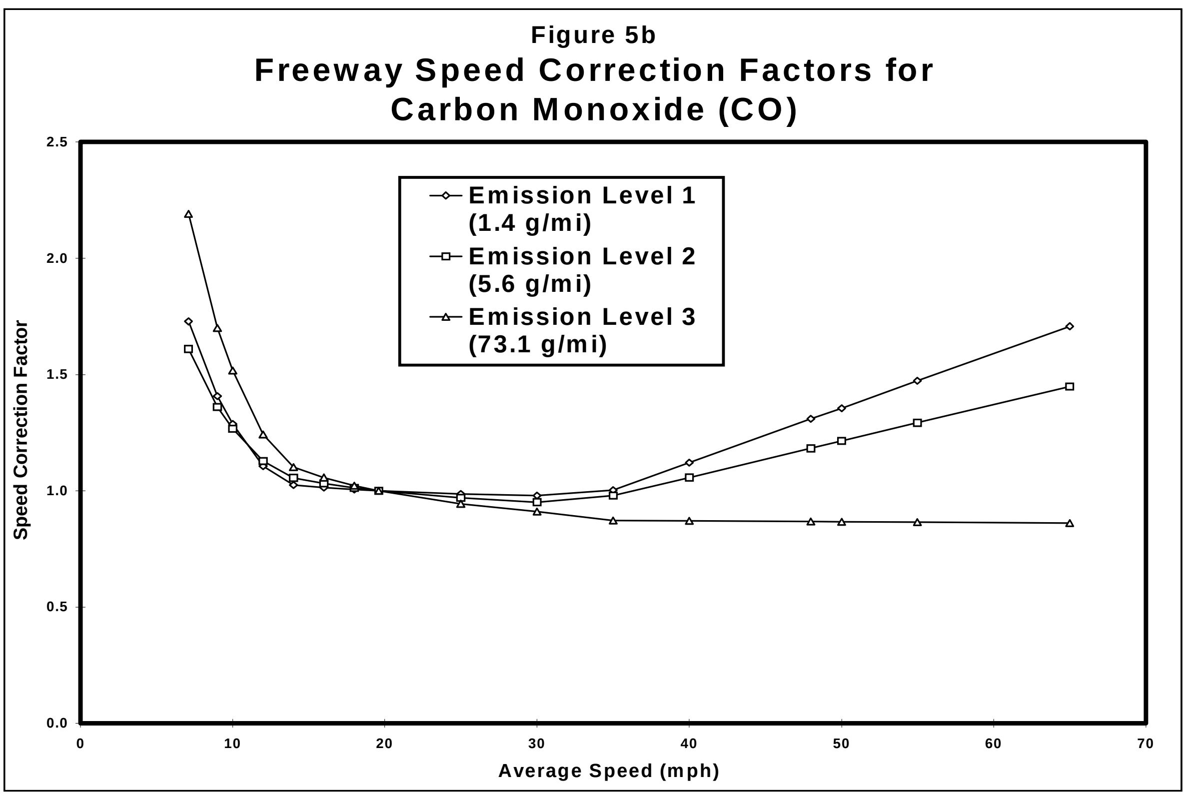


Figure 5b
Freeway Speed Correction Factors for
Carbon Monoxide (CO)
Speed Correction Factor
Average Speed (mph)
Emission Level 1
(1.4 g/mi)
Emission Level 2
(5.6 g/mi)
Emission Level 3
(73.1 g/mi)
0.0
0.5
1.0
1.5
2.0
2.5
0
10
20
30
40
50
60
70

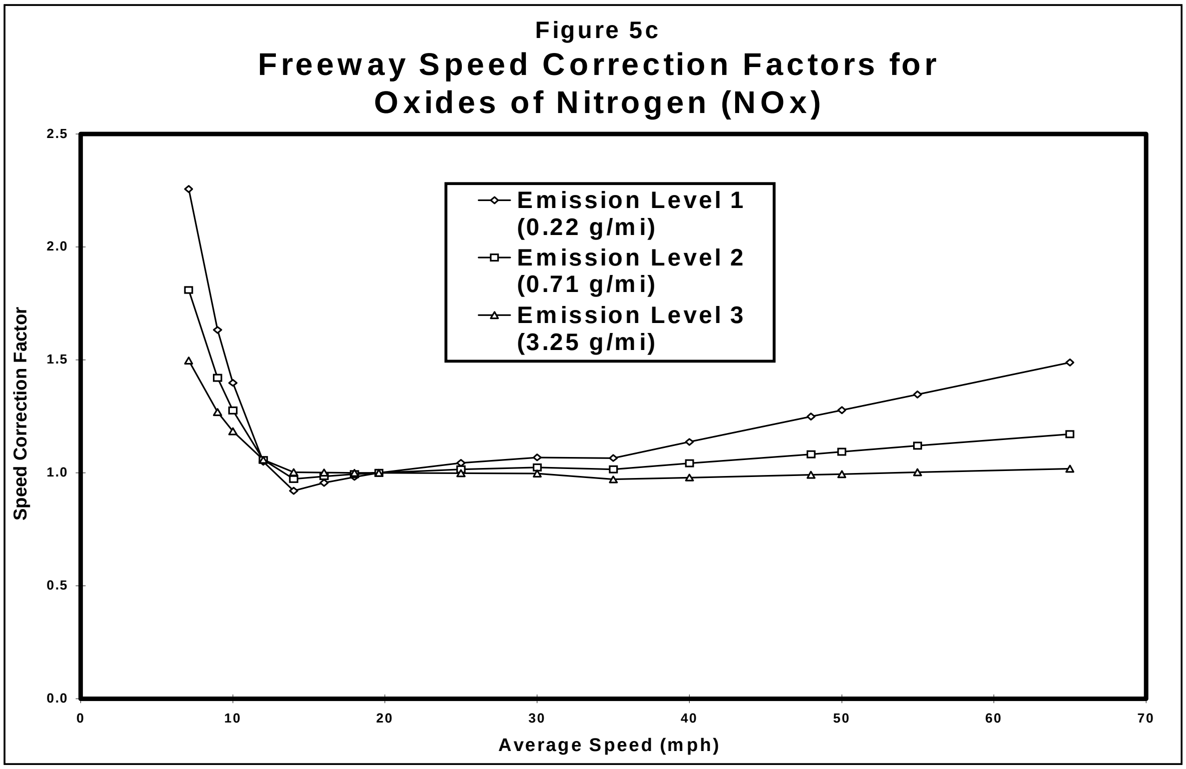


Figure 5c
Freeway Speed Correction Factors for
Oxides of Nitrogen (NOx)
Emission Level 1
(0.22 g/mi)
Emission Level 2
(0.71 g/mi)
Emission Level 3
(3.25 g/mi)
Speed Correction Factor
Average Speed (mph)
0.0
0.5
1.0
1.5
2.0
2.5
0
10
20
30
40
50
60
70

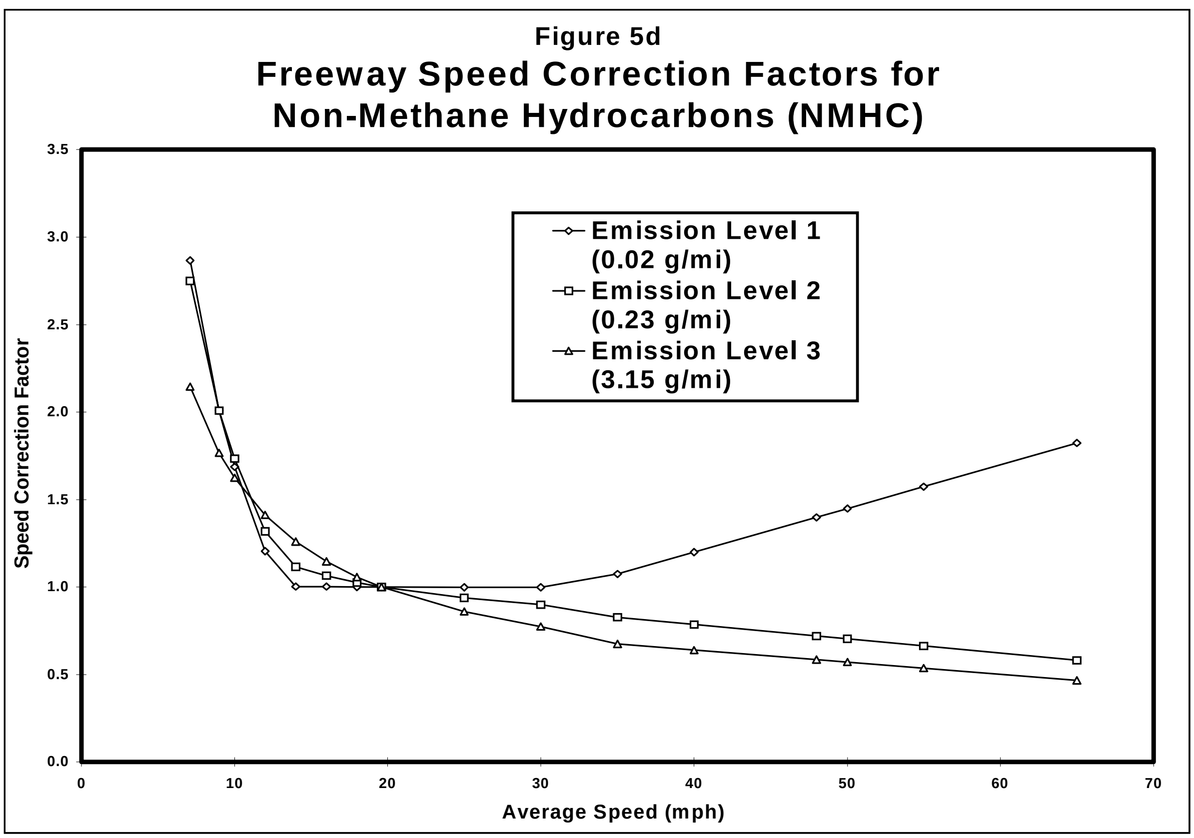


Figure 5d
Freeway Speed Correction Factors for
Non-Methane Hydrocarbons (NMHC)
Emission Level 1
(0.02 g/mi)
Emission Level 2
(0.23 g/mi)
Emission Level 3
(3.15 g/mi)
Speed Correction Factor
Average Speed (mph)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
10
20
30
40
50
60
70

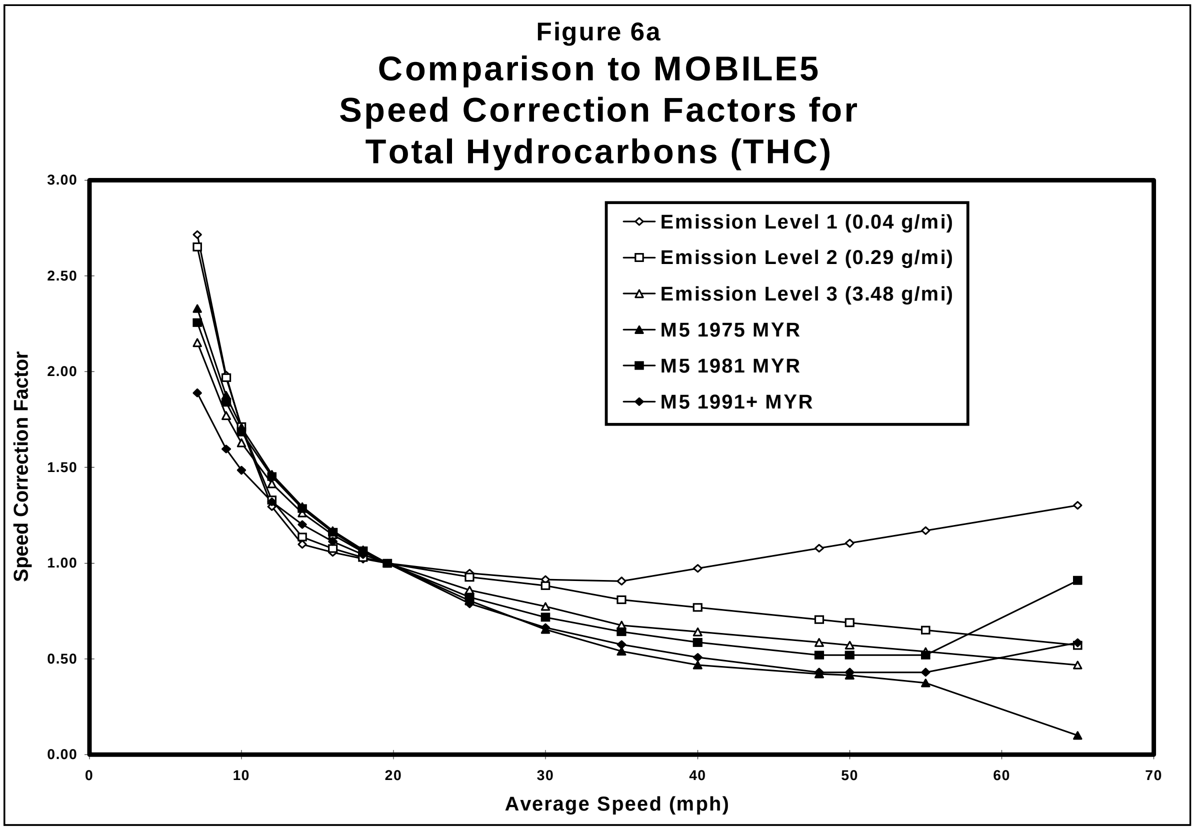


Figure 6a
Comparison to MOBILE5
Speed Correction Factors for
Total Hydrocarbons (THC)
Emission Level 1 (0.04 g/mi)
Emission Level 2 (0.29 g/mi)
Emission Level 3 (3.48 g/mi)
M5 1975 MYR
M5 1981 MYR
M5 1991+ MYR
Speed Correction Factor
Average Speed (mph)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
0
10
20
30
40
50
60
70

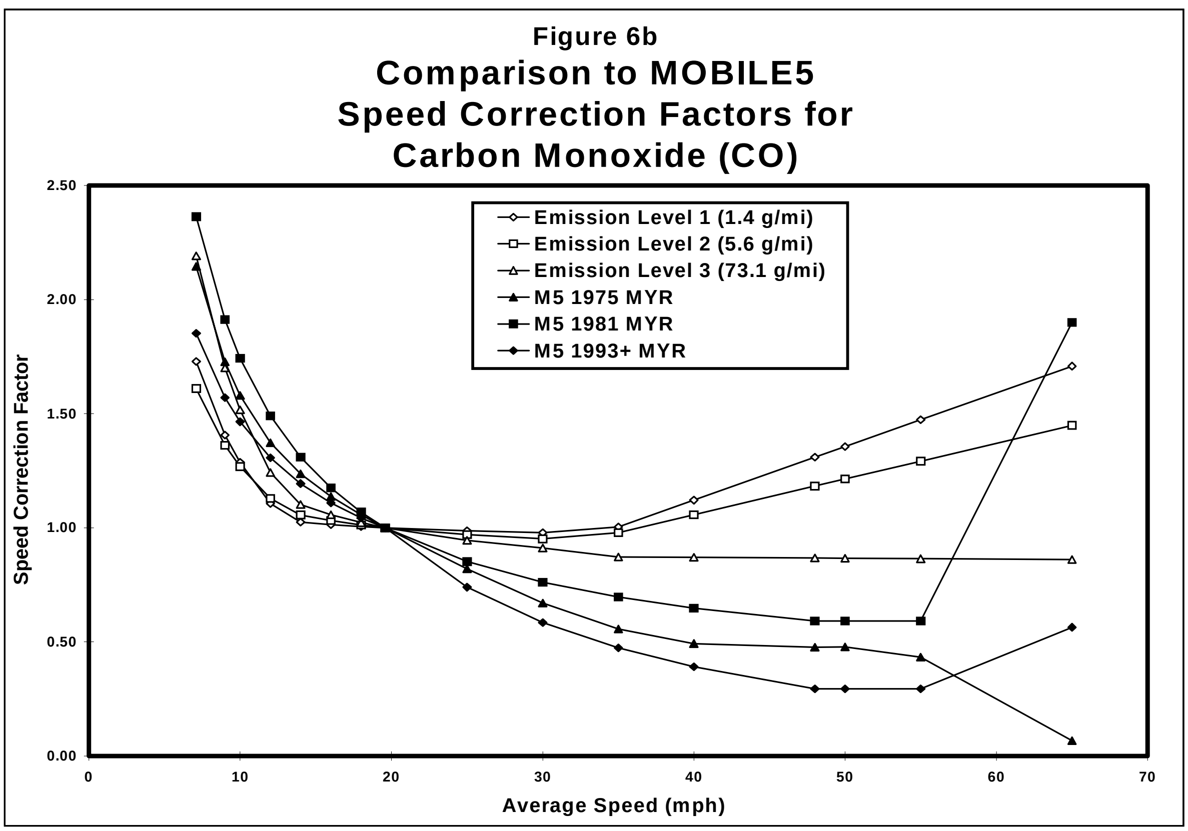


Figure 6b
Comparison to MOBILE5
Speed Correction Factors for
Carbon Monoxide (CO)
Emission Level 1 (1.4 g/mi)
Emission Level 2 (5.6 g/mi)
Emission Level 3 (73.1 g/mi)
M5 1975 MYR
M5 1981 MYR
M5 1993+ MYR
Speed Correction Factor
Average Speed (mph)
0.00
0.50
1.00
1.50
2.00
2.50
0
10
20
30
40
50
60
70

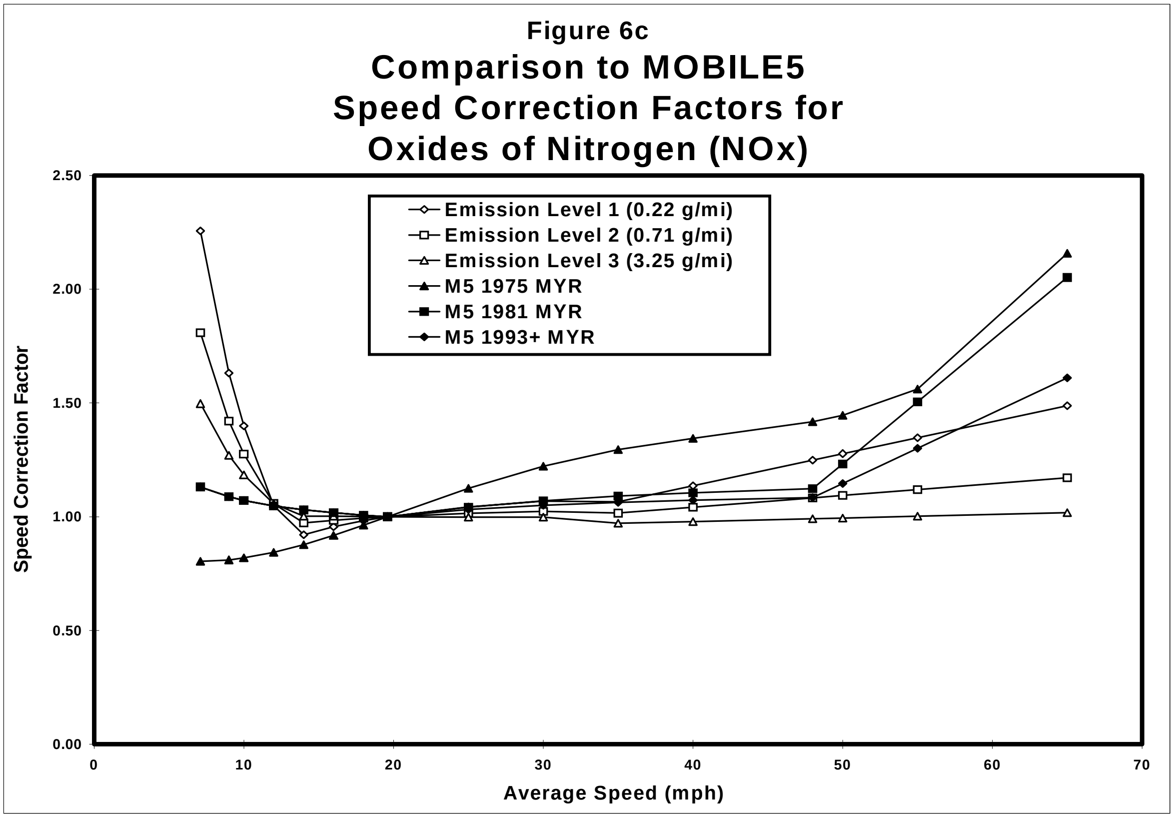


Figure 6c
Comparison to MOBILE5
Speed Correction Factors for
Oxides of Nitrogen (NOx)
Emission Level 1 (0.22 g/mi)
Emission Level 2 (0.71 g/mi)
Emission Level 3 (3.25 g/mi)
M5 1975 MYR
M5 1981 MYR
M5 1993+ MYR
Speed Correction Factor
Average Speed (mph)
0.00
0.50
1.00
1.50
2.00
2.50
0
10
20
30
40
50
60
70

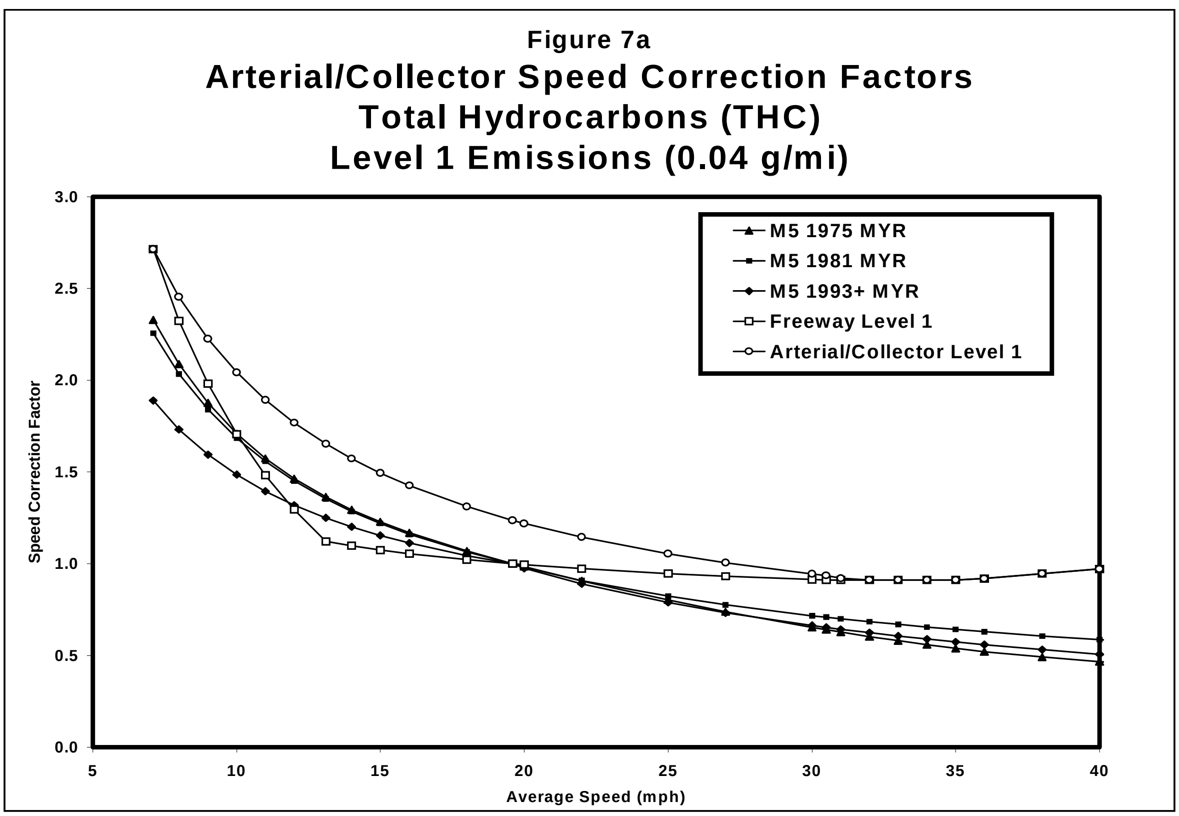


Figure 7a
Arterial/Collector Speed Correction Factors
Total Hydrocarbons (THC)
Level 1 Emissions (0.04 g/mi)
M5 1975 MYR
M5 1981 MYR
M5 1993+ MYR
Freeway Level 1
Arterial/Collector Level 1
Speed Correction Factor
Average Speed (mph)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
5
10
15
20
25
30
35
40

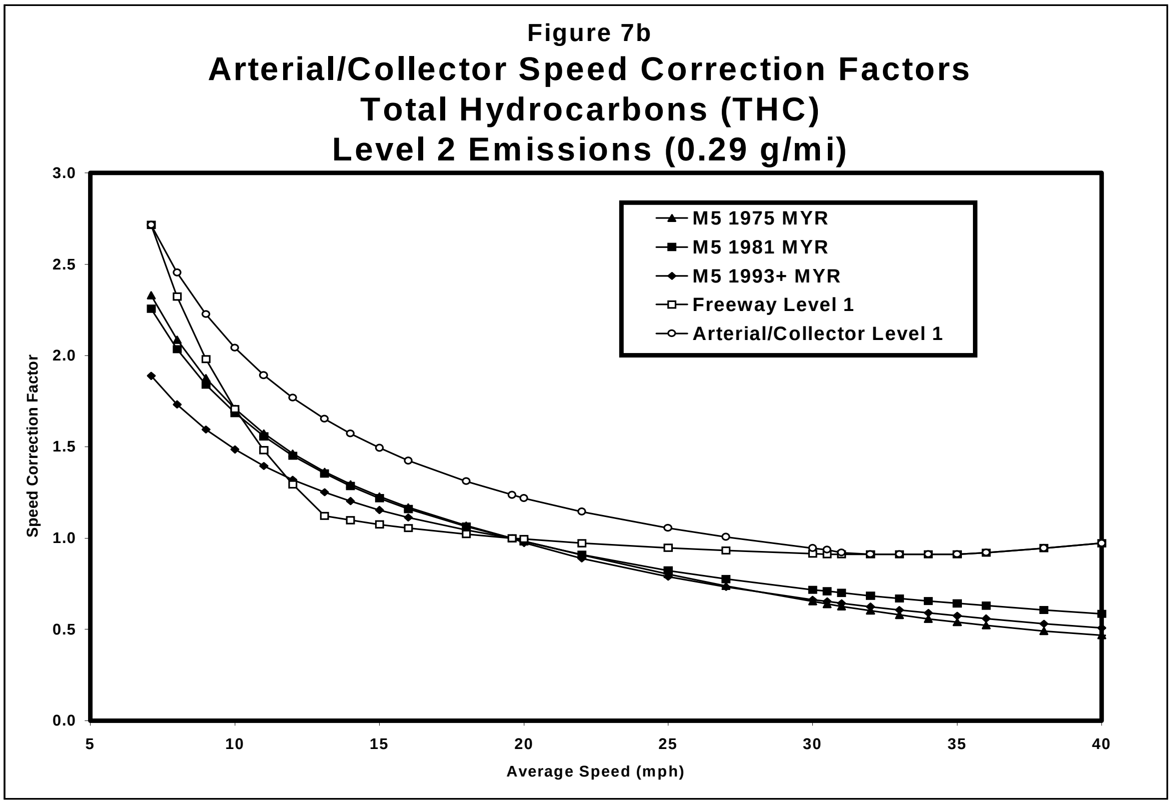


Figure 7b
Arterial/Collector Speed Correction Factors
Total Hydrocarbons (THC)
Level 2 Emissions (0.29 g/mi)
M5 1975 MYR
M5 1981 MYR
M5 1993+ MYR
Freeway Level 1
Arterial/Collector Level 1
Speed Correction Factor
Average Speed (mph)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
5
10
15
20
25
30
35
40

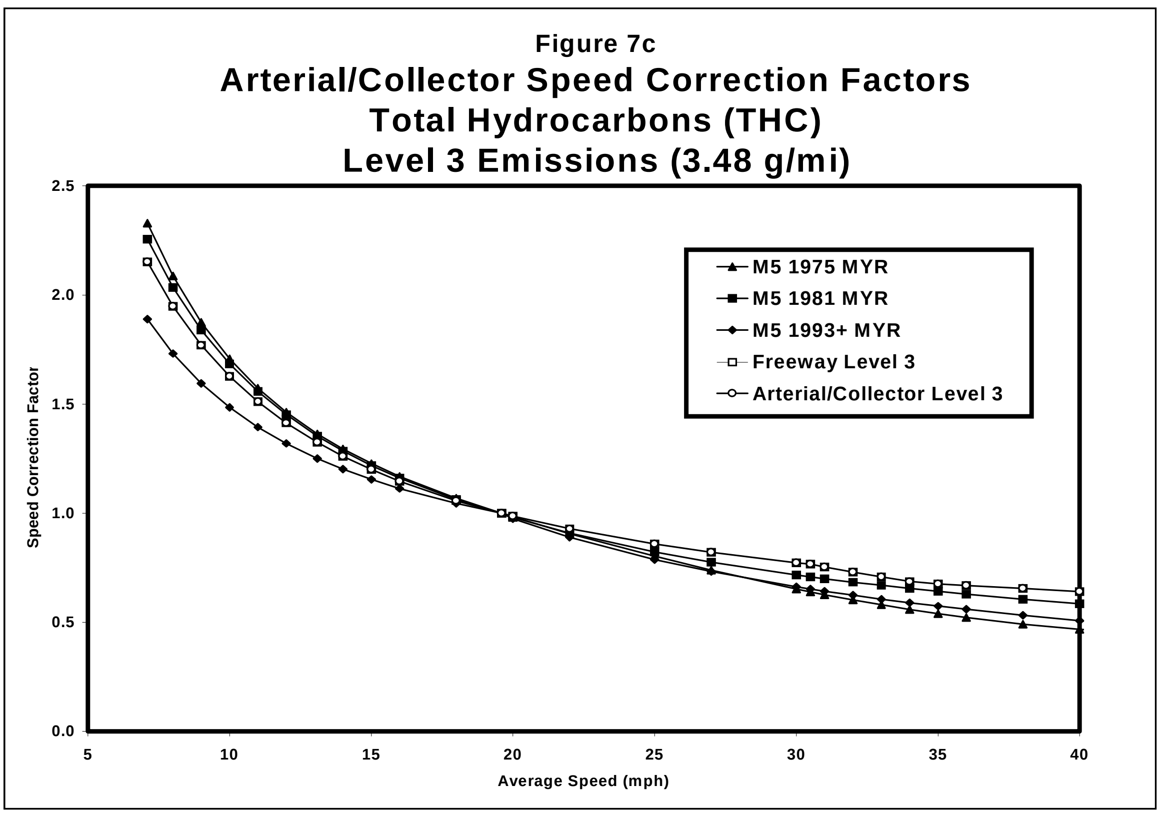


Figure 7c
Arterial/Collector Speed Correction Factors
Total Hydrocarbons (THC)
Level 3 Emissions (3.48 g/mi)
M5 1975 MYR
M5 1981 MYR
M5 1993+ MYR
Freeway Level 3
Arterial/Collector Level 3
Speed Correction Factor
Average Speed (mph)
0.0
0.5
1.0
1.5
2.0
2.5
5
10
15
20
25
30
35
40

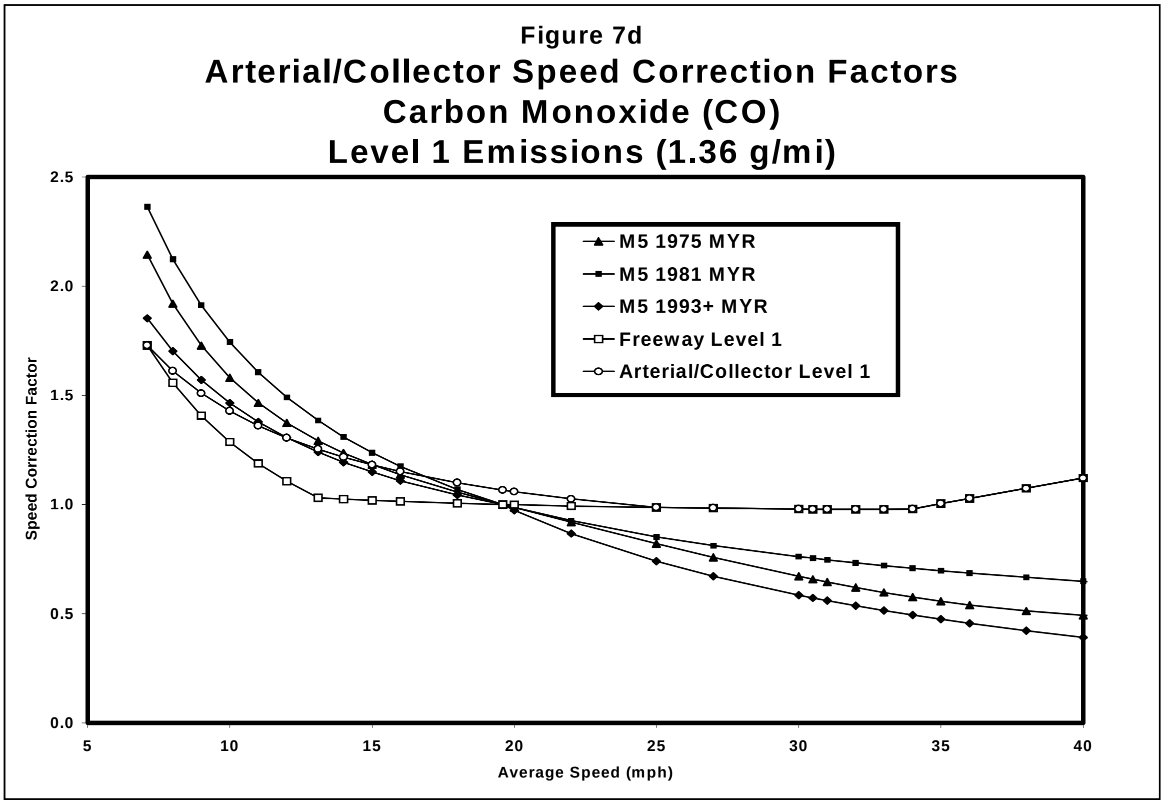


Figure 7d
Arterial/Collector Speed Correction Factors
Carbon Monoxide (CO)
Level 1 Emissions (1.36 g/mi)
M5 1975 MYR
M5 1981 MYR
M5 1993+ MYR
Freeway Level 1
Arterial/Collector Level 1
Speed Correction Factor
Average Speed (mph)
0.0
0.5
1.0
1.5
2.0
2.5
5
10
15
20
25
30
35
40

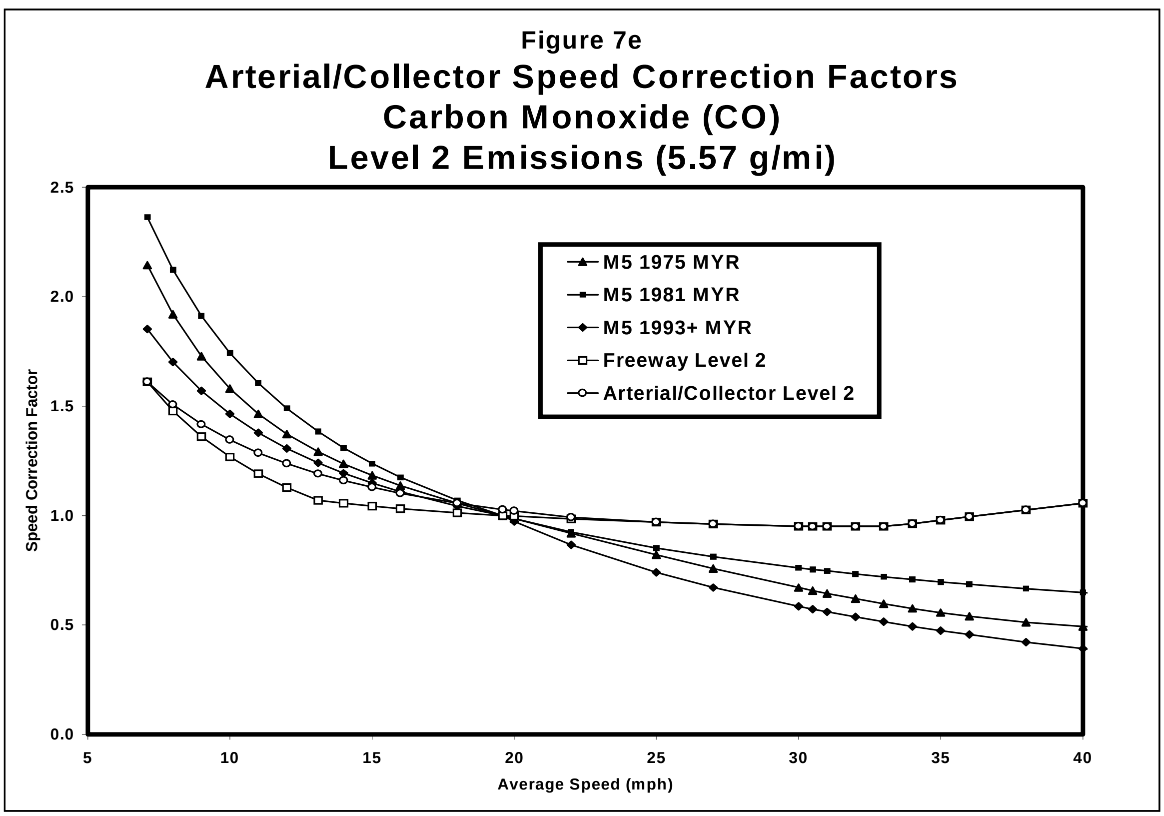


Figure 7e
Arterial/Collector Speed Correction Factors
Carbon Monoxide (CO)
Level 2 Emissions (5.57 g/mi)
M5 1975 MYR
M5 1981 MYR
M5 1993+ MYR
Freeway Level 2
Arterial/Collector Level 2
Speed Correction Factor
Average Speed (mph)
0.0
0.5
1.0
1.5
2.0
2.5
5
10
15
20
25
30
35
40

Figure 7f
Arterial/Collector Speed Correction Factors
Carbon Monoxide (CO)
Level 3 Emissions (73.1 g/mi)

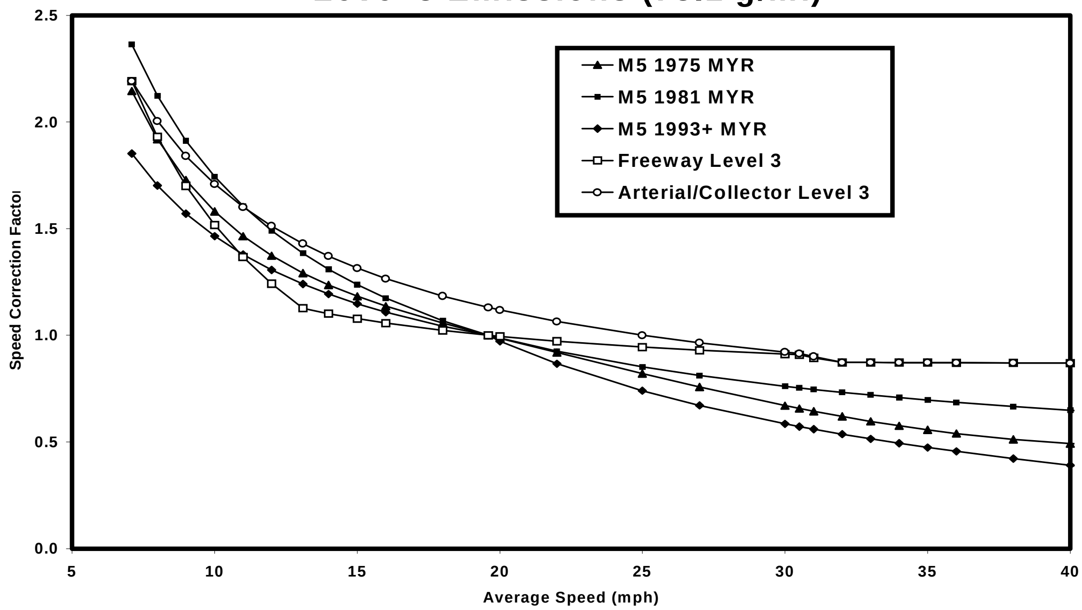


Figure 7g
Arterial/Collector Speed Correction Factors
Oxides of Nitrogen (NOx)
Level 1 Emissions (0.22 g/mi)

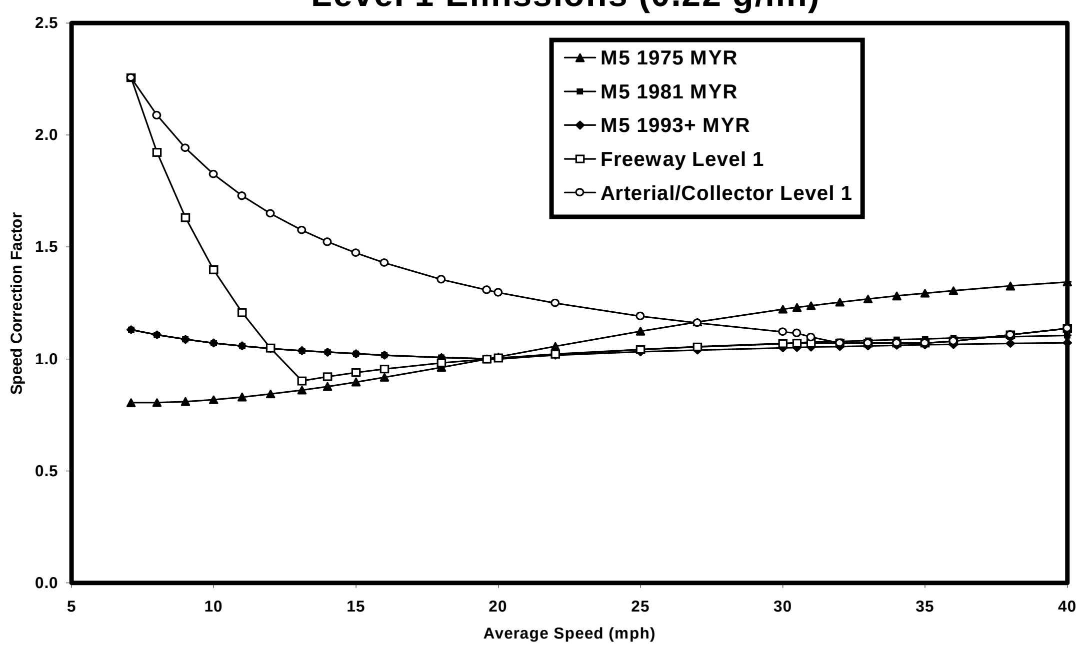


Figure 7h

Arterial/Collector Speed Correction Factors
Oxides of Nitrogen (NOx)
Level 2 Emissions (0.71 g/mi)

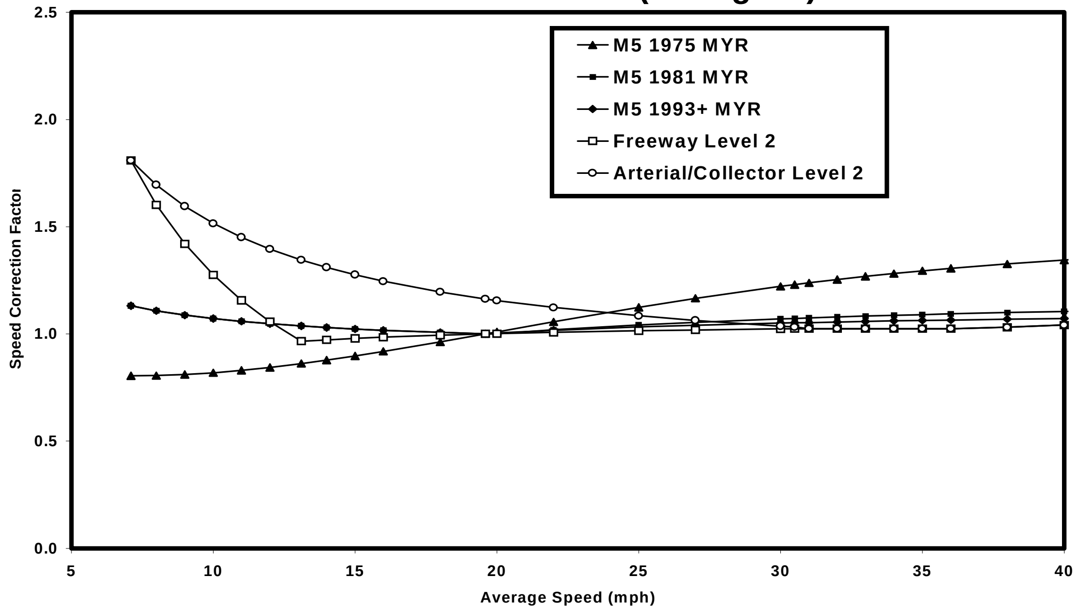
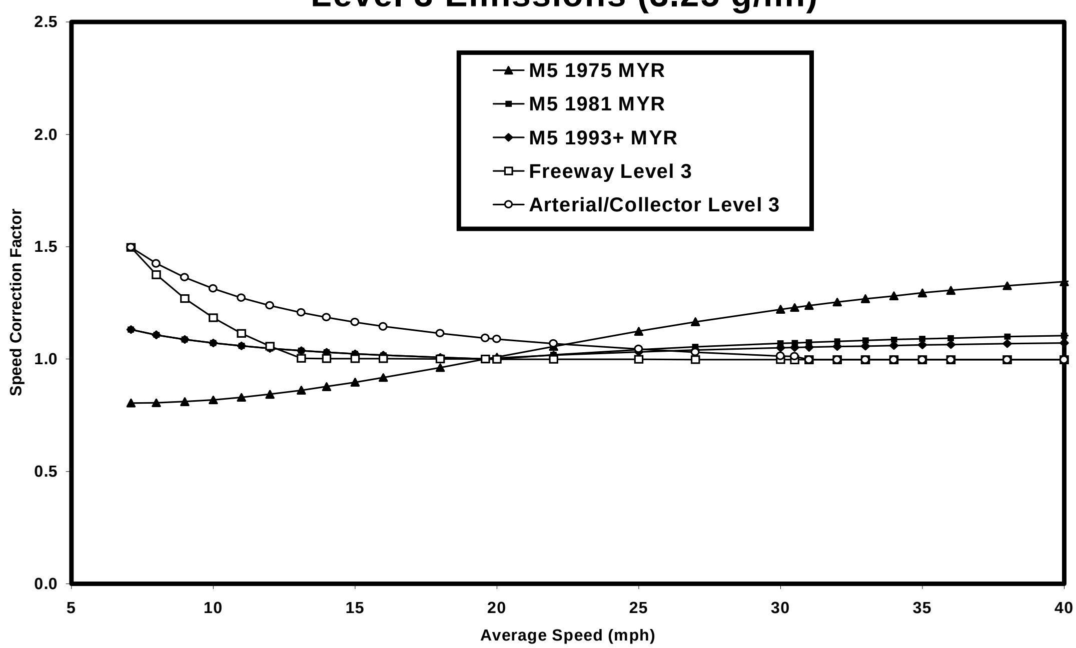


Figure 7i

Arterial/Collector Speed Correction Factors
Oxides of Nitrogen (NOx)
Level 3 Emissions (3.25 g/mi)



Appendices

Appendix A

MAIN EFFECTS & INTERACTIONS WITH SPEED

All Vehicles

FACTOR	THC	NMHC	CO	NOX
S	0.0000	0.0001	0.0000	0.0000
EMIT_CLASS	0.0000	0.0000	0.0000	0.0000
S*EMIT_CLASS	0.1411	0.1271	0.0152	0.9894

EMIT NORMAL - ACTUAL TIER CLASS

ROAD	FACTOR	THC	NMHC	CO	NOX
ART/FWY	ROADTYPE	0.0046	0.0050	0.0006	0.0000
	S*ROADTYPE	0.0354	0.0440	0.0020	0.0000
	VEH_TYPE	0.0016	0.0404	0.0031	0.0012
	S*VEH_TYPE	0.1754	0.1802	0.8680	0.5723
	STANDARD	0.0000	0.0000	0.0000	0.0000
	S*STANDARD	0.0002	0.0001	0.0576	0.6491
LOCAL	VEH_TYPE	0.0830	0.5008	0.4038	0.0124
	STANDARD	0.0000	0.0000	0.0000	0.0028
RAMP	VEH_TYPE	0.2922	0.7707	0.0443	0.0018
	STANDARD	0.0003	0.0007	0.0002	0.0000

EMIT HIGH - ACTUAL TIER CLASS

ROAD	FACTOR	THC	NMHC	CO	NOX
ART/FWY	ROADTYPE	0.1236	0.1307	0.3307	0.0000
	S*ROADTYPE	0.1176	0.1203	0.6233	0.0000
	VEH_TYPE	0.5942	0.5693	0.8984	0.3961
	S*VEH_TYPE	0.0641	0.0699	0.0241	0.9560
	STANDARD	N/A	N/A	N/A	N/A
	S*STANDARD	N/A	N/A	N/A	N/A
LOCAL	VEH_TYPE	0.8787	0.8821	0.5511	0.6093
	STANDARD	N/A	N/A	N/A	N/A
RAMP	VEH_TYPE	0.3701	0.4075	0.1471	0.6942
	STANDARD	N/A	N/A	N/A	N/A

EMIT NORMAL - CLEAN TIER 0 CLASS

ROAD	FACTOR	THC	NMHC	CO	NOX
ART/FWY	ROADTYPE	0.0046	0.0050	0.0006	0.0000
	S*ROADTYPE	0.0354	0.0440	0.0020	0.0000
	VEH_TYPE	0.0004	0.0243	0.0062	0.0026
	S*VEH_TYPE	0.1322	0.1476	0.8361	0.5608
	CLEANT0	0.0000	0.0000	0.0000	0.0000
	S*CLEANT0	0.0002	0.0001	0.0576	0.6491
LOCAL	VEH_TYPE	0.0572	0.4049	0.1660	0.0184
	CLEANT0	0.0000	0.0000	0.0000	0.0028
RAMP	VEH_TYPE	0.1570	0.5501	0.0201	0.0009
	CLEANT0	0.0003	0.0007	0.0002	0.0000

EMIT HIGH - CLEAN TIER 0 CLASS

ROAD	FACTOR	THC	NMHC	CO	NOX
ART/FWY	ROADTYPE	0.1236	0.1307	0.3307	0.0000
	S*ROADTYPE	0.1176	0.1203	0.6233	0.0000
	VEH_TYPE	0.5942	0.5693	0.8984	0.3961
	S*VEH_TYPE	0.0641	0.0699	0.0241	0.9560
	CLEANT0	.	.	.	.
	S*CLEANT0	.	.	.	.
LOCAL	VEH_TYPE	0.8787	0.8821	0.5511	0.6093
	CLEANT0	.	.	.	.
RAMP	VEH_TYPE	0.3701	0.4075	0.1471	0.6942
	CLEANT0	.	.	.	.

EMIT NORMAL

ROAD	FACTOR	THC PROB	NMHC PROB	CO PROB	NOX PROB
ART/FWY	ROADWAY TYPE	0.0001	0.0000	0.0405	0.0000
	VEHICLE CLASS	0.0000	0.0640	0.0000	0.0000
	STANDARD	0.0000	0.0000	0.0000	0.0000
LOCAL	VEHICLE CLASS	0.1017	0.5022	0.1380	0.0408
	STANDARD	0.0000	0.0000	0.0000	0.0000
RAMP	VEHICLE CLASS	0.2047	0.6109	0.0213	0.0035
	STANDARD	0.0000	0.0000	0.0000	0.0000

EMIT HIGH

ROAD	FACTOR	THC PROB	NMHC PROB	CO PROB	NOX PROB
ART/FWY	ROADWAY TYPE	0.9736	0.9570	0.0151	0.0201
	VEHICLE CLASS	0.0667	0.0873	0.0004	0.1444
	STANDARD	.	.	.	.

Note: these probabilities are for tests of factor main effects, not interactions with speed.

EMIT NORMAL - CLEAN TIER 0 CLASS

ROAD	FACTOR	THC	NMHC	CO	NOX
ART/FWY	ROADTYPE	0.0001	0.0000	0.0405	0.0000
	VEH_TYPE	0.0000	0.0186	0.0000	0.0000
	STANDARD	0.0000	0.0000	0.0000	0.0000
LOCAL	VEH_TYPE	0.0572	0.4049	0.1660	0.0184
	STANDARD	0.0000	0.0000	0.0000	0.0028
RAMP	VEH_TYPE	0.1570	0.5501	0.0201	0.0009
	STANDARD	0.0003	0.0007	0.0002	0.0000

EMIT NORMAL - ACTUAL TIER CLASS

ROAD	FACTOR	THC	NMHC	CO	NOX
ART/FWY	ROADTYPE	0.0001	0.0000	0.0405	0.0000
	VEH_TYPE	0.0000	0.0686	0.0001	0.0000
	STANDARD	0.0000	0.0000	0.0000	0.0000
LOCAL	VEH_TYPE	0.0830	0.5008	0.4038	0.0124
	STANDARD	0.0002	0.0001	0.0000	0.0024
RAMP	VEH_TYPE	0.2922	0.7707	0.0443	0.0018
	STANDARD	0.0013	0.0002	0.0001	0.0010

EMIT HIGH

ROAD	FACTOR	THC	NMHC	CO	NOX
ART/FWY	ROADTYPE	0.9736	0.9570	0.0151	0.0201
	VEH_TYPE	0.0667	0.0873	0.0004	0.1444
	STANDARD	.	.	.	.
LOCAL	VEH_TYPE	0.8787	0.8821	0.5511	0.6093
	STANDARD	.	.	.	.
RAMP	VEH_TYPE	0.3701	0.4075	0.1471	0.6942
	STANDARD	.	.	.	.

GLM P-VALUES FOR MODELS WITH NO SPEED INTERACTIONS (FROM FACVEHA.SAS)

EMIT NORMAL - CLEAN TIER 0 CLASS

ROAD	FACTOR	P THC PROB	P NMHC PROB	P CO PROB	P NOX PROB
ART/FWY	S*ROADTYPE	0.0354	0.0440	0.0020	0.0000
	S*VEH_TYPE	0.1322	0.1476	0.8361	0.5608
	S*STANDARD	0.0002	0.0001	0.0576	0.6491

EMIT HIGH - CLEAN TIER 0 CLASS

ROAD	FACTOR	P THC PROB	P NMHC PROB	P CO PROB	P NOX PROB
ART/FWY	S*ROADTYPE	0.1176	0.1203	0.6233	0.0000
	S*VEH_TYPE	0.0641	0.0699	0.0241	0.9560
	S*STANDARD	.	.	.	.

EMIT NORMAL - CLEAN ACTUAL TIER CLASS

ROAD	FACTOR	P THC PROB	P NMHC PROB	P CO PROB	P NOX PROB
ART/FWY	S*ROADTYPE	0.0354	0.0440	0.0020	0.0000
	S*VEH_TYPE	0.1754	0.1802	0.8680	0.5723
	S*STANDARD	0.0024	0.0020	0.0560	0.0151

EMIT HIGH - CLEAN ACTUAL TIER CLASS

ROAD	FACTOR	P THC PROB	P NMHC PROB	P CO PROB	P NOX PROB
ART/FWY	S*ROADTYPE	0.1176	0.1203	0.6233	0.0000
	S*VEH_TYPE	0.0641	0.0699	0.0241	0.9560
	S*STANDARD	.	.	.	.

GLM P-VALUES FOR MODELS WITH NO SPEED INTERACTIONS (FROM FACVEHA.SAS)

EMIT NORMAL - CLEAN TIER 0 CLASS

		P			
		THC	NMHC	CO	NOX
		PROB	PROB	PROB	PROB
ROAD	FACTOR				
ART/FWY	ROADTYPE	0.0046	0.0050	0.0006	0.0000
	VEH_TYPE	0.0004	0.0243	0.0062	0.0026
	STANDARD	0.0000	0.0000	0.0000	0.0000

EMIT HIGH - CLEAN TIER 0 CLASS

		P			
		THC	NMHC	CO	NOX
		PROB	PROB	PROB	PROB
ROAD	FACTOR				
ART/FWY	ROADTYPE	0.1236	0.1307	0.3307	0.0000
	VEH_TYPE	0.5942	0.5693	0.8984	0.3961
	STANDARD	.	.	.	.

EMIT NORMAL - CLEAN ACTUAL TIER CLASS

		P			
		THC	NMHC	CO	NOX
		PROB	PROB	PROB	PROB
ROAD	FACTOR				
ART/FWY	ROADTYPE	0.0046	0.0050	0.0006	0.0000
	VEH_TYPE	0.0016	0.0404	0.0031	0.0012
	STANDARD	0.0000	0.0000	0.0000	0.0000

EMIT HIGH - CLEAN ACTUAL TIER CLASS

		P			
		THC	NMHC	CO	NOX
		PROB	PROB	PROB	PROB
ROAD	FACTOR				
ART/FWY	ROADTYPE	0.1236	0.1307	0.3307	0.0000
	VEH_TYPE	0.5942	0.5693	0.8984	0.3961
	STANDARD	.	.	.	.

GLM P-VALUES FOR MODELS WITH NO SPEED INTERACTIONS (FROM FACVEHA.SAS)

Appendix B

Example Application of Speed Adjustment to Exhaust Emissions

The following description is meant as an example of how the basic exhaust emission rates estimated by MOBILE6 will be adjusted for the effects of average speed and roadway type. The example will show how the various parts of the overall emission estimate are weighted together. It is beyond the scope of this document to explain fully the derivation of the basic exhaust emission estimates or the weighting factors. The derivation of these distributions are described in other documents. It is also not the intent of this example to reveal the values for emissions or weighting factors that are proposed to be used in MOBILE6. All of the values shown in this example should, therefore, be considered as draft and may not match values shown in other documents. This should not detract from the value of this example in showing the process of how the basic emission rates are adjusted for speed.

<u>Basic Emission Rates</u>

For each scenario, MOBILE6 will calculate a basic exhaust emission rate (BER) for two emission levels (high and normal) for each pollutant for each model year for each vehicle class. The basic unit for the BER is the hot running LA4 (with an average speed of 19.6 mph) at standard operating conditions (i.e., temperature, humidity, etc.). The effect of engine starts on emissions is calculated separately and is not adjusted for the effects of average speed.

MOBILE6 calculates the emissions for each hour of the day, so the first step is to adjust the BER for the conditions that affect exhaust emissions. For example, the temperature at 6 a.m. will be different than the temperature at 1 p.m., so the BER at 6 a.m. will not be the same as the BER at 1 p.m. after adjustment for temperature. Some adjustments (such as the effects of fuel sulfur content) will not vary by time of day. Ultimately, there will be 24 values, one for each hour of the day calculated from the same BER, adjusted for hourly conditions. There will be two sets of adjusted BER values, one for normal emissions and one for high emitters.

<u>Example Basic Emission Rates</u>

For this example, we will follow the calculation of NOx emissions from a 1990 model year passenger car. The calculation would be similar for the other pollutants and other vehicle classes. This example will not fabricate values for all hours. The calculations will be similar in all hours, so a single hour example is all that should be required. So, for a given hour, the NOx emissions (BERs) for our vehicles will be assumed to be:

- 0.65 g/mi for normal emitters
- 2.10 g/mi for high emitters

After adjustment, these values must be weighted together by their occurrence in the fleet. The number of high emitters will depend on many things (i.e., age, I/M programs, OBD, etc.), but for our example, we will assume that high emitters are 10% of 1990 model year passenger cars in this scenario.

Freeway Ramps and Local Roadways

There are four basic roadway types; freeways, arterial/collectors, freeway ramps and local roadways. The freeway ramps and local roadways can be determined directly from the BER, since they do not vary with average speed. The freeway ramp and local roadway emissions are a function of the BER (see Table 13). The NOx BERs we will use (described above) are in grams per mile units and must be converted to grams per hour. The average speed of the hot running LA4 is 19.6 miles per hour. For normal emitters, 0.65 grams per mile times 19.6 miles per hour is 12.74 grams per hour. For high emitters, 2.10 grams per mile times 19.6 miles per hour is 41.16 grams per hour. Using the equation shown in Table 13, the freeway ramp and local roadway emissions in grams per hour are:

Normal Ramp = $5.353 + 2.863*(12.74) - 0.0101*(12.74)^2 = 40.19$ g/hr
Normal Local = $1.870 + 0.701*(12.74) + 0.000609*(12.74)^2 = 10.90$ g/hr

High Ramp = $5.353 + 2.863*(41.16) - 0.0101*(41.16)^2 = 106.08$ g/hr
High Local = $1.870 + 0.701*(41.16) + 0.000609*(41.16)^2 = 31.75$ g/hr

The results will be weighted using VMT and must be converted to grams per mile units. The freeway ramp cycle has an average speed of 34.6 miles per hour and the local roadway cycle has an average speed of 12.9 miles per hour.

Normal Ramp = (40.19 g/hr) / 34.6 mph = 1.16 g/mi
Normal Local = (10.90 g/hr) / 12.9 mph = 0.84 g/mi

High Ramp = (106.08 g/hr) / 34.6 mph = 3.07 g/mi
High Local = (31.75 g/hr) / 12.9 mph = 2.46 g/mi

Since we have assumed that 10% of the vehicles are high emitters, we can now weight the normal and high emitter results to give a complete freeway ramp and local roadway estimate for the 1990 model year in this hour.

Freeway Ramp = 1.16* 0.90 + 3.07 * 0.10 = 1.35 g/mi
Local Roadway = 0.84 * 0.90 + 2.46 * 0.10 = 1.01 g/mi

Each hour will have its own basic exhaust emission rate. Since the Freeway Ramp and Local Roadway emission levels depend on the basic exhaust emission rate, a separate calculation will be done for each hour of the day.

Emission Offset

The emission offset (EO) represents the difference between the LA4-based BER and freeway emissions at 19.6 miles per hour. The values for the EO are shown in Table 14. Since the BER values lie between the LA4 values (0.591 and 3.245 g/mi) shown in Table 14, the EO must be calculated using interpolation.

Normal EO = 0.121 + ((0.008-0.121)/(3.245-0.591))*(0.65-0.591) = 0.12 g/mi
High EO = 0.121 + ((0.008-0.121)/(3.245-0.591))*(2.10-0.591) = 0.06 g/mi

An additional emission offset is used for arterial/collector roadways, however this offset depends on average speed and emissions. These are shown in Table 15. The ratio of the freeway emission level at each speed plus the arterial/collector offset for that speed, divided by the freeway emission level at 19.6 miles per hour is the arterial/collector speed correction factor. These are shown in Table 17.

Freeway Emissions

Freeway emissions depend on average speed. For each hour of the day, MOBILE6 has a default distribution of average speeds for freeways. Users will be able to enter local distributions of freeway average speeds. This is not the same as a distribution of speeds on a particular freeway.

The MOBILE6 default distribution of average speeds for freeways assumes that there are many freeways in the area and the distribution represents the average speeds observed from the different freeways at that hour. The cycles used to develop the speed correction factors each contain the entire range of vehicle speeds on freeways grouped by ranges of observed congestion. So, changing speed in the MOBILE6 model is changing the average speed of the combination of all vehicles on freeways. MOBILE6 does not effectively model the effect of average speed on individual vehicles or small groups of vehicles within a single freeway section. If you wish to model a specific freeway, you would want to reduce the default distribution down to a single, average speed for the freeway of interest.

In each hour, MOBILE6 will calculate values for each average speed "bin" from 5 to 65 mph in 5 mph increments and for 2.5 mph (14 speed bins) by applying the speed correction factors from Table 16 to the base freeway emission level at 19.6 mph. The base freeway emission level is simply the sum of the BER and the adjusted off-cycle emissions (EO).

Normal Base Freeway Emission at 19.6 mph = 0.65 + 0.12 = 0.77 g/mi
High Base Freeway Emission at 19.6 mph = 2.10 + 0.06 = 2.16 g/mi

There are three sets of speed correction factors in Table 16, one for each of three emission levels. Both the Normal and High base freeway emission levels we have calculated lie between the Level 2 and Level 3 emission levels, shown in Table 16. So the speed correction factor will be interpolated between the values for Level 2 and Level 3 in Table 16. However, these speed correction factors do not apply below 7.1 mph. We propose that MOBILE6 will use the MOBILE5 speed correction factors (See Table 1.6B in AP-42) for speeds below 7.1 mph. For our example, the NOx speed correction factors for the 1990 model year have A and B coefficients of 1.456 and 0.926 respectively, where the form of the equation is A/speed + B, resulting in the following speed correction factors:

SCF for 2.5 mph = (1.456/2.5) + 0.926 = 1.51
SCF for 5.0 mph = (1.456/5.0) + 0.926 = 1.22
SCF for 7.1 mph = (1.456/7.1) + 0.926 = 1.13

The MOBILE5 speed correction factor at 7.1 mph (1.13) was applied to all emission levels in MOBILE5. The MOBILE5 speed correction factors will be adjusted to match the speed correction factors in Table 16 for NOx at 7.1 mph of 2.26, 1.81 and 1.50 for emission levels 1, 2 and 3 respectively by adding the difference to each value.

Level 1 SCF for 2.5 mph = 1.51 + (2.26 - 1.13) = 2.63
Level 1 SCF for 5.0 mph = 1.22 + (2.26 - 1.13) = 2.34

Level 2 SCF for 2.5 mph = 1.51 + (1.81 - 1.13) = 2.19
Level 2 SCF for 5.0 mph = 1.22 + (1.81 - 1.13) = 1.90

Level 3 SCF for 2.5 mph = 1.51 + (1.50 - 1.13) = 1.87
Level 3 SCF for 5.0 mph = 1.22 + (1.50 - 1.13) = 1.58

Using the average emissions for each speed correction factor emission level (from Table 14) of 0.712 and 3.253 g/mi NOx for Level 2 and Level 3 respectively and the predicted base freeway emission rates of 0.77 and 2.16 g/mi for Normals and High categories, weighting factors can be derived for interpolating between the speed correction factors. The sum of the two weighting factors will equal 1.

Normal Level 2 Weighting = (3.253 - 0.77)/(3.253 - 0.712) = 0.978
Normal Level 3 Weighting = (1.0 - 0.978) = 0.022

High Level 2 Weighting = (3.253 - 2.16)/(3.253 - 0.712) = 0.431
High Level 3 Weighting = (1.0 - 0.431) = 0.569

These weighting factors are used to combine the Level 2 and Level 3 speed correction factors for the calculated base freeway emission case. A new weighted speed correction factor is calculated for each of the fourteen speed bins for Normals and Highs. For example, the 10 mph speed bin speed correction factors (using values from Table 16) would be:

Normal SCF for 10 mph = 0.978 * 1.28 + 0.022 * 1.18 = 1.28
High SCF for 10 mph = 0.431 * 1.28 + 0.569 * 1.18 = 1.22

These speed correction factors are applied to the predicted base freeway emission rates to determine speed corrected emission rates for each speed bin. For example the speed corrected emission rates for the 10 mph speed bin would be:

Normal emission level for 10 mph = 1.28 * 0.77 = 0.99 g/mi
High emission level for 10 mph = 1.22 * 2.16 = 2.64 g/mi

Each hour has a default VMT distribution of average freeway speeds that correspond to these speed bins. The emission rates for each of the bins can be weighted, using this VMT distribution, to give a composite freeway emission rate. This weighting is repeated for normal and high emitters, and the two emitter groups can be combined to give an overall freeway NOx emission rate for 1990 model year vehicles for that hour of the day.

Arterial/Collector Emissions

The arterial/collector speed correction factors shown in Table 17 are applied to the base freeway emission rate calculated for the freeway emission levels. Since the three emission level groups are identical for arterial/collector roadways and freeways, the same weighting factors are used to interpolate between the speed correction factors. For example, the 10 mph speed bin speed correction factors (using values from Table 17) would be:

Normal SCF for 10 mph = 0.978 * 1.52 + 0.022 * 1.31 = 1.52
High SCF for 10 mph = 0.431 * 1.52 + 0.569 * 1.31 = 1.40

These speed correction factors are applied to the base freeway emission levels to determine emission levels for each speed bin. For example the emission levels for the 10 mph speed bin would be:

Normal emission level for 10 mph = 1.52 * 0.77 = 1.17 g/mi
High emission level for 10 mph = 1.40 * 2.16 = 3.02 g/mi

Since the speed correction factors for arterial/collectors (shown in Table 17) converge with freeway speed correction factors (shown in Table 16) at higher speeds and below 7.1 mph, the emission rate for arterial/collectors and freeways will be the same for some speed bins. All of the speed bins are combined, weighted by the fraction of VMT in that speed bin for that hour. The composite arterial/collector emissions for Normals and Highs are combined weighted by their proportions in the fleet for that model year.

Areawide Emissions

Once a fleetwide (combined Normal and High), hourly (combined speed bins) estimate is available for each roadway type (freeway, arterial/collector, freeway ramp and local roadway), these estimates can be combined in a variety of ways, depending on the needs of the user. If an areawide, hourly result is needed, the results for the four roadway types can be combined, weighted by the fraction of VMT for each roadway for that hour. An areawide daily result can be obtained by combining the hourly results weighted by the VMT fraction for each hour. Although there are default values for the fraction of VMT for each roadway and the VMT fraction for each hour, users may substitute their own values.

Composite Engine Start and Running Emissions

The emission rates addressed in this document do not contain the effects of engine starts. The effect of engine start on emissions is calculated separately and is calculated in units of grams per engine start. These emission effects resulting from engine starts are not determined by roadway type and do not depend on average trip speed. They can, however, be combined with the running emissions to give an overall exhaust emission estimate.

Since the MOBILE6 model does not include a distribution of the effects of engine start on emissions by roadway type, the combination of the effects of engine start and running emissions is best done on areawide (combined roadway) emission results. This can be done on an hourly or daily basis.

MOBILE6 has an estimate of the average daily vehicle miles traveled (VMT) for each model year in a given calendar year and a distribution of that average VMT over the day by hour. MOBILE6 also has an estimate for the number of engine starts per day and the distribution of those starts over the day by hour. For a given hour, the grams due to engine starts in that hour are calculated as:

Grams / Engine Start * Fraction of Starts in the Hour * Number of Starts / Day

This value can be converted to grams per mile by determination of the average number of miles traveled by vehicles in that hour:

Hourly VMT = Daily VMT * Fraction of VMT in the Hour

Once the effect of engine start on emissions is converted to grams per mile, it can be added directly to the areawide emission estimate for that hour.

Total Exhaust = Engine Start / Hourly VMT + Areawide Emissions for the Hour

Similarly, a daily total exhaust emission rate can be calculated. Although there are default values for the number of daily engine starts, the fraction of engine start in each hour, the daily VMT and the fraction of VMT in each hour, users may substitute their own values.

A calculation is done for each model year of each vehicle class. These values are weighted using travel fractions (as is done in MOBILE5) to calculate areawide, daily emission rates for highway mobile sources.

<u>FTP Emissions</u>

The Federal Test Procedure (FTP) is a special case of vehicle driving. It can be simulated in MOBILE6 by careful choice of weighting factors for engine start soak time, vehicle miles traveled and roadway types. Since this case will be of special interest for comparison of MOBILE6 emission rates to Federal certification standards, we plan to build in the appropriate weighting factors so that calculation of FTP emission estimates using MOBILE6 can be done simply and consistently.