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## 1.0 ABSTRACT

Revised air conditioning exhaust emission correction factors are included in MOBILE6. The proposed factors are based on testing of 38 vehicles at two locations, using a test procedure meant to simulate air conditioning emission response under extreme "real world" ambient conditions. These factors are meant to predict emissions which would occur during full loading of the air conditioning system, and will be scaled down in MOBILE6 according to ambient conditions input by the user if appropriate. It was concluded that the data used in the development of the proposed factors adequately represents real world conditions, based on the results of a correlation vehicle tested at both test sites and a full environmental chamber. In general, running emissions were found to increase during air conditioning operation, but under some conditions HC and CO emissions decreased. Correction factors for start driving were also assessed.

## 2.0 INTRODUCTION

Recent studies conducted primarily as part of the Supplemental Federal Test Procedure (SFTP) rulemaking development process indicate that vehicle fuel consumption and exhaust emissions increase substantially when the air conditioner is in operation. As the traditional method for accounting for the effects of air conditioner load - increasing dynamometer horsepower by 10% - is not adequate for characterizing this emission increase, new certification test procedures aimed at reducing emissions when the air conditioner is in operation were implemented as part of the SFTP rule. Air conditioning correction factors are included as an optional element of MOBILE5; however, these factors are based on testing performed in the early 1970's and are considered so outdated that the user is discouraged from using them in the MOBILE User's Guide. Given the recent findings on air conditioning emissions, revised air conditioning correction factors are clearly needed.

This report presents the "full-usage" air conditioning exhaust correction factors proposed for MOBILE6. Full-usage correction factors are meant to represent the emission increase when the A/C system is inducing full system load on the vehicle, as would occur under extreme ambient (temperature, humidity and solar load) conditions. Since it not appropriate to apply these factors to all ambient conditions, MOBILE6 will scale these factors down based on the ambient conditions under which the model is being run (the development of appropriate scaling factors is discussed in Report Number M6.ACE.001, "Air Conditioning Activity Effects in MOBILE6"). Discussion in this report includes the testing used to generate A/C emission data, correlation between the two test sites and with expected real-world results, and the development of the full-usage correction factors. The treatment of air conditioning correction factors for vehicles complying with the SFTP requirement are also addressed in this report.

Subsequent to publication of the draft version of this report in March 1998, the document was put out for stakeholder review. Formal peer review comments were also solicited from two independent sources. No comments were received through the stakeholder review process, hence peer review comments represent the only external feedback received on this report. A summary of peer review comments are contained in Appendix K. Major revisions were made to the methodology presented in the March 1998 version, and a revised report was published in December 1999 as part of the Tier 2 regulatory support documentation. The primary update to this final report from the December 1999 version is the inclusion of the discussion for SFTP benefits in Section 8.0.

## 3.0 TESTING

### 3.1 Vehicles

The data used for this analysis was generated through testing performed at EPA's National Vehicle and Fuel Emissions Laboratory and through an EPA contractor, Automotive Testing Laboratories (ATL), in East Liberty, Ohio. 26 vehicles were tested at EPA and 12 were tested at ATL, including one vehicle tested at both locations for correlation purposes (treated as two separate vehicles for the purpose of this analysis). A list of the vehicles tested is contained in Table 1 of Appendix A. The sample consisted of 1990 and later vehicles categorized as follows: 24 cars / 14 trucks, 32 Ported Fuel Injection (PFI) / 6 Throttle-Body Injection (TBI), and 28 Tier 0 / 10 Tier 1. Each vehicle was designated either as a "normal" emitter or "high" emitter using the following emission cutpoints over the Running LA4[1] : 0.8 g/mi HC, 15.0 g/mi CO and 2.0 g/mi NOx (the cutpoints were applied independently for each pollutant, so that a vehicle could be a high emitter for HC and a normal emitter for NOx). These cutpoints yielded five high emitters for HC, three for CO and two for NOx. It should be noted that during the analysis the data was divided into different strata; by facility cycle, vehicle class, etc.. There are some instances in the analysis where a vehicles emissions classification changes. For example, a vehicle that is classified as a normal emitter on the LA94, may have been reclassified as a high emitter for a specific cycle, such as the local cycle.

### 3.2 Test Procedure

EPA's new air conditioning test procedure is based on use of a full environmental chamber at 95° F, 40% Relative Humidity and full solar load (850 Watts/Meter$^2$). This type of facility was not available to EPA at the time of testing, so use of a procedure which simulated these conditions was required. A/C-on tests were conducted in a standard emission test cell at 95° F and 50 grains/pound of humidity with a standard cooling fan and the driver window down. The A/C system was set according to the SFTP requirements; maximum A/C and blower setting with recirculation mode if so equipped. Rather than attempting to represent a condition that would actually occur in-use, this simulation is meant solely to induce the level of A/C system load on the vehicle which would occur in the real world under extreme ambient conditions. Operating

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[1] "Running LA4" emissions were derived from the combination of emissions from Bag 2 and a 505 cycle run warmed-up (i.e. without a soak). More detail on this calculation can be found in MOBILE6 Report No. M6.STE.002, "The Determination of Hot Running Emissions from FTP Bag Emissions"

with the driver window down and with standard cooling is meant to compensate for the lower humidity level and lack of solar load inherent in the standard cell. This simulation method showed adequate correlation with SFTP environmental cell conditions during the development of the SFTP rulemaking[2], and is a straightforward way to approximate real-world air conditioning emissions using a standard cell setup. A/C-off tests were run in standard FTP ambient conditions (75° F, 50 grains/pound humidity).

The vehicles were run in a warmed-up condition over EPA's facility-specific inventory cycles[3], ARB's Unified Cycle (the LA92), and the New York City Cycle one time each with the A/C on and A/C off. A cold start ST01[4] cycle was also run in both conditions for the purpose of assessing start A/C factors (information on all driving cycles used in this test program is shown in Table 2). The EPA tests were run on a 48-inch electric dynamometer, while the ATL testing used a twin 20-inch electric dynamometer; all tests were run without the 10% A/C load adjustment factor typical to standard emission tests. Both bag and modal data were collected.

### 3.3 Correlation

Preliminary data presented at the October 1997 MOBILE6 workshop indicated a potential offset between the results from vehicles tested at EPA and those tested at ATL[5]. A/C ratios from the ATL sample were lower than EPA on average for fuel consumption and all three pollutants. This raised a question about whether the simulation as conducted at ATL induced comparable A/C system loading to the procedure as conducted at EPA. A related issue is whether loading induced by the simulation as conducted at either site could be considered "full-usage", as defined for the purpose of this analysis by the conditions used for the SFTP certification test (95° F, 40% Relative Humidity, 850 $W/m^2$ solar load). To investigate both issues, a correlation vehicle was run over all test cycles using the simulation procedure at EPA and ATL, and on a subset of cycles under the SFTP test conditions at GM's environmental chamber in Rochester, New York. This vehicle was instrumented to monitor A/C compressor cycling and compressor pressures (high and low side) on a real-time basis to gain a fuller sense of how the vehicle's A/C system was loaded at each location.

Emission results for the four cycles tested at all three locations are shown in Table 3 of Appendix

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[2] Results from a correlation program between this simulation and a full environmental chamber over a sample of six Tier 1 vehicles can be found in AAMA/AIAM's comments to EPA on the proposed SFTP rulemaking (EPA Docket No. A-92-64 Item IV-D-10).

[3] For detail on the development of EPA's facility-specific inventory cycles, see MOBILE6 Report No. M6.SPD.001, "Development of Speed Correction Cycles"

[4] ST01 is a 1.4 mile cycle developed to specifically characterize driving behavior following startup. The cycle was developed from an in-use driving survey conducted in Baltimore, Spokane and Los Angeles as part of the SFTP rulemaking process.

[5] "A/C Effects in MOBILE6", presentation at the October 1997 MOBILE6 workshop

A. There is quite a bit of variability in the HC, CO and NOx results, making it difficult to discern any clear trend. Judging from the large swings in each pollutant, it appears that the vehicle went into enrichment sporadically between sites, resulting in a wide range of A/C ratio results across the test matrix. Thus, it is difficult to draw conclusions from the emission data (and particularly the A/C ratios) alone. The correlation analysis therefore focused on fuel consumption (carbon) ratio and compressor operation to determine whether a difference in the relative loading placed on the vehicle between the three sites can be distinguished. The carbon ratio results in Table 3 show the ATL results to be slightly lower than EPA for each cycle. However, the EPA and ATL carbon ratios are higher than the GM ratio for three of the four cycles, and the three locations show relatively consistent carbon ratios over the New York City, Unified and Arterial cycles. The exception to the latter point is the High Speed Freeway cycle, for which the GM ratio (as well as the A/C-on carbon levels) are significantly lower than EPA or ATL.

Table 4 of Appendix A contains compressor behavior data, expressed in terms of the compressor fraction (the fraction of time the compressor in engaged during the test), and average high and low side compressor pressures, on which compressor torque in based. The data indicate that a) the compressor was engaged at all locations 97% or more of the time on each of the cycles, and b) for the New York City, Unified and Arterial cycles a strong difference is not observed in the compressor pressures. The exception again is the High Speed Freeway cycle, for which the GM data shows significantly lower compressor pressures than ATL or EPA. From these data and the fuel consumption results, it is apparent that the A/C system load on the high speed freeway cycle in the full environmental cell was much less than that produced by the simulation at EPA or ATL. The most plausible explanation for this is the use of a variable speed fan in the full environmental cell, which would create a much higher airflow than produced by the standard one-speed fan used on the simulation. Higher air flow across the vehicle's A/C system can increase system efficiency, reducing relative load demand on the engine. This suggests that the simulation could be over predicting A/C loading (and hence emissions) at the higher speed levels; however, this effect does not appear in the overall LA92 results, a cycle which also contains significant high speed operation. Unfortunately sufficient data does not exist over high speed operation with representative air flow to make a more full assessment; further research will be needed to address this issue.

From the fuel consumption and compressor data it was concluded for the purposes of this study that despite observed emission differences between ATL and EPA, the vehicles were adequately loaded at both sites to represent full-usage conditions. Therefore, no vehicles will be excluded from the analysis and the emission results from the data set will be used directly (i.e. with no scaling) to develop the full-usage correction factors.

## 4.0 DATA

As with previous versions of the model, MOBILE6 will contain correction factors which estimate the emission impact of changes in temperature. Emissions at temperatures higher than

75° F will be determined in the model first by applying a base temperature correction, then applying the A/C correction factor appropriate for that temperature.  A/C correction factors must be developed separately from the baseline temperature corrections in order to avoid double-counting temperature impacts. For this analysis, therefore, the A/C-off results were corrected from the temperature the test was conducted (nominally 75°, although minor variability is common) to the A/C-on temperature (nominally 95°) for each paired test. Since MOBILE6 temperature correction factors will not change from the MOBILE5 corrections, MOBILE5 temperature corrections were used[6]. The Bag 2 corrections were used for all running tests, and Bag 1 corrections were used for the cold start ST01 test[7].

Once the temperature correction was applied, the A/C impact was analyzed by taking the difference between vehicle emissions with A/C on and the corrected vehicle emissions with the A/C off (A/C base). This impact is referred to throughout this report as the "A/C effect." This approach to looking at A/C impact differs from the proposed approach in the draft version of this report. The draft proposal looked at the A/C impact as a ratio, therefore making the A/C correction factor a multiplicative adjustment. This significant shift in approach between the draft and final report because of concern that the multiplicative adjustment approach may overstate the impact of air conditioning on emissions. The use of an additive A/C effect is meant to mute the emission impact for technologies which were not represented in the A/C dataset. The shift from a multiplicative to an additive approach was supported by peer review comments, as discussed in Appendix K.

## 5.0 RUNNING CORRECTION FACTORS ANALYSIS

The development of running correction factors requires analysis of what vehicle groupings merit separate treatment. Simple factorial Analysis of Variance (ANOVA) was used, for each pollutant, to look at the A/C effect as a function of the following factors: base emissions (i.e. without A/C), referred to as "A/C base"; vehicle class (i.e. cars vs. trucks), emitter category (i.e. high emitter vs normal emitter), average cycle speed, and facility cycle. For the purposes of this analysis, a factor is considered significant if it is below the 0.05 significance level. Also, for each pollutant both linear space and log space fits were investigated. For each pollutant, the best fit was chosen. A more detailed analysis to determine the appropriate stratifications given sample size and technical merit followed this initial screening. A discussion of this investigation follows for each pollutant.

### 5.1 NMHC

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[6] The temperature corrections will be modified to accommodate the start/running split new to MOBILE6, but the base corrections will not change. The start/running split has not be developed, so for this analysis the MOBILE5 Bag corrections were applied.

[7] MOBILE5 temperature correction factors can be found in "Compilation of Air Pollutant Emission Factors, Volume II - Mobile Sources" (AP-42), Page H-24

Based on the following analysis, MOBILE6 will contain two equations that will model the A/C effect for NMHC for vehicles classified as normal emitters. There will be no A/C effect for NMHC for vehicles classified as high emitters. The initial screening ANOVA results indicate significance to the 0.05 level for A/C base and for emitter category. (See Appendix B, Section A; Test of Between-Subjects Effects[8]) Therefore, a more in depth analysis was performed looking at A/C effect for both normal emitters and high emitters separately.

### *5.1.1 Normal Emitters - Freeway, Arterial, Ramp*

ANOVA was performed over a sample of vehicles that are classified as normal emitters for NMHC, with A/C effect as the dependant versus A/C base, average speed, facility cycle, and vehicle class. The results of this analysis indicate facility cycle as a significant factor. (See Appendix B, Section B; Test of Between-Subjects Effects) When looking at the pairwise comparisons for facility cycle it is evident that the Local cycle was significantly different from the others (for the purpose of this analysis and throughout the report, Local cycle refers to the Local facility cycle and the NYCC facility cycle combined).(See Appendix B, Section B; Pairwise Comparison) Therefore the Local cycle was removed from the sample (to be analyzed separately) and ANOVA was performed on the remaining sample. Again, A/C effect was the dependant as a function of the following factors: A/C base, average speed, and vehicle class. The results of this analysis indicated that there would be one correction factor for both LDVs and LDTs, and that average speed was the only significant factor.(See Appendix B, Section C; Test of Between-Subjects Effects) Therefore, an equation that will model the NMHC correction factors for all normal emitters, on all facility cycles, excluding Local, was developed by fitting a linear function to the sample by average speed.(See Appendix B, Section E; Parameter Estimates)

$$\textbf{A/C Effect} = \textbf{0.001162*(Speed)}; \; \mathbf{R^2 = .044}$$

Figure 1 in Appendix C show the predicted A/C effect, based on the above equation, versus the original data for all vehicles on each facility cycle.

### *5.1.2 Normal Emitters - Local Cycle*

Next, ANOVA was performed on the sample that contained only tests performed on the Local cycle. For this analysis, A/C effect was looked at as a function of vehicle class, average speed and A/C base. The results of this analysis indicated that there was significance to the 0.05 level for vehicle class.(See Appendix B, Section F; Test of Between-Subjects Effects) When looking at the pairwise comparisons for vehicle class, it showed the significance was between LDT1 and LDT2, and between LDV and LDT2. (See Appendix B, Section F; Pairwise Comparison)

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[8] The corrected vehicle emissions with the A/C off (i.e. A/C Base) is referred to as NMHC_Off, CO_Off, and NOx_Off in the ANOVA results. Also “Veh_Class” refers to LDV, LDT1 and LDT2, while “Class” refers to LDV and LDT

However, because the LDT2 results are based on a sample of only 3 trucks, it was decided that the truck classes should not be split, but instead would be combined and re-analyzed. This re-analysis shows there is no significant difference between LDVs and LDTs. It also indicated no significance for average speed, but that there is significance to the 0.05 level for A/C base. (See Appendix B, Section G; Test of Between-Subjects Effects) Therefore, the following equation was developed to model the NMHC A/C effect for all normal emitting vehicles on the local cycle: (See Appendix B, Section H; Parameter Estimates)

**A/C Effects = 0.506 * (A/C Base); $R^2$ = .127**

Figure 2 in Appendix C show the predicted A/C effect, based on the above equation, versus the actual data.

### *5.1.3 High Emitters - Freeway, Arterial, Ramp, Local*

ANOVA results indicate that vehicle class and A/C base are significant. (See Appendix B, Section I; Test of Between-Subjects Effects) As with normal emitters, the pairwise comparison shows LDT2 are significantly different from LDT1 and LDVs. (See Appendix B, Section I; Pairwise Comparison) Again, due to the small sample size for LDT2 (only 1 truck), the truck classes were combined and re-analyzed. The results of this analysis did not indicate any significant difference between LDVs and LDTs, but did indicate A/C base to be significant. (See Appendix B, Section J; Test of Between-Subjects Effects) An equation to model high emitters for NMHC was developed from this analysis. (See Appendix B, Section K; Parameter Estimates) When the predicted A/C effect, based on this equation, was plotted versus the original data**,** the graphs show the equation to be over predicting the A/C effect. (See Figures 3-16 in Appendix C) The original data lies very near or below the zero gram/mile mark. This strongly indicates that there is no A/C effect for NMHC high emitters. The technical basis for this observation is that it is more likely that NMHC high emitters are operating with enrichment and/or very low catalyst efficiency without air conditioning. There is less opportunity for emissions to increase significantly when efficiency with the A/C on won't have the same relative impact. Therefore, based on this observation, there will be no NMHC A/C effect for vehicles classified as NMHC high emitters.

## **5.2 <u>CO</u>**

Based on ANOVA results, there will be five equations in MOBILE6 used to model A/C effect for CO. The initial screening ANOVA results indicate that the sample should be separated by emission category and that the Local cycle is significantly different from the other cycles, therefore warrantying separate analysis. (See Appendix D, Section A; Pairwise Comparison) Also, the results indicate that the sample should be separated by vehicle class, LDV vs LDTs. (See Appendix D, Section B; Test of Between-Subjects Effects) The following will describe the analysis used to determine each equation for each subcategory.

### *5.2.1 Normal Emitters - Freeway, Arterial, Ramp*

The normal emitter samples for LDVs and LDTs, not tested on the local cycle, were analyzed using ANOVA, looking at A/C effect as a function of A/C base and average speed. Average speed and A/C base are significant factors for LDVs (See Appendix D, Section C; Test of Between-Subjects Effects), while average speed is the only significant factor for LDTs. (See Appendix D, Section D; Test of Between-Subjects Effects) The following equations were developed by fitting a linear function through each sample based on the significant factors for each.

**Light-Duty Vehicle A/C Effect = 0.815*(A/C base) + 0.05272*(Speed); $R^2$ = .255**
**Light-Duty Truck A/C Effect = 0.104*(Speed); $R^2$ = .059**

Figures 1 & 2 in Appendix E show the predicted A/C effect, based on the above equations, versus the original data.

### *5.2.2 High Emitters - Freeway, Arterial, Ramp*

In MOBILE6 there will be a CO A/C effect for vehicles classified as high emitters for CO, but only for average speeds below nineteen miles per hour (19 mph). For average speeds above 19 mph, there will be no CO A/C effect for high emitters. This is based on analysis of a sample of vehicles classified as high emitters for CO and excludes the vehicles' test on the Local cycle. This section describes this analysis.

The initial screening ANOVA resulting in the development of an equation based on CO base and average speed, that modeled all vehicle classes. (See Appendix D, Section E; Parameter Estimates) When this equation was plotted against the data, the graphs showed the model to be overestimating the A/C effect for cycles with an average speed greater than 19mph. The data showed the A/C effect, for these cycles, to be near or below zero. Based on this observation, the sample was split into two sets; cycles with an average speed below 19 mph and cycles with an average speed above 19 mph. It was concluded that for average speed above 19 mph, there will be no CO A/C effect for high emitters. The sample with average speed below 19 mph was re-analyzed.

ANOVA was performed on the sample of high emitters with cycles having an average speed below 19 mph. CO effect was the independent and vehicle class, CO base, and average speed were the factors. The results of this analysis indicates there is no significant difference between LDVs and LDTs, therefore, vehicle classes were combined for continued analysis. (See Appendix D, Section F; Test of Between-Subjects Effects) Continued analysis indicates that CO base is the only significant factor for high emitters on cycles with an average speed below 19 mph. (See Appendix D, Section G; Test of Between-Subjects Effects) Based on these results, an equation was developed by fitting a linear function through the sample based on CO base. (See Appendix D, Section H; Parameter Estimates) The following equation models all vehicles classified as CO high emitters on cycles with an average speed less than 19 mph:

$$\textbf{CO Effect} = 0.154 * (\textbf{CO base});\ R^2 = .831$$

Figures 3 in Appendix E show the predicted A/C effect, based on the above equation, versus the original data.

*5.2.3 Local Cycle*

The first look ANOVA of vehicles tested only on the local cycle determined that A/C base is significant and that there is a significant difference between LDT1 and LDT2. (See Appendix D, Section I; Test of Between-Subjects Effects) Again, based on the fact that there were very few LDT2 in the sample (only 4 trucks), LDT were not split. Continued analysis developed an equation to model A/C effect for all LDVs and LDTs on the Local cycle. (See Appendix D, Section J; Parameter Estimates) The predicted A/C effect was calculated based on this linear equation and was plotted against the original data.(Figure 4, Appendix E) Although ANOVA analysis did not characterize emitter classification as significant, the graph clearly indicates a need to split by emitter classification.

*5.2.3a Normal Emitters - Local cycle*

ANOVA was performed on a sample containing only vehicles classified as normal emitters for CO. CO effect was looked at as a function of vehicle class, average speed, and CO base. From this analysis it was determined that average speed was not significant and that there is a significant difference between LDT1 and LDT2 (See Appendix D, Section K; Pairwise Comparison), but, due to the small sample size of LDT2, the two classes were combined. When analyzing the sample again with the two classes combined, initially the results indicate a significance between LDVs and LDTs. (See Appendix D, Section L; Test of Between-Subjects Effects) A more in depth look at the pairwise comparisons shows that there is no significant difference between LDVs and LDTs. (See Appendix D, Section L; Pairwise Comparison) Based on the pairwise comparisons, vehicle class was not considered as a factor for the analysis. The following equation was developed based on ANOVA results indicating CO base as a significant factor for CO effect, for all normal emitting vehicles on the Local cycle. (See Appendix D, Section M; Parameter Estimates)

$$\textbf{CO Effect} = 0.678 * (\textbf{CO base});\ R^2 = .217$$

Figures 5 in Appendix E show the predicted A/C effect, based on the above equation, versus the original data.

*5.2.3b High Emitters - Local Cycle*

When looking at CO effect as a function of vehicle class, average speed, and CO base, ANOVA results indicate that vehicle class and average speed are not significant for high emitting vehicles on the Local cycle. (See Appendix D, Sections N & O; Test of Between-Subjects Effects) However, CO base is considered significant and was used to develop the following linear equation that will model CO effect for all high emitting vehicles on the Local cycle. (See Appendix D, Section P; Parameter Estimates)

**CO Effect = 0.119 * (CO base); $R^2$ = .852**

Figures 6 in Appendix E show the predicted A/C effect, based on the above equation, versus the original data.

## 5.3 NOx

There will be three equations in MOBILE6 used to model the A/C effect on NOx emissions for three different strata. Unlike CO and NMHC, these equations will be in log space. This section will describe the analysis used to develop these equations.

ANOVA was performed on the NOx data set with A/C effect as the independent variable and A/C base, average speed, vehicle class, and facility cycle as the factors. The conclusion from this analysis was that there was a significant difference between LDVs and LDTs and that the Ramp cycle should be analyzed separately. (See Appendix F, Section A; Test of Between-Subjects Effects & Pairwise Comparison, Ramp = #5)

### *5.3.1 LDV - Freeway, Arterial, Local*

ANOVA was performed three separate times on a sample of LDVs with tests on all cycles excluding the Ramp cycle. For each ANOVA, A/C effect was the independent variable. The factors that were used varied for each analysis. The following are the combinations of factors used for the three ANOVA analyses.

1) NOx base, Average Speed
2) Log (NOx base), Log (Average Speed)
3) Log (NOx base + 1), Log (Average Speed)

Of the three analyses, the one using the factors listed as number three above had the best fit. (See Appendix F, Section B & C; Test of Between-Subjects Effects) The log function fits well because it is able to capture the drop in A/C effect at the lower end of the base emissions seen in the NOx sample. Log functions stabilize at the higher end of the base emissions, where a linear function would continue to rise. NOx base + 1 is used so that the log of a base emission equal to zero will be zero. Based on this analysis, log (NOx base + 1) was the only significant factor and was used to develop an equation to model A/C effect for LDVs. The following is the general equation form that was developed.

*A/C Effect = x * Log (NOx base +1)*

Although the analysis results did not indicate average speed as a significant factor, it was decided to investigate whether there might be an interaction between average speed and base emissions. In order to do so, the data sample was divided into three separate speed bins: below 15 mph, between 15 mph and 31 mph, and above 31 mph. These speed bins were chosen to represent where the average speeds for the different cycles fall between. The equation form, noted above, was modeled for these three speed bins. This analysis showed a trend where the "x" term decreased as average speed increased. (See Appendix F, Section D; Test of Between-Subjects Effects) In order to capture this effect in the equation form above, the following steps were followed:

1) If *A/C Effect = x * Log (NOx base + 1)* and
2) If *x = a + b (Log (Average Speed))*, then
3) *A/C Effect = [a + b (Log (Average Speed))] * Log (NOx base + 1)*
*= a Log (NOx base + 1) + b (Log (Average Speed) * Log (NOx base + 1))*

When this equation form (3) was modeled for the three speed bins, both the "a" and "b" terms were deemed significant. (See Appendix F, Section E; Test of Between-Subjects Effects) The following equation was developed from this analysis to model NOx A/C effect for LDVs on all freeway, arterial, and local cycles.

**A/C Effect = (4.867 Log (NOx base + 1) - 2.296 (Log (Average Speed)) * Log (NOx base + 1)); $R^2$ = 0.612**

Figure 1 in Appendix G show the predicted A/C effect, based on the above equation, versus the original data.

*5.3.2 LDT- Freeway, Arterial, Local*

The analysis use for LDV, described above, was also performed on the sample of LDT with tests on all cycles, excluding the Ramp cycle. The analysis lead to similar conclusions for LDTs as LDVs; a interactive effect between average speed and base emissions. (See Appendix F, Sections F-H; Test of Between-Subjects Effects & Parameter Estimates) The following equation was developed from this analysis to model NOx A/C effect for LDTs on all freeway, arterial, and local cycles.

**A/C Effect = (1.93 Log (NOx base + 1) - 0.769 (Log (Average Speed)) * Log (NOx base + 1)); $R^2$ = 0.371**

Figures 2 in Appendix G show the predicted A/C effect, based on the above equation, versus the original data.

### *5.3.3 Ramp Cycle*

ANOVA was performed on a sample of LDV and LDT with test on the Ramp cycle. For this analysis, A/C effect was looked at as a function of vehicle class and the log of NOx base + 1. Results indicate that there is no significant difference between LDVs and LDTs tested on the ramp cycle. (See Appendix F, Section I; Test of Between-Subjects Effects) Also, this analysis concluded that the log of NOx base + 1 is significant. Therefore the following equation was developed to model A/C effect for both LDVs and LDTs on the Ramp cycle. (See Appendix F, Section J; Test of Between-Subjects Effects)

$$\textbf{A/C Effect} = \mathbf{0.655 * Log(NOx\ base + 1);\ R^2 = 0.342}$$

Figures 3 in Appendix G show the predicted A/C effect, based on the above equation, versus the original data.

## 6.0 VALIDATION

Results of this analysis were compared with initial results from the Coordinating Research Council (CRC) project E-37 investigating air conditioning emissions.[9] The tests that were performed for this project were held in an environmental chamber, under several different ambient conditions. The models that are described in this report, EPA Report Number M6.ACE.002, "Air Conditioning Correction Factors," were used in conjunction with CRC's data. The purpose of doing this is to see how the models that were developed with data not from an environmental chamber compare to the data from environmental chamber testing. Though CRC performed tests under many different conditions, only the tests performed under conditions similar to what EPA and ATL were trying to simulate were used for comparison. Therefore, data from tests performed on the SCO3 driving cycle with the following conditions were used; 95$^\circ$F, full solar load (850 watts/meter$^2$), 100 grains water/ lb. dry-air, with the A/C on and off. Figures 1 - 4 in Appendix H show the comparison for several of the models. Considering the variation in CRC's data, the MOBILE6 model approach performs well on average.

## 7.0 START CORRECTION FACTORS

A primary change between MOBILE6 and MOBILE5 is the separation of FTP-based emissions into start and running components. This change draws a distinction between start emissions and emissions over start driving. Running emissions will represent not only emissions over warmed-up operation, but the baseline emissions inherent in start driving; start emissions will be defined as the incremental emission increase above this baseline which occurs during start driving. Total emissions over start driving, therefore, will be comprised of the baseline running emissions plus

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[9] Draft Report, CRC Project E-37, "Effects of Air Conditioning on Regulated Emissions for In-Use Vehicles," Coordinating Research Council, Inc.

incremental start emissions. In terms of air conditioning correction factors, the running correction factors developed in Section 5 will carry over to start driving to the extent that start driving emissions are comprised of the baseline running component. The pertinent issue for start air conditioning correction factors is therefore whether an A/C impact exists on the incremental start component as well.

Data required to make this assessment based on the methodology used in the development of base start and running emission factors[10] were not gathered as part of the air conditioning test program. An assessment was therefore made by analyzing the ratio for each pollutant over a cold start ST01 run with the A/C on and off, shown for relevant stratifications in Table 1 of Appendix I. The NOx and fuel consumption results indicate there is an increase over start driving due to air conditioning, but smaller (by 13% for LDV's, 7% for LDT's) than the impact over running operation at the average speed of the ST02 cycle (20.2 mph). It is presumed from this result that the NOx ratio observed over ST01 is attributable solely to the baseline running component, with no A/C-related increase occurring on the start increment. Based on this presumption, a NOx correction factor for the incremental start component is not proposed for MOBILE6.

HC and CO results vary somewhat, particularly across emitter class. Cold start HC and CO emissions are dominated by emissions incurred by startup enrichment. Under cold start enrichment the air-fuel ratio will likely not change due to air conditioner operation and/or increased engine load, so increased HC or CO emissions are not expected over the start component. It is therefore proposed that no A/C correction factor be applied to the HC or CO start components.

It is important to note that although air conditioning correction factors are not proposed for the start components of any pollutant, air conditioning emissions over start driving will be estimated by MOBILE6. Because the running correction factors are carried over to start driving, they will be applied to the extent running emissions contribute to overall start emissions. This will be true for all starts, including those following "intermediate" soak durations in which the engine and/or catalyst are partially warmed up. For the most part, the contribution of running emissions (and hence the influence of the running air conditioning correction factors) will become greater as the soak duration shortens.

## 8.0 BENEFITS OF THE SFTP REQUIREMENT

Increasing attention to the importance of off-cycle emissions led to the development of a new compliance procedure, known as the Supplemental Federal Test Procedure (SFTP). In addition to "off-cycle" emissions, the SFTP addresses emissions which are generated with the air conditioning on, which were also inadequately represented by the FTP. The SFTP requirements grew out of the 1990 Clean Air Act Amendments, which instructed EPA to review the existing

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[10] This methodology referred to is the separation of FTP emissions into Start and Running components as described in MOBILE6 Report No. M6.STE.002, "The Determination of Hot Running Emissions from FTP Bag Emissions"

procedures and revise them in whatever ways were necessary to make them more representative of actual in-use conditions. Developed in conjunction with the California Air Resources Board (ARB) and auto manufacturers, the SFTP requirement adds two additional certification cycles, and tailpipe standards associated with those cycles, to impose control of off-cycle (US06 cycle) and air conditioning emissions (SC03 cycle). The US06 is run with the vehicle in the hot stabilized condition; that is, with the vehicle fully warmed up to insure that the engine and catalytic converter have reached typical operating temperatures. The SC03 follows a 10-minute soak and is run with vehicle air conditioning (A/C) in operation or with an appropriate simulation of air-conditioning operation.

The assigned benefits of the SFTP rule will depend on whether a vehicle is a Tier 1 vehicle or a LEV. EPA and ARB promulgated separate requirements applying to these standard levels, and hence the benefits resulting from the rule must take into account the relative stringency of the EPA and ARB rules. Under NLEV, the Tier 1 rule will only apply to LDTs above 6000 pounds (LDT3s and LDT4s), which phase in to the SFTP requirement at 40 percent in 2002, 80 percent in 2003, and 100 percent in 2004.[1] These trucks will be allowed to certify to the Tier 1 SFTP standards until they begin phasing into the Tier 2 final standards in 2008, at which point they will be required to comply with the SFTP provisions under the Tier 2 rule discussed below.

For Tier 1 and interim Tier 2 LDT3s and LDT4s, the benefits derived in EPA's SFTP final rulemaking shown in Appendix J, Table 1 will be used directly in MOBILE6 (Post-SFTP CO air conditioning emissions are a special case, as discussed below). The percent reductions shown for the SFTP rule will be applied directly to the off-cycle adjustment to generate final off-cycle adjustments for SFTP-compliant vehicles.

A detailed derivation of these benefits are contained in the SFTP final rulemaking.[2] Because vehicles complying with the SFTP are just starting to enter the market, an assessment of SFTP benefit on the in-use fleet is not yet possible. We therefore consider the approach used in the EPA SFTP rule to be the best available.

Under NLEV, the ARB rule will apply to LEV LDVs and LDTs under 6,000 pounds (LDT1/2). The ARB rule contains NOx and HC certification standards which differ from EPA's both in terms of the relative stringency over the US06 and SC03 cycles, and the mileage at which a vehicle is required to show compliance. The percent reductions derived for EPA's Tier 1 ruletherefore cannot be applied directly to vehicles complying with the ARB standards.

LEV SFTP benefits for HC are estimated to be 100 percent. This is because ARB has required the elimination of "commanded enrichment" when the air conditioner is used, which we expect will eradicate excess HC emissions due to air conditioning usage. Although this same provision will reduce CO as well, we are setting the post-SFTP emission level so that CO emissions with the air conditioner on are higher than without the air conditioner off by the amount of additional fuel consumed. This reflects the fact that although we expect excess CO emission resulting from commanded enrichment to be eliminated, the SFTP does not address the unavoidable load (and hence fuel consumption) increase that results from air conditioner usage. An analysis presented in the draft version of this report (published in March 1998) estimated the percentage increase in fuel consumption with the air conditioning on as a function of speed; these equations were adopted directly for calculating a multiplicative adjustment which, when applied to running CO emissions without air conditioning, will result in post-SFTP CO emissions accounting for the "full-usage" air conditioning effect. These equations are as follows:

$$\textbf{Post-SFTP CO Correction Factor (LDV/LDT1)} = 1.34 - 0.006134(\text{speed}) + 0.000053(\text{speed})^2$$
$$\textbf{Post-SFTP CO Correction Factor (LDT2/3/4)} = 1.27 - 0.004939(\text{speed}) + 0.000048(\text{speed})^2$$

For estimating post-SFTP NOx air conditioning emissions, we developed a methodology which estimated the percent reductions in NOx for the ARB standards on LEVs based on the EPA Tier 1 benefits presented in Table 1. This methodology required an assessment of the relative stringency of the EPA and ARB SFTP standards compared to their respective FTP standard. Several factors added complication to this analysis: first, the ARB standards are applicable at 4,000 miles whereas the EPA standards are applicable at 50,000 miles and full useful life (100/120K miles); second, the SFTP standards are expressed at NMHC+NOx, while MOBILE treats these pollutants separately. Third, the SFTP standards are based on operation when the vehicle is warmed-up, necessitating that the warmed-up component of the FTP be extracted in order to performing comparisons with the SFTP standards. An analytical step was required to address each of these factors.

Reductions in air conditioning emissions due to ARB's LEV SFTP standards for NOx were estimated through a determination of the stringency of the ARB and EPA SC03 standards. The stringency of the ARB and EPA standards is characterized by how well they control air conditioning emissions for LEVs and Tier 1 vehicles, respectively. This stringency was determined through a direct comparison between these standards and emissions over the FTP. The basis for this determination was a comparison between the SC03 standards and an estimation of "running certification levels" (i.e. the running component of FTP certification levels) calculated for Tier 1 vehicles and LEVs, according to the following steps, shown in Table J-2:

1) Average certification emissions for model year 1999 LDVs and LDTs were generated from EPA's CFEIS database at 4,000 miles for LEVs and 50,000 miles for Tier 1 (Row 1). The certification database used to generate these averages are provided with this report.

2) "Running certification levels" were estimated for Tier 1 and LEV by multiplying the certification levels from Step 2 by the appropriate running BER fractions discussed in Draft Final MOBILE6 Report M6.EXH.007 (December 1999); 0.90 for NOx and 0.23 for HC. The FTP certification levels and the derived "running certification levels" are shown in Row 2.

3) NMHC+NOx US06 and SC03 standards were split into separate NMHC and NOx

standards by applying a split of 0.14/0.86 for NMHC/NOx, derived from the development of EPA's Tier 1 standards, and discussed in EPA's final SFTP rule (Rows 3 and 4).

4) A ratio of the resulting 50,000 mile SFTP NMHC and NOx "standards" from Step 3 and the running certification levels from Step 2 were calculated for both the Tier 1 (EPA) and LEV(ARB) requirements for US06 (Row 5). The ratio (R) represents the magnitude of increase allowed between the FTP and US06 cycles, and hence represents the stringency of the SFTP standard relative to the FTP standards.

5) The stringency of the ARB standards relative to the EPA standards were estimated by comparing the value of R calculated in Step 4, according to the following equation (Row 6):

$$\text{Additional Stringency of ARB Standards (\%)} = [(R_{EPA} - 1) - (R_{ARB} - 1)] / (R_{EPA} - 1)$$

The additional stringency represents the additional off-cycle emissions which would be eliminated above and beyond the reductions under the Tier 1 standards.

6) Benefits under the ARB rule were then derived by adjusting the Tier 1 benefits (Row 7) from Table 7-1 according to the additional stringency contained in Step 5, according to the following equation (Row 8):

$$\text{ARB Benefit (\%)} = \text{EPA Benefit} + (\text{Step 5}) * (1 - \text{EPA Benefit})$$

The resulting NOx SFTP benefits for LEVs are presented in Tables J-3. Full-usage air conditioning correction factors which reflect the SFTP rule are calculated in MOBILE6 by first estimating the additive NOx air conditioning increment without the SFTP using the methodology presented in Section 5, and reducing this increment by the appropriate percent reduction shown in Table J-3.

## ACKNOWLEDGMENTS

Several individuals contributed considerable time and resources to gathering and analyzing the data presented here. Carl Fulper, Carl Scarbro, Dave Boshenek and Manish Patel of OTAQ designed and implemented the test program and developed the attendant data set. Steve Baldus and Kevin Cullen of GM made GM's environmental chamber available and coordinated testing at that facility.

## Appendix A:

Testing Vehicles, Cycles, and Correlation Results

**Table 1** - Vehicle Sample

| Site | Year | Vehicle | Class | Fuel | Std | Emit* |
|---|---|---|---|---|---|---|
| ATL | 91 | CHEVROLET CAVALIER | LDV | TBI | Tier 0 | N/N/N |
| ATL | 91 | FORD ECONOLINE 150 | LDT2 | PFI | Tier 0 | H/H/N |
| ATL | 91 | FORD ESCORT | LDV | PFI | Tier 0 | H/N/H |
| ATL | 91 | PLYMOUTH VOYAGER | LDT1 | TBI | Tier 0 | N/N/N |
| ATL | 91 | CHEVROLET ASTRO VAN | LDT1 | TBI | Tier 0 | H/N/N |
| ATL | 93 | CHEVROLET CORSICA | LDV | PFI | Tier 0 | N/N/N |
| ATL | 93 | CHEVROLET S10 | LDT1 | TBI | Tier 0 | N/N/N |
| ATL | 93 | TOYOTA CAMRY | LDV | PFI | Tier 0 | N/N/N |
| ATL | 93 | HONDA ACCORD | LDV | PFI | Tier 0 | N/N/N |
| ATL | 90 | NISSAN MAXIMA | LDV | PFI | Tier 0 | N/N/N |
| ATL | 93 | EAGLE SUMMIT | LDV | PFI | Tier 0 | N/N/N |
| EPA | 92 | TOYOTA COROLLA | LDV | PFI | Tier 0 | N/N/N |
| EPA | 96 | HONDA ACCORD | LDV | PFI | Tier 1 | N/N/N |
| EPA | 92 | SATURN SL | LDV | TBI | Tier 0 | N/N/N |
| EPA | 92 | CHEVROLET BERETTA | LDV | PFI | Tier 0 | H/H/N |
| EPA | 94 | FORD F150 | LDT2 | PFI | Tier 0 | N/N/N |
| EPA | 96 | FORD F150 | LDT2 | PFI | Tier 1 | N/N/N |
| EPA | 92 | MAZDA PROTEGE | LDV | PFI | Tier 0 | N/N/N |
| EPA | 96 | CHEVROLET LUMINA | LDV | PFI | Tier 1 | N/N/N |
| EPA | 92 | CHEVROLET CAVALIER | LDV | PFI | Tier 0 | N/N/N |
| EPA | 96 | FORD RANGER | LDT1 | PFI | Tier 1 | N/N/N |
| EPA | 90 | JEEP CHEROKEE | LDT1 | PFI | Tier 0 | H/H/H |
| EPA | 90 | CHEVROLET SUBURBAN | LDT2 | TBI | Tier 0 | N/N/N |
| EPA | 94 | CHRYSLER LHS | LDV | PFI | Tier 0 | N/N/N |
| EPA | 96 | HONDA CIVIC | LDV | PFI | Tier 1 | N/N/N |
| EPA | 94 | CHEVROLET ASTRO VAN | LDT1 | PFI | Tier 0 | N/N/N |
| EPA | 94 | SATURN SL | LDV | PFI | Tier 0 | N/N/N |
| EPA | 94 | HYUNDAI ELAN | LDV | PFI | Tier 0 | N/N/N |
| EPA | 92 | CHEVROLET LUMINA VAN | LDT1 | PFI | Tier 0 | N/N/N |
| EPA | 94 | FORD ESCORT | LDV | PFI | Tier 1 | N/N/N |
| EPA | 90 | PLYMOUTH VOYAGER | LDT1 | PFI | Tier 0 | N/N/N |
| EPA | 92 | CHEVROLET LUMINA | LDV | PFI | Tier 0 | N/N/N |
| EPA | 96 | FORD EXPLORER | LDT1 | PFI | Tier 1 | N/N/N |
| EPA | 94 | PONTIAC TRANSPORT | LDT1 | PFI | Tier 1 | N/N/N |
| EPA | 96 | TOYOTA CAMRY | LDV | PFI | Tier 1 | N/N/N |
| EPA | 90 | DODGE DYNASTY | LDV | PFI | Tier 0 | N/N/N |
| BOTH | 96 | PONTIAC GRAND PRIX | LDV | PFI | Tier 1 | N/N/N |

*HC/CO/NOx

**Table 2** - Test Cycles

| Cycle | Description | Distance (miles) | Average Speed (mph) | Max Speed (mph) | Max Accel (mph/sec) |
|---|---|---|---|---|---|
| ***NYCC*** | New York City Cycle | 1.18 | 7.1 | 27.7 | 6.0 |
| ***LOCL*** | Local Roadways | 7.24 | 12.9 | 38.3 | 3.7 |
| ***ARTE*** | Arterial **L**evel **O**f **S**ervice E-F | 1.62 | 11.6 | 39.9 | 5.8 |
| ***ARTC*** | Arterial LOS C-D | 3.35 | 19.2 | 49.5 | 5.7 |
| ***ARTA*** | Arterial LOS A-B | 5.06 | 24.7 | 58.9 | 5.0 |
| ***FWYG*** | Freeway LOS G | 1.42 | 13.1 | 35.7 | 3.8 |
| ***FWYF*** | Freeway LOS F | 2.28 | 18.6 | 49.9 | 6.9 |
| ***FWYE*** | Freeway LOS E | 3.85 | 30.5 | 63.0 | 5.3 |
| ***FWYD*** | Freeway LOS D | 5.95 | 52.9 | 70.6 | 2.3 |
| ***FWAC*** | Freeway LOS A-C | 8.54 | 59.7 | 73.1 | 3.4 |
| ***FWHS*** | Freeway High Speed | 10.70 | 63.2 | 74.7 | 2.7 |
| ***RAMP*** | Freeway Ramp | 2.56 | 34.7 | 60.2 | 5.7 |
| ***AREA*** | Non-Freeway Area-Wide | 7.25 | 19.4 | 52.3 | 6.4 |
| ***LA92*** | California "Unified" Cycle | 9.81 | 24.6 | 67.2 | 6.9 |
| ***ST01*** | Start Cycle | 1.39 | 20.2 | 41.0 | 5.1 |

**Table 3** - Correlation Vehicle Emission Results (g/mi)

| | | NMHC | | | CO | | | NOx | | | Carbon | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Off** | **On** | **Ratio** | **Off** | **On** | **Ratio** | **Off** | **On** | **Ratio** | **Off** | **On** | **Ratio** |
| **NYCC** | *ATL* | 0.07 | 0.67 | 9.39 | 1.36 | 4.34 | 3.19 | 0.03 | 0.33 | 10.20 | 214.1 | 281.6 | 1.31 |
| | *EPA* | 0.07 | 0.07 | 1.03 | 0.98 | 3.32 | 3.39 | 0.11 | 0.25 | 2.15 | 208.6 | 275.4 | 1.32 |
| | *GM* | 0.06 | 0.07 | 1.25 | 0.60 | 7.71 | 12.94 | 0.11 | 0.28 | 2.52 | 217.8 | 283.5 | 1.30 |
| **LA92** | *ATL* | 0.04 | 0.10 | 2.76 | 0.39 | 7.92 | 20.35 | 0.38 | 0.21 | 0.55 | 115.3 | 138.7 | 1.20 |
| | *EPA* | 0.02 | 0.02 | 0.94 | 0.15 | 0.53 | 3.52 | 0.38 | 0.51 | 1.34 | 110.1 | 133.0 | 1.21 |
| | *GM* | 0.04 | 0.03 | 0.61 | 0.54 | 1.83 | 3.37 | 0.67 | 1.04 | 1.55 | 216.8 | 267.2 | 1.23 |
| **FWHS** | *ATL* | 0.08 | 1.32 | 15.72 | 2.82 | 100.04 | 35.47 | 0.25 | 0.03 | 0.12 | 88.2 | 120.7 | 1.37 |
| | *EPA* | 0.05 | 1.33 | 24.23 | 4.63 | 112.24 | 24.26 | 0.22 | 0.00 | 0.01 | 82.7 | 120.0 | 1.45 |
| | *GM* | 0.02 | 0.03 | 1.75 | 0.82 | 2.41 | 2.94 | 0.30 | 0.62 | 2.05 | 82.0 | 85.9 | 1.05 |
| **ARTC** | *ATL* | 0.04 | 0.04 | 1.11 | 1.70 | 1.41 | 0.83 | 0.11 | 0.16 | 1.48 | 120.0 | 145.3 | 1.21 |
| | *EPA* | 0.03 | 0.05 | 1.48 | 1.41 | 3.00 | 2.13 | 0.13 | 0.28 | 2.14 | 116.7 | 144.4 | 1.24 |
| | *GM* | 0.01 | 0.03 | 2.83 | 0.33 | 2.99 | 9.15 | 0.19 | 0.37 | 1.94 | 120.2 | 144.5 | 1.20 |

**Table 4** - Correlation Vehicle Compressor Behavior

| | | Compressor Fraction | Average High Pressure (lb/in$^2$) | Average Low Pressure (lb/in$^2$) |
|---|---|---|---|---|
| **NYCC** | *ATL* | 1.00 | 311.5 | 49.7 |
| | *EPA* | 0.99 | 306.4 | 58.1 |
| | *GM* | 0.97 | 320.9 | 44.5 |
| **LA92** | *ATL* | 0.99 | 334.2 | 48.2 |
| | *EPA* | 0.97 | 339.4 | 57.9 |
| | *GM* | 0.99 | 312.1 | 40.3 |
| **FWHS** | *ATL* | 1.00 | 361.1 | 43.7 |
| | *EPA* | 0.99 | 367.3 | 50.3 |
| | *GM* | 1.02 | 264.8 | 34.3 |
| **ARTC** | *ATL* | 1.00 | 310.7 | 46.4 |
| | *EPA* | 0.98 | 315.3 | 54.7 |
| | *GM* | 0.99 | 310.8 | 39.0 |

**Appendix B:**
NMHC ANOVA Results

# SECTION A
# NMHC Univariate Analysis of Variance
# LDV & LDT
# All Emitter Categories
# All Cycles

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CYCLE_ID | ART | 148 |
| | FWY | 221 |
| | LA92 | 37 |
| | LOCAL | 74 |
| | RAMP | 37 |
| CLASS | LDT | 182 |
| | LDV | 335 |

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 156.576[a] | 9 | 17.397 | 70.033 | .000 |
| CYCLE_ID | 1.486 | 4 | .372 | 1.496 | .202 |
| NMHC_EMT | 51.228 | 1 | 51.228 | 206.216 | .000 |
| AVG_SPD | .213 | 1 | .213 | .859 | .355 |
| NMHC_OFF | 138.427 | 1 | 138.427 | 557.236 | .000 |
| CLASS | .145 | 1 | .145 | .585 | .445 |
| Error | 126.196 | 508 | .248 | | |
| Total | 282.771 | 517 | | | |

a. R Squared = .554 (Adjusted R Squared = .546)

## Estimated Marginal Means

## 1. CYCLE_ID

**Estimates**

Dependent Variable: NMHC_DIFF

| CYCLE_ID | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| ART | 9.934E-03[a] | .044 | -7.706E-02 | 9.692E-02 |
| FWY | 7.662E-02[a] | .039 | -6.782E-04 | .154 |
| LA92 | 1.276E-02[a] | .082 | -.149 | .175 |
| LOCAL | .161[a] | .065 | 3.256E-02 | .290 |
| RAMP | -1.808E-02[a] | .083 | -.181 | .145 |

a. Evaluated at covariates appeared in the model: nmhc emit cat = 7.930E-02, AVG_SPD = 27.95300, NMHC_OFF = .58475.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) CYCLE_ID | (J) CYCLE_ID | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| ART | FWY | -6.668E-02 | .063 | .292 | -.191 | 5.739E-02 |
| | LA92 | -2.823E-03 | .092 | .976 | -.184 | .178 |
| | LOCAL | -.151* | .073 | .037 | -.294 | -8.819E-03 |
| | RAMP | 2.801E-02 | .095 | .769 | -.159 | .215 |
| FWY | ART | 6.668E-02 | .063 | .292 | -5.739E-02 | .191 |
| | LA92 | 6.386E-02 | .092 | .488 | -.117 | .244 |
| | LOCAL | -8.463E-02 | .083 | .309 | -.248 | 7.851E-02 |
| | RAMP | 9.470E-02 | .089 | .287 | -8.002E-02 | .269 |
| LA92 | ART | 2.823E-03 | .092 | .976 | -.178 | .184 |
| | FWY | -6.386E-02 | .092 | .488 | -.244 | .117 |
| | LOCAL | -.148 | .103 | .151 | -.352 | 5.453E-02 |
| | RAMP | 3.084E-02 | .117 | .792 | -.199 | .261 |
| LOCAL | ART | .151* | .073 | .037 | 8.819E-03 | .294 |
| | FWY | 8.463E-02 | .083 | .309 | -7.851E-02 | .248 |
| | LA92 | .148 | .103 | .151 | -5.453E-02 | .352 |
| | RAMP | .179 | .108 | .098 | -3.350E-02 | .392 |
| RAMP | ART | -2.801E-02 | .095 | .769 | -.215 | .159 |
| | FWY | -9.470E-02 | .089 | .287 | -.269 | 8.002E-02 |
| | LA92 | -3.084E-02 | .117 | .792 | -.261 | .199 |
| | LOCAL | -.179 | .108 | .098 | -.392 | 3.350E-02 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 1.486 | 4 | .372 | 1.496 | .202 |
| Error | 126.196 | 508 | .248 | | |

The F tests the effect of CYCLE_ID. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# 2. CLASS

**Estimates**

Dependent Variable: NMHC_DIFF

| CLASS | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| LDT | 3.016E-02[a] | .042 | -5.227E-02 | .113 |
| LDV | 6.683E-02[a] | .033 | 2.050E-03 | .132 |

a. Evaluated at covariates appeared in the model: nmhc emit cat = 7.930E-02, AVG_SPD = 27.95300, NMHC_OFF = .58475.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) CLASS | (J) CLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] Lower Bound | 95% Confidence Interval for Difference[a] Upper Bound |
|---|---|---|---|---|---|---|
| LDT | LDV | -3.667E-02 | .048 | .445 | -.131 | 5.751E-02 |
| LDV | LDT | 3.667E-02 | .048 | .445 | -5.751E-02 | .131 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | .145 | 1 | .145 | .585 | .445 |
| Error | 126.196 | 508 | .248 | | |

The F tests the effect of CLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

## SECTION B
## NMHC Univariate Analysis of Variance
## LDV & LDT
## All cycles
## Normal emitter only

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CYCLE_ID | ART | 128 |
| | FWY | 192 |
| | LA92 | 32 |
| | LOCAL | 64 |
| | RAMP | 32 |
| CLASS | LDT | 140 |
| | LDV | 308 |

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 1.943[a] | 8 | .243 | 4.722 | .000 |
| NMHC_OFF | 7.789E-05 | 1 | 7.789E-05 | .002 | .969 |
| AVG_SPD | 7.479E-02 | 1 | 7.479E-02 | 1.454 | .229 |
| CYCLE_ID | .732 | 4 | .183 | 3.555 | .007 |
| CLASS | 4.724E-02 | 1 | 4.724E-02 | .918 | .338 |
| Error | 22.638 | 440 | 5.145E-02 | | |
| Total | 24.582 | 448 | | | |

a. R Squared = .079 (Adjusted R Squared = .062)

# Estimated Marginal Means

# 1. CYCLE_ID

**Estimates**

Dependent Variable: NMHC_DIFF

| CYCLE_ID | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| ART | 2.136E-02[a] | .022 | -2.156E-02 | 6.429E-02 |
| FWY | 3.242E-02[a] | .019 | -5.649E-03 | 7.050E-02 |
| LA92 | 1.977E-02[a] | .040 | -5.973E-02 | 9.927E-02 |
| LOCAL | .152[a] | .032 | 8.809E-02 | .216 |
| RAMP | 4.676E-02[a] | .041 | -3.360E-02 | .127 |

a. Evaluated at covariates appeared in the model: NMHC_OFF = .12027, AVG_SPD = 28.01429.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) CYCLE_ID | (J) CYCLE_ID | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| ART | FWY | -1.106E-02 | .031 | .721 | -7.180E-02 | 4.967E-02 |
| | LA92 | 1.595E-03 | .045 | .972 | -8.701E-02 | 9.020E-02 |
| | LOCAL | -.130* | .036 | .000 | -.201 | -6.017E-02 |
| | RAMP | -2.540E-02 | .047 | .588 | -.117 | 6.670E-02 |
| FWY | ART | 1.106E-02 | .031 | .721 | -4.967E-02 | 7.180E-02 |
| | LA92 | 1.266E-02 | .045 | .779 | -7.578E-02 | .101 |
| | LOCAL | -.119* | .041 | .004 | -.200 | -3.919E-02 |
| | RAMP | -1.433E-02 | .044 | .743 | -.100 | 7.161E-02 |
| LA92 | ART | -1.595E-03 | .045 | .972 | -9.020E-02 | 8.701E-02 |
| | FWY | -1.266E-02 | .045 | .779 | -.101 | 7.578E-02 |
| | LOCAL | -.132* | .051 | .010 | -.232 | -3.219E-02 |
| | RAMP | -2.699E-02 | .058 | .639 | -.140 | 8.610E-02 |
| LOCAL | ART | .130* | .036 | .000 | 6.017E-02 | .201 |
| | FWY | .119* | .041 | .004 | 3.919E-02 | .200 |
| | LA92 | .132* | .051 | .010 | 3.219E-02 | .232 |
| | RAMP | .105* | .053 | .048 | 9.523E-04 | .209 |
| RAMP | ART | 2.540E-02 | .047 | .588 | -6.670E-02 | .117 |
| | FWY | 1.433E-02 | .044 | .743 | -7.161E-02 | .100 |
| | LA92 | 2.699E-02 | .058 | .639 | -8.610E-02 | .140 |
| | LOCAL | -.105* | .053 | .048 | -.209 | -9.523E-04 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | .732 | 4 | .183 | 3.555 | .007 |
| Error | 22.638 | 440 | 5.145E-02 | | |

The F tests the effect of CYCLE_ID. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# 2. CLASS

**Estimates**

Dependent Variable: NMHC_DIFF

| CLASS | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| LDT | 4.328E-02[a] | .021 | 1.576E-03 | 8.499E-02 |
| LDV | 6.557E-02[a] | .016 | 3.488E-02 | 9.626E-02 |

a. Evaluated at covariates appeared in the model: NMHC_OFF = .12027, AVG_SPD = 28.01429.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) CLASS | (J) CLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT | LDV | -2.229E-02 | .023 | .338 | -6.800E-02 | 2.343E-02 |
| LDV | LDT | 2.229E-02 | .023 | .338 | -2.343E-02 | 6.800E-02 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 4.724E-02 | 1 | 4.724E-02 | .918 | .338 |
| Error | 22.638 | 440 | 5.145E-02 | | |

The F tests the effect of CLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION C
# NMHC Univariate Analysis of Variance
# No Local Cycle
# LDV and LDT
# Normal Emitters

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CLASS | LDT | 120 |
| | LDV | 264 |

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | .870[a] | 4 | .218 | 5.947 | .000 |
| NMHC_OFF | .125 | 1 | .125 | 3.412 | .066 |
| AVG_SPD | .113 | 1 | .113 | 3.079 | .080 |
| CLASS | .109 | 2 | 5.468E-02 | 1.495 | .226 |
| Error | 13.902 | 380 | 3.658E-02 | | |
| Total | 14.772 | 384 | | | |

a. R Squared = .059 (Adjusted R Squared = .049)

# Estimated Marginal Means

# CLASS

**Estimates**

Dependent Variable: NMHC_DIFF

| CLASS | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| LDT | 1.546E-02[a] | .018 | -1.897E-02 | 4.989E-02 |
| LDV | 4.539E-02[a] | .012 | 2.221E-02 | 6.856E-02 |

a. Evaluated at covariates appeared in the model: NMHC_OFF = .10894, AVG_SPD = 31.01667.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) CLASS | (J) CLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT | LDV | -2.992E-02 | .021 | .158 | -7.150E-02 | 1.166E-02 |
| LDV | LDT | 2.992E-02 | .021 | .158 | -1.166E-02 | 7.150E-02 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 7.325E-02 | 1 | 7.325E-02 | 2.002 | .158 |
| Error | 13.902 | 380 | 3.658E-02 | | |

The F tests the effect of CLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION D
# NMHC Univariate Analysis of Variance
# LDT and LDV together
# Normal emitters
# No Local Cycle

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | .761[a] | 2 | .380 | 10.373 | .000 |
| NMHC_OFF | .108 | 1 | .108 | 2.945 | .087 |
| AVG_SPD | .736 | 1 | .736 | 20.076 | .000 |
| Error | 14.011 | 382 | 3.668E-02 | | |
| Total | 14.772 | 384 | | | |

a. R Squared = .052 (Adjusted R Squared = .047)

# SECTION E
# NMHC Univariate Analysis of Variance
# Normal emitters only
# All Vehicle Classes
# No Local Cycle

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | .653[a] | 1 | .653 | 17.710 | .000 |
| AVG_SPD | .653 | 1 | .653 | 17.710 | .000 |
| Error | 14.119 | 383 | 3.686E-02 | | |
| Total | 14.772 | 384 | | | |

a. R Squared = .044 (Adjusted R Squared = .042)

**Parameter Estimates**

Dependent Variable: NMHC_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| AVG_SPD | 1.162E-03 | .000 | 4.208 | .000 | 6.193E-04 | 1.705E-03 |

# SECTION F

# NMHC Univariate Analysis of Variance
# All Vehicle Classes
# Normal Emitters only
# Local Cycle only

**Between-Subjects Factors**

| | | N |
|---|---|---|
| VEHCLASS | LDT1 | 14 |
| | LDT2 | 6 |
| | LDV | 44 |

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 2.725[a] | 5 | .545 | 4.538 | .001 |
| VEHCLASS | 1.201 | 3 | .400 | 3.333 | .025 |
| NMHC_OFF | 4.981E-02 | 1 | 4.981E-02 | .415 | .522 |
| AVG_SPD | 2.129E-02 | 1 | 2.129E-02 | .177 | .675 |
| Error | 7.085 | 59 | .120 | | |
| Total | 9.810 | 64 | | | |

a. R Squared = .278 (Adjusted R Squared = .217)

# Estimated Marginal Means

# VEHCLASS

**Estimates**

Dependent Variable: NMHC_DIFF

| VEHCLASS | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| LDT1 | -5.315E-03[a] | .093 | -.191 | .180 |
| LDT2 | .547[a] | .149 | .249 | .844 |
| LDV | .128[a] | .053 | 2.285E-02 | .233 |

a. Evaluated at covariates appeared in the model: NMHC_OFF = .18830, AVG_SPD = 10.00000.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) VEHCLASS | (J) VEHCLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT1 | LDT2 | -.552* | .175 | .003 | -.903 | -.201 |
| | LDV | -.133 | .106 | .215 | -.346 | 7.963E-02 |
| LDT2 | LDT1 | .552* | .175 | .003 | .201 | .903 |
| | LDV | .419* | .159 | .011 | 9.992E-02 | .737 |
| LDV | LDT1 | .133 | .106 | .215 | -7.963E-02 | .346 |
| | LDT2 | -.419* | .159 | .011 | -.737 | -9.992E-02 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 1.194 | 2 | .597 | 4.970 | .010 |
| Error | 7.085 | 59 | .120 | | |

The F tests the effect of VEHCLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION G
# NMHC Univariate Analysis of Variance
# LDV & LDT
# Local Cycle only
# Normal Emitters only

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CLASS | LDT | 20 |
| | LDV | 44 |

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 1.535[a] | 4 | .384 | 2.782 | .035 |
| NMHC_OFF | .282 | 1 | .282 | 2.043 | .158 |
| AVG_SPD | 6.065E-02 | 1 | 6.065E-02 | .440 | .510 |
| CLASS | 1.080E-02 | 2 | 5.398E-03 | .039 | .962 |
| Error | 8.275 | 60 | .138 | | |
| Total | 9.810 | 64 | | | |

a. R Squared = .156 (Adjusted R Squared = .100)

# SECTION G cont.
# NMHC Univariate Analysis of Variance

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 1.524[a] | 2 | .762 | 5.702 | .005 |
| NMHC_OFF | .354 | 1 | .354 | 2.650 | .109 |
| AVG_SPD | .276 | 1 | .276 | 2.063 | .156 |
| Error | 8.286 | 62 | .134 | | |
| Total | 9.810 | 64 | | | |

a. R Squared = .155 (Adjusted R Squared = .128)

# SECTION H
# NMHC Univariate Analysis of Variance
# LDV and LDT
# Normal Emitters Only
# Local Cycle Only

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 1.248[a] | 1 | 1.248 | 9.187 | .004 |
| NMHC_OFF | 1.248 | 1 | 1.248 | 9.187 | .004 |
| Error | 8.561 | 63 | .136 | | |
| Total | 9.810 | 64 | | | |

a. R Squared = .127 (Adjusted R Squared = .113)

**Parameter Estimates**

Dependent Variable: NMHC_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| NMHC_OFF | .506 | .167 | 3.031 | .004 | .172 | .839 |

# SECTION I
# NMHC Univariate Analysis of Variance
# High Emitter only
# All Cycles
# All Vehicle Classes

**Between-Subjects Factors**

| | | N |
|---|---|---|
| VEHCLASS | LDT1 | 28 |
| | LDT2 | 14 |
| | LDV | 27 |
| CYCLE_ID | ART | 20 |
| | FWY | 29 |
| | LA92 | 5 |
| | LOCAL | 10 |
| | RAMP | 5 |

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 168.489[a] | 9 | 18.721 | 12.522 | .000 |
| NMHC_OFF | 100.729 | 1 | 100.729 | 67.377 | .000 |
| AVG_SPD | 1.098E-02 | 1 | 1.098E-02 | .007 | .932 |
| VEHCLASS | 17.928 | 2 | 8.964 | 5.996 | .004 |
| CYCLE_ID | 4.098 | 4 | 1.025 | .685 | .605 |
| Error | 89.701 | 60 | 1.495 | | |
| Total | 258.190 | 69 | | | |

a. R Squared = .653 (Adjusted R Squared = .600)

## Estimated Marginal Means

## 1. VEHCLASS

**Estimates**

Dependent Variable: NMHC_DIFF

| VEHCLASS | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| LDT1 | .418[a] | .272 | -.125 | .962 |
| LDT2 | -.936[a] | .348 | -1.633 | -.240 |
| LDV | .189[a] | .284 | -.379 | .757 |

a. Evaluated at covariates appeared in the model: NMHC_OFF = 3.60049, AVG_SPD = 27.55507.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) VEHCLASS | (J) VEHCLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] Lower Bound | 95% Confidence Interval for Difference[a] Upper Bound |
|---|---|---|---|---|---|---|
| LDT1 | LDT2 | 1.355* | .405 | .001 | .545 | 2.164 |
| | LDV | .229 | .379 | .548 | -.530 | .988 |
| LDT2 | LDT1 | -1.355* | .405 | .001 | -2.164 | -.545 |
| | LDV | -1.125* | .423 | .010 | -1.971 | -.280 |
| LDV | LDT1 | -.229 | .379 | .548 | -.988 | .530 |
| | LDT2 | 1.125* | .423 | .010 | .280 | 1.971 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 17.928 | 2 | 8.964 | 5.996 | .004 |
| Error | 89.701 | 60 | 1.495 | | |

The F tests the effect of VEHCLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

## 2. CYCLE_ID

**Estimates**

Dependent Variable: NMHC_DIFF

| CYCLE_ID | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| ART | -.244[a] | .295 | -.834 | .345 |
| FWY | .170[a] | .266 | -.361 | .702 |
| LA92 | -.259[a] | .550 | -1.360 | .841 |
| LOCAL | .263[a] | .440 | -.617 | 1.142 |
| RAMP | -.477[a] | .555 | -1.587 | .633 |

a. Evaluated at covariates appeared in the model: NMHC_OFF = 3.60049, AVG_SPD = 27.55507.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) CYCLE_ID | (J) CYCLE_ID | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] Lower Bound | 95% Confidence Interval for Difference[a] Upper Bound |
|---|---|---|---|---|---|---|
| ART | FWY | -.415 | .422 | .330 | -1.259 | .429 |
| | LA92 | 1.498E-02 | .615 | .981 | -1.215 | 1.245 |
| | LOCAL | -.507 | .487 | .302 | -1.481 | .467 |
| | RAMP | .232 | .637 | .716 | -1.041 | 1.506 |
| FWY | ART | .415 | .422 | .330 | -.429 | 1.259 |
| | LA92 | .430 | .614 | .486 | -.798 | 1.657 |
| | LOCAL | -9.244E-02 | .559 | .869 | -1.210 | 1.025 |
| | RAMP | .647 | .594 | .281 | -.542 | 1.836 |
| LA92 | ART | -1.498E-02 | .615 | .981 | -1.245 | 1.215 |
| | FWY | -.430 | .614 | .486 | -1.657 | .798 |
| | LOCAL | -.522 | .693 | .454 | -1.909 | .865 |
| | RAMP | .218 | .782 | .782 | -1.346 | 1.781 |
| LOCAL | ART | .507 | .487 | .302 | -.467 | 1.481 |
| | FWY | 9.244E-02 | .559 | .869 | -1.025 | 1.210 |
| | LA92 | .522 | .693 | .454 | -.865 | 1.909 |
| | RAMP | .740 | .727 | .313 | -.714 | 2.193 |
| RAMP | ART | -.232 | .637 | .716 | -1.506 | 1.041 |
| | FWY | -.647 | .594 | .281 | -1.836 | .542 |
| | LA92 | -.218 | .782 | .782 | -1.781 | 1.346 |
| | LOCAL | -.740 | .727 | .313 | -2.193 | .714 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 4.098 | 4 | 1.025 | .685 | .605 |
| Error | 89.701 | 60 | 1.495 | | |

The F tests the effect of CYCLE_ID. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION J
# NMHC Univariate Analysis of Variance
# High Emitters Only
# LDV & LDT
# All Cycles

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CYCLE_ID | ART | 20 |
| | FWY | 29 |
| | LA92 | 5 |
| | LOCAL | 10 |
| | RAMP | 5 |
| CLASS | LDT | 42 |
| | LDV | 27 |

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 151.736[a] | 8 | 18.967 | 10.868 | .000 |
| NMHC_OFF | 90.932 | 1 | 90.932 | 52.106 | .000 |
| CYCLE_ID | 4.211 | 4 | 1.053 | .603 | .662 |
| AVG_SPD | 5.203E-06 | 1 | 5.203E-06 | .000 | .999 |
| CLASS | 1.175 | 1 | 1.175 | .673 | .415 |
| Error | 106.454 | 61 | 1.745 | | |
| Total | 258.190 | 69 | | | |

a. R Squared = .588 (Adjusted R Squared = .534)

## Estimated Marginal Means

## 1. CYCLE_ID

**Estimates**

Dependent Variable: NMHC_DIFF

| CYCLE_ID | Mean | Std. Error | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|
| ART | -4.725E-02[a] | .317 | -.681 | .586 |
| FWY | .358[a] | .284 | -.210 | .925 |
| LA92 | -7.017E-02[a] | .593 | -1.256 | 1.115 |
| LOCAL | .488[a] | .477 | -.466 | 1.443 |
| RAMP | -.280[a] | .598 | -1.476 | .915 |

a. Evaluated at covariates appeared in the model: NMHC_OFF = 3.60049, AVG_SPD = 27.55507.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| (I) CYCLE_ID | (J) CYCLE_ID | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| ART | FWY | -.405 | .456 | .378 | -1.316 | .507 |
| | LA92 | 2.293E-02 | .665 | .973 | -1.306 | 1.352 |
| | LOCAL | -.536 | .526 | .313 | -1.588 | .516 |
| | RAMP | .233 | .688 | .736 | -1.142 | 1.609 |
| FWY | ART | .405 | .456 | .378 | -.507 | 1.316 |
| | LA92 | .428 | .663 | .521 | -.898 | 1.753 |
| | LOCAL | -.131 | .604 | .829 | -1.338 | 1.076 |
| | RAMP | .638 | .642 | .324 | -.646 | 1.922 |
| LA92 | ART | -2.293E-02 | .665 | .973 | -1.352 | 1.306 |
| | FWY | -.428 | .663 | .521 | -1.753 | .898 |
| | LOCAL | -.559 | .749 | .459 | -2.056 | .939 |
| | RAMP | .210 | .844 | .804 | -1.478 | 1.899 |
| LOCAL | ART | .536 | .526 | .313 | -.516 | 1.588 |
| | FWY | .131 | .604 | .829 | -1.076 | 1.338 |
| | LA92 | .559 | .749 | .459 | -.939 | 2.056 |
| | RAMP | .769 | .785 | .331 | -.801 | 2.338 |
| RAMP | ART | -.233 | .688 | .736 | -1.609 | 1.142 |
| | FWY | -.638 | .642 | .324 | -1.922 | .646 |
| | LA92 | -.210 | .844 | .804 | -1.899 | 1.478 |
| | LOCAL | -.769 | .785 | .331 | -2.338 | .801 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 4.211 | 4 | 1.053 | .603 | .662 |
| Error | 106.454 | 61 | 1.745 | | |

The F tests the effect of CYCLE_ID. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

## 2. CLASS

**Estimates**

Dependent Variable: NMHC_DIFF

| | | | 95% Confidence Interval | |
|---|---|---|---|---|
| CLASS | Mean | Std. Error | Lower Bound | Upper Bound |
| LDT | -6.297E-02[a] | .249 | -.561 | .435 |
| LDV | .242[a] | .306 | -.370 | .854 |

a. Evaluated at covariates appeared in the model: NMHC_OFF = 3.60049, AVG_SPD = 27.55507.

**Pairwise Comparisons**

Dependent Variable: NMHC_DIFF

| | | | | | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| (I) CLASS | (J) CLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | Lower Bound | Upper Bound |
| LDT | LDV | -.305 | .372 | .415 | -1.049 | .439 |
| LDV | LDT | .305 | .372 | .415 | -.439 | 1.049 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NMHC_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 1.175 | 1 | 1.175 | .673 | .415 |
| Error | 106.454 | 61 | 1.745 | | |

The F tests the effect of CLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION K
# NMHC Univariate Analysis of Variance

# High Emitters Only
# All Vehicle classes
# All Cycles

**Tests of Between-Subjects Effects**

Dependent Variable: NMHC_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 93.686[a] | 1 | 93.686 | 38.727 | .000 |
| NMHC_OFF | 93.686 | 1 | 93.686 | 38.727 | .000 |
| Error | 164.504 | 68 | 2.419 | | |
| Total | 258.190 | 69 | | | |

a. R Squared = .363 (Adjusted R Squared = .353)

**Parameter Estimates**

Dependent Variable: NMHC_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| NMHC_OFF | .220 | .035 | 6.223 | .000 | .149 | .290 |

**Appendix C:**

NMHC Graphs

## NMHC High Emitter Graphs

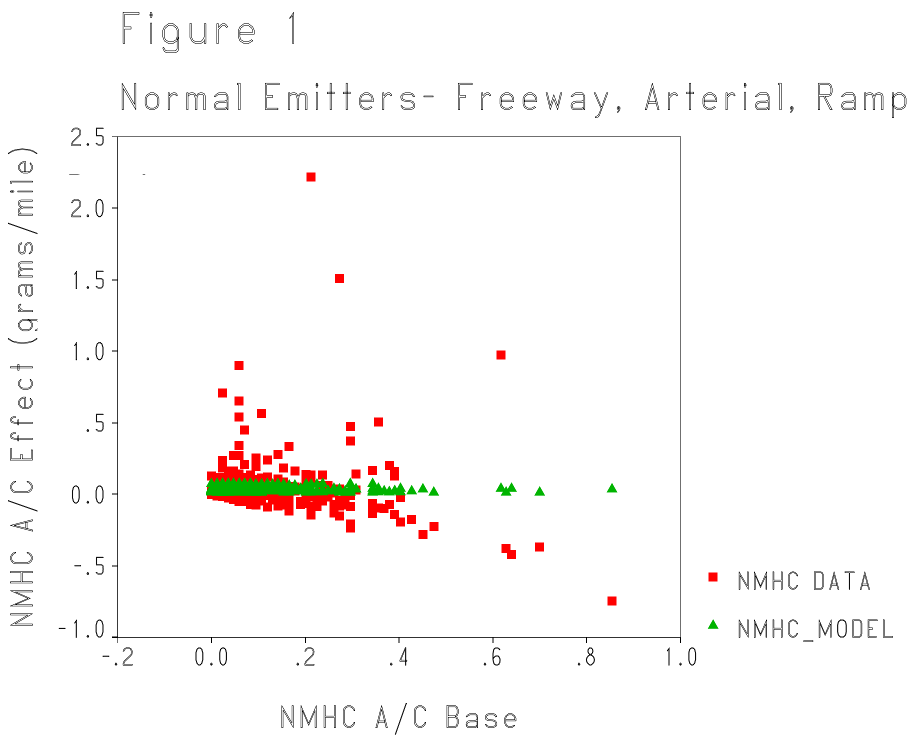


Figure 3

SCHED_ID: ART-AB :

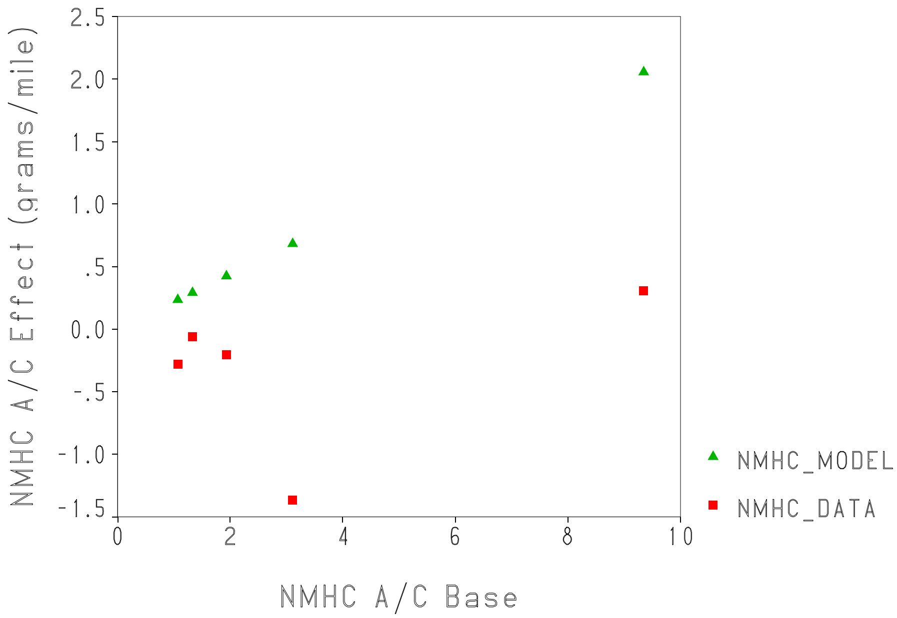



Figure 4

SCHED_ID: ART-CD :

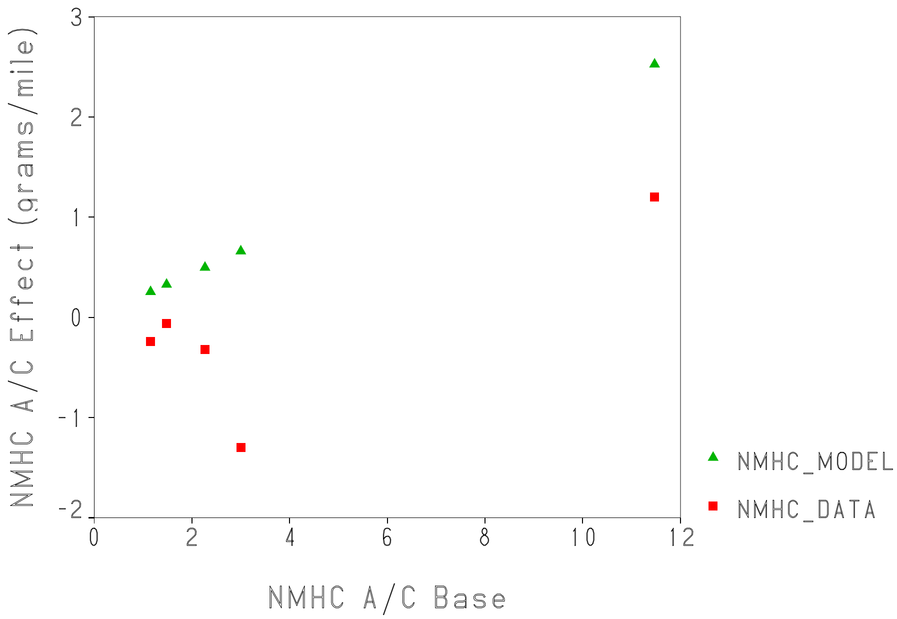


Figure 5

SCHED_ID: ART-EF :

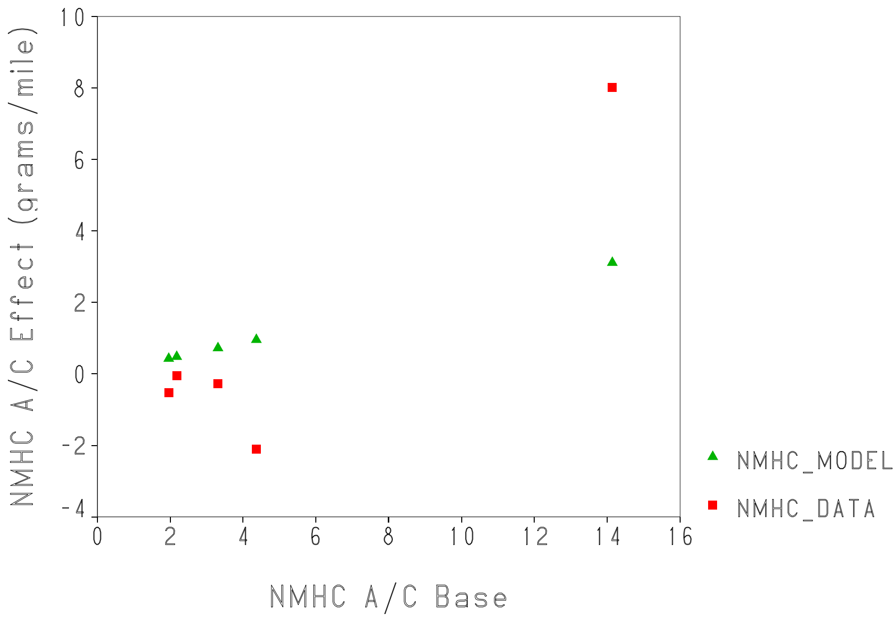



Figure 6

SCHED_ID: FWY-AC :

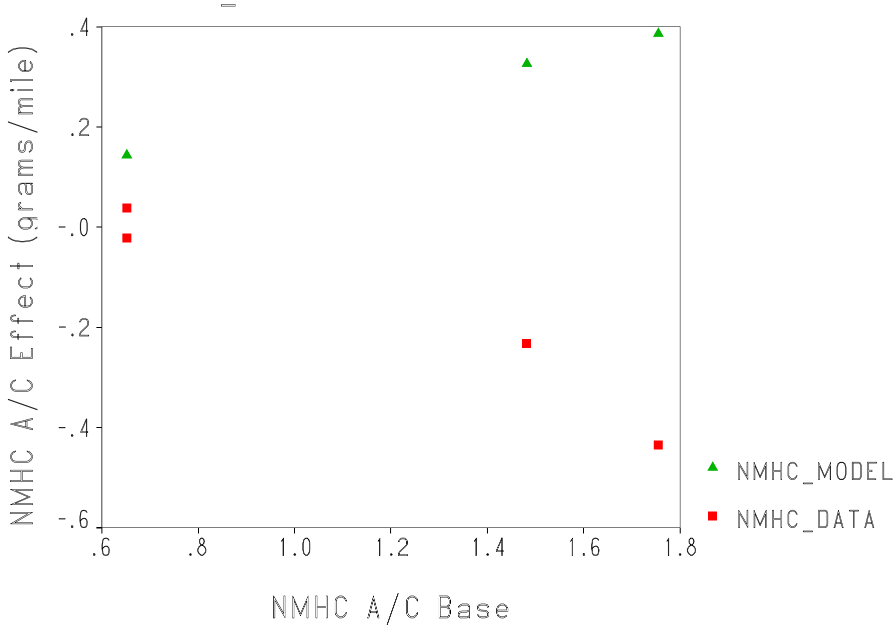


Figure 7

SCHED_ID: FWY-D :

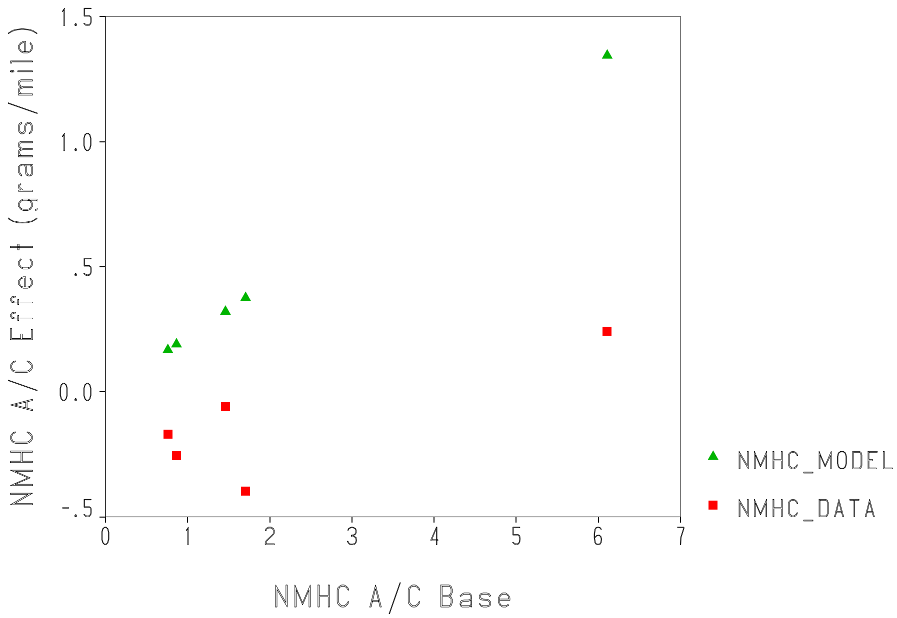



Figure 8

SCHED_ID: FWY-E :

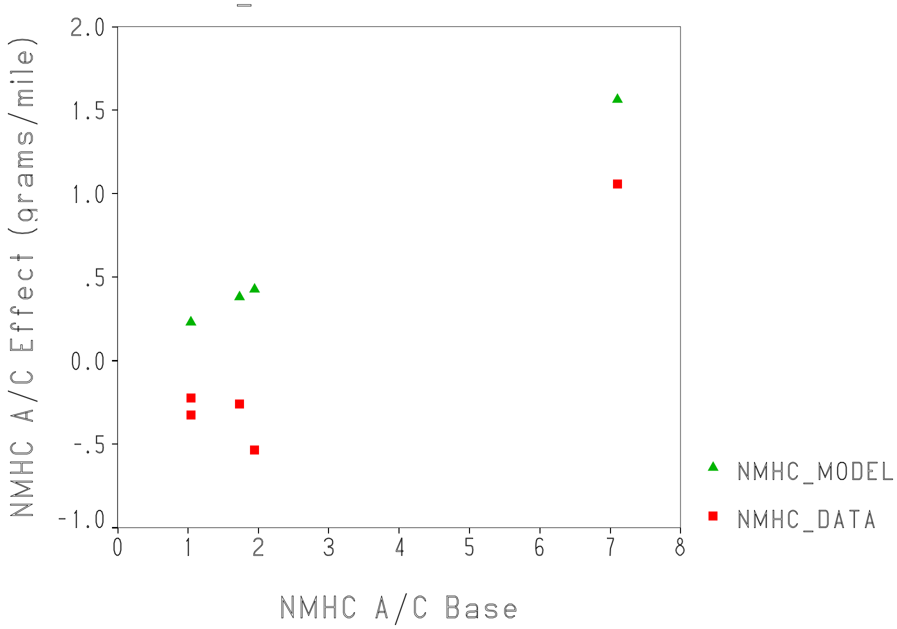


Figure 9

SCHED_ID: FWY-F :

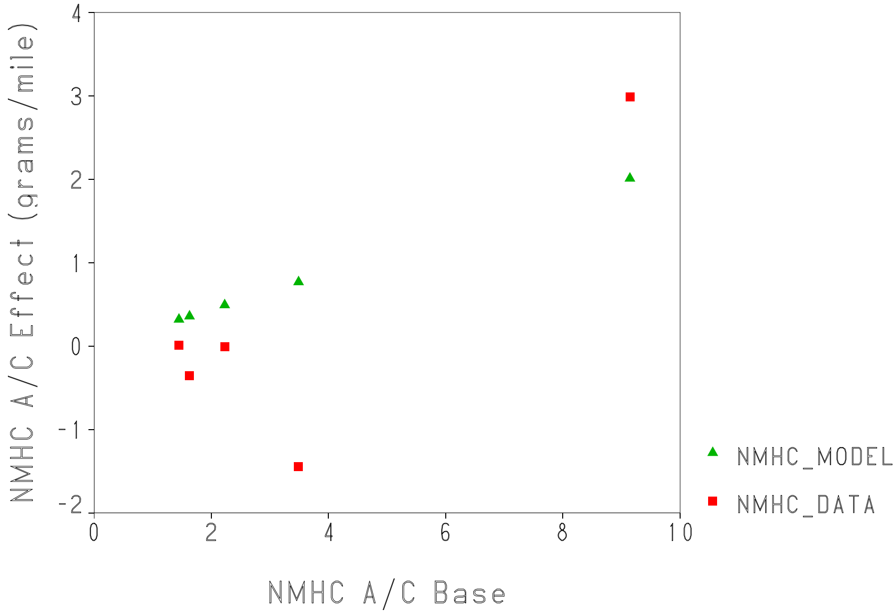



Figure 10

SCHED_ID: FWY-G :

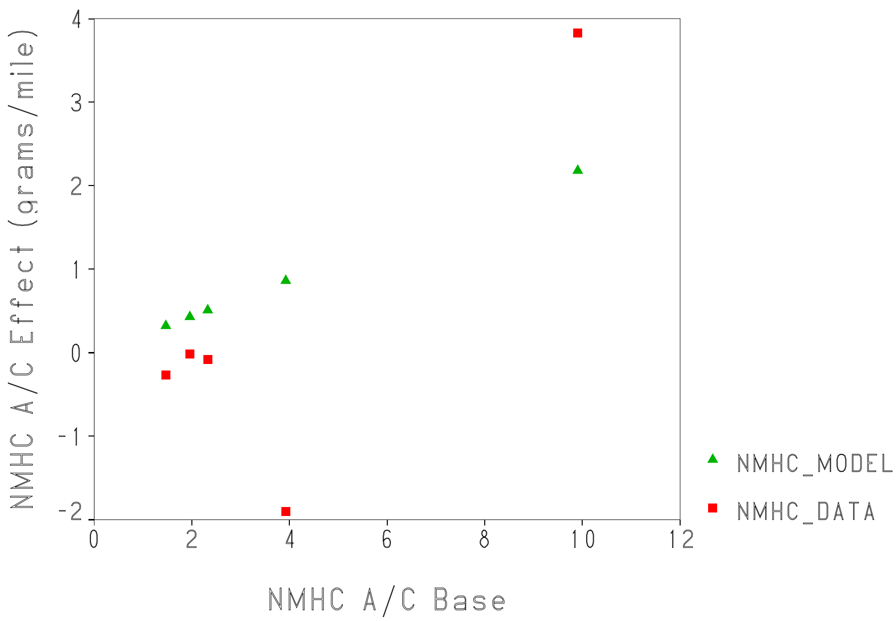


Figure 11

SCHED_ID: FWY-HI :

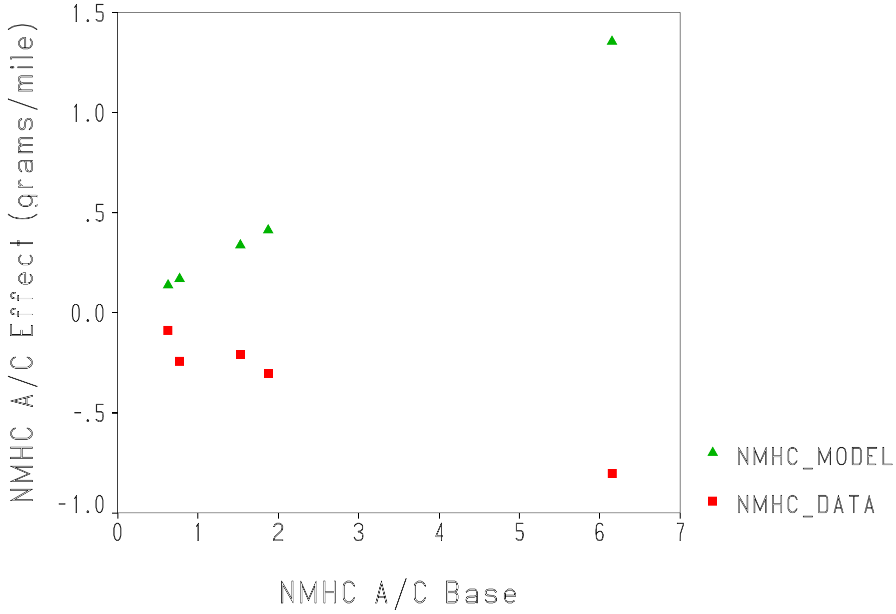



Figure 12

SCHED_ID: LA92 :

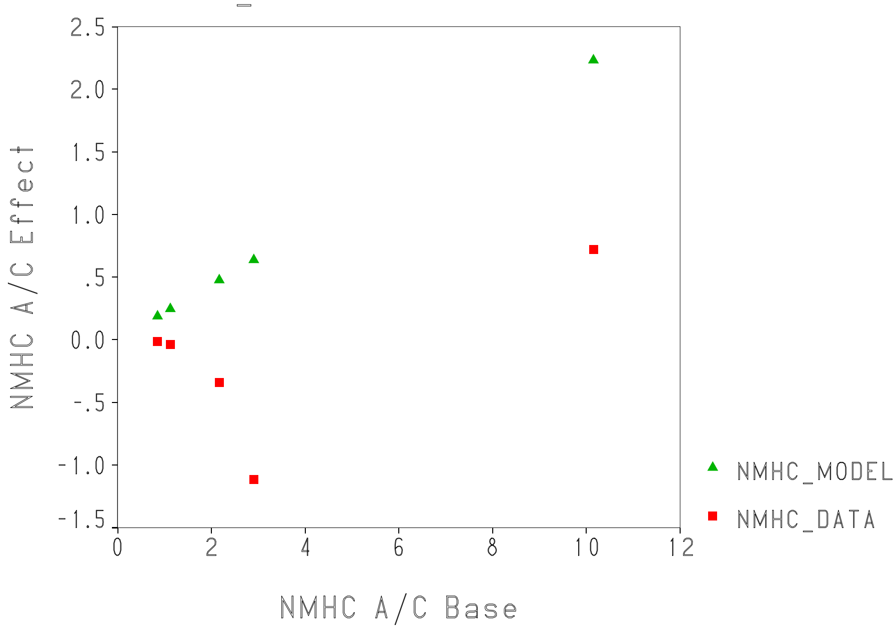


Figure 13

SCHED_ID: LOCAL :

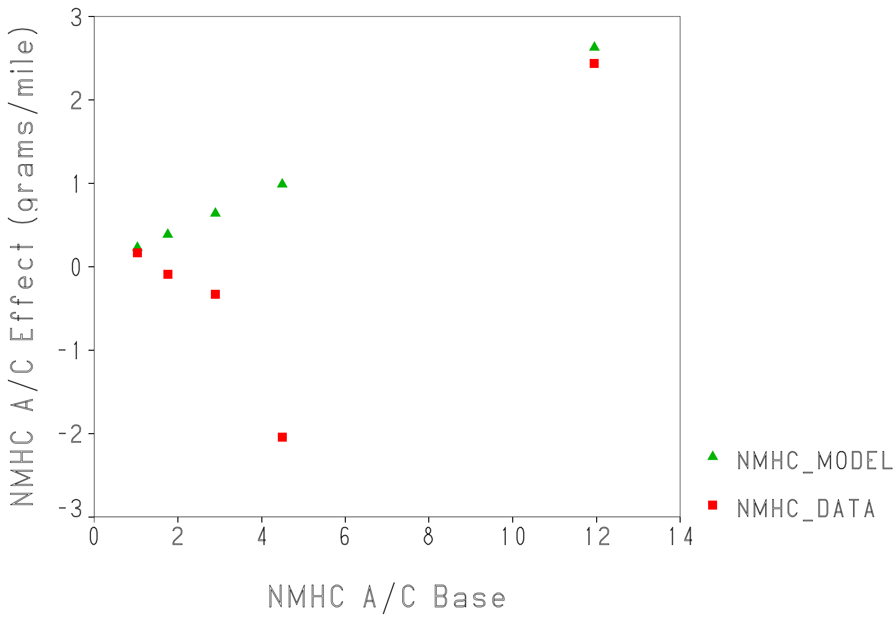
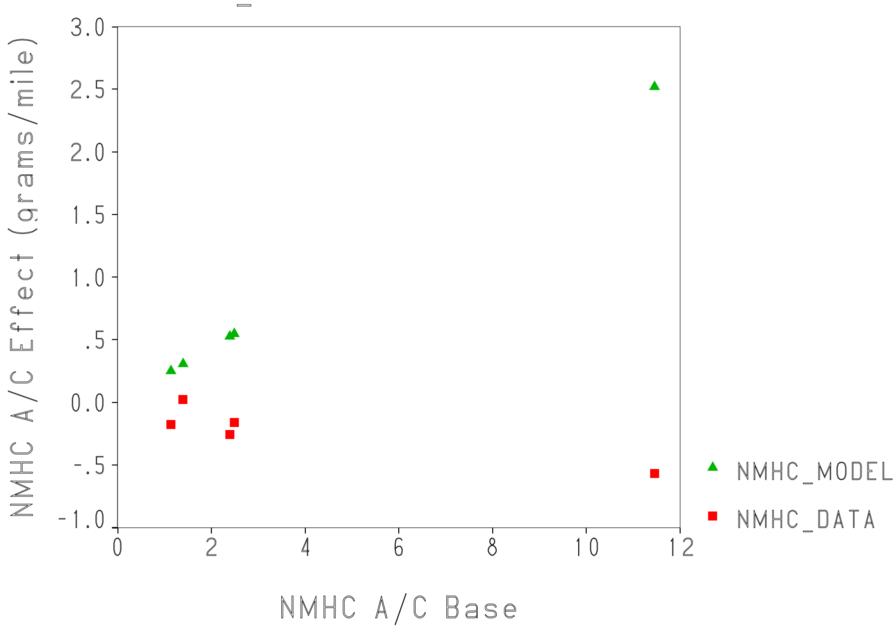


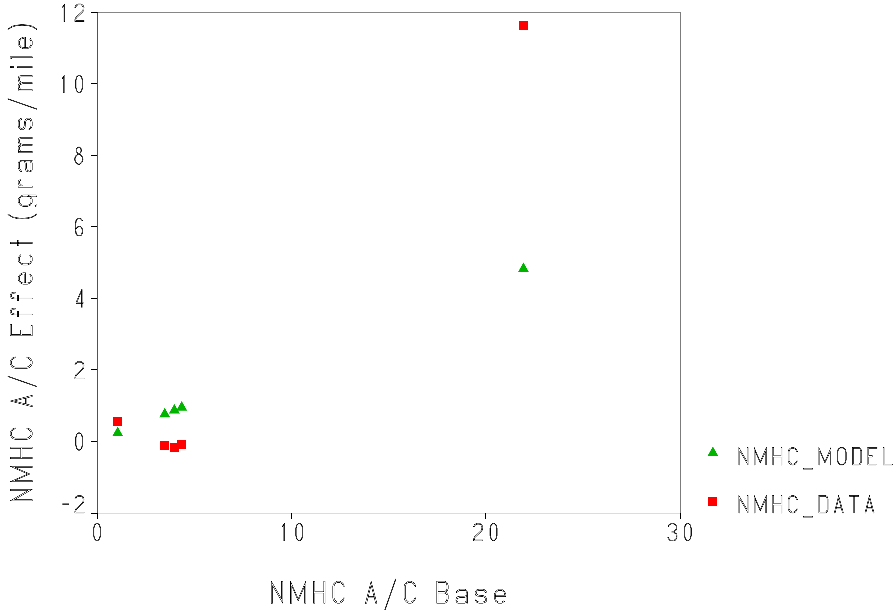

Figure 14

SCHED_ID: NONFWY :



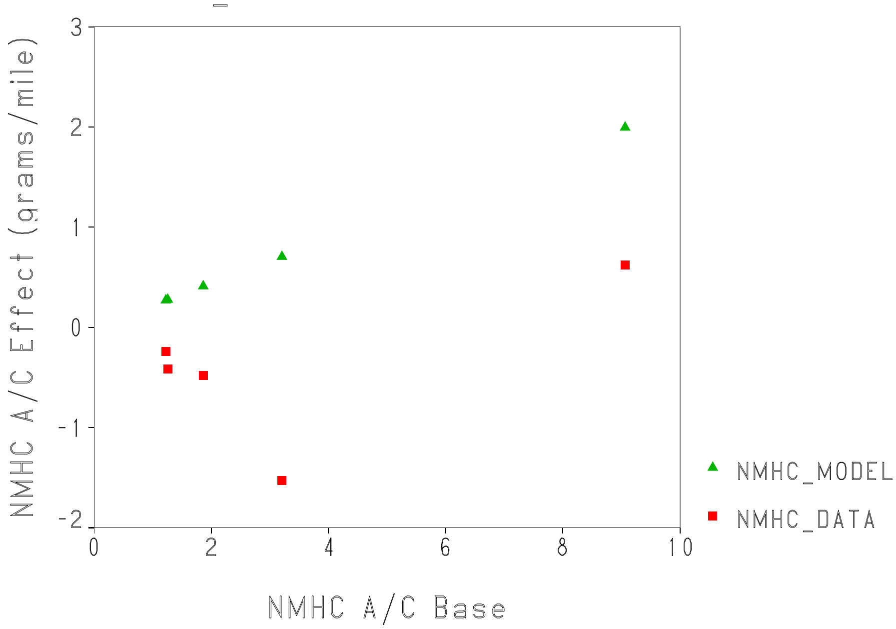
## Figure 15

SCHED_ID: NYCC :




## Figure 16

SCHED_ID: RAMP :



**Appendix D:**
CO ANOVA Results

# SECTION A
# CO Univariate Analysis of Variance
# All Veh. Classes
# All Cycles
# All Emitter Categories

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CYCLE_ID | ART | 148 |
| | FWY | 221 |
| | LA92 | 37 |
| | LOCAL | 74 |
| | RAMP | 37 |
| VEHCLASS | LDT1 | 126 |
| | LDT2 | 56 |
| | LDV | 335 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 7114.230[a] | 9 | 790.470 | 4.268 | .000 |
| Intercept | 797.635 | 1 | 797.635 | 4.307 | .038 |
| CYCLE_ID | 1250.449 | 4 | 312.612 | 1.688 | .151 |
| CO_OFF | 4653.597 | 1 | 4653.597 | 25.127 | .000 |
| AVG_SPD | 93.187 | 1 | 93.187 | .503 | .478 |
| COEM_CAT | 2547.696 | 1 | 2547.696 | 13.756 | .000 |
| VEHCLASS | 353.086 | 2 | 176.543 | .953 | .386 |
| Error | 93896.679 | 507 | 185.201 | | |
| Total | 111971.495 | 517 | | | |
| Corrected Total | 101010.908 | 516 | | | |

a. R Squared = .070 (Adjusted R Squared = .054)

## Estimated Marginal Means

## 1. CYCLE_ID

**Estimates**

Dependent Variable: CO_DIFF

| CYCLE_ID | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| ART | 3.135[a] | 1.298 | .586 | 5.684 |
| FWY | 4.018[a] | 1.174 | 1.712 | 6.325 |
| LA92 | 2.532[a] | 2.300 | -1.986 | 7.049 |
| LOCAL | 7.962[a] | 1.846 | 4.335 | 11.589 |
| RAMP | 4.820[a] | 2.313 | .277 | 9.364 |

a. Evaluated at covariates appeared in the model: CO_OFF = 16.77908, AVG_SPD = 27.95300, COEM_CAT = 7.930E-02.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) CYCLE_ID | (J) CYCLE_ID | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| ART | FWY | -.883 | 1.724 | .609 | -4.271 | 2.504 |
| | LA92 | .604 | 2.515 | .810 | -4.338 | 5.545 |
| | LOCAL | -4.827* | 1.979 | .015 | -8.714 | -.939 |
| | RAMP | -1.685 | 2.603 | .518 | -6.799 | 3.428 |
| FWY | ART | .883 | 1.724 | .609 | -2.504 | 4.271 |
| | LA92 | 1.487 | 2.510 | .554 | -3.445 | 6.418 |
| | LOCAL | -3.944 | 2.265 | .082 | -8.394 | .506 |
| | RAMP | -.802 | 2.430 | .741 | -5.576 | 3.972 |
| LA92 | ART | -.604 | 2.515 | .810 | -5.545 | 4.338 |
| | FWY | -1.487 | 2.510 | .554 | -6.418 | 3.445 |
| | LOCAL | -5.430 | 2.819 | .055 | -10.969 | .108 |
| | RAMP | -2.289 | 3.197 | .474 | -8.569 | 3.992 |
| LOCAL | ART | 4.827* | 1.979 | .015 | .939 | 8.714 |
| | FWY | 3.944 | 2.265 | .082 | -.506 | 8.394 |
| | LA92 | 5.430 | 2.819 | .055 | -.108 | 10.969 |
| | RAMP | 3.142 | 2.956 | .288 | -2.667 | 8.950 |
| RAMP | ART | 1.685 | 2.603 | .518 | -3.428 | 6.799 |
| | FWY | .802 | 2.430 | .741 | -3.972 | 5.576 |
| | LA92 | 2.289 | 3.197 | .474 | -3.992 | 8.569 |
| | LOCAL | -3.142 | 2.956 | .288 | -8.950 | 2.667 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

### Univariate Tests

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 1250.449 | 4 | 312.612 | 1.688 | .151 |
| Error | 93896.679 | 507 | 185.201 | | |

The F tests the effect of CYCLE_ID. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

## 2. VEHCLASS

### Estimates

Dependent Variable: CO_DIFF

| | | | 95% Confidence Interval | |
|---|---|---|---|---|
| VEHCLASS | Mean | Std. Error | Lower Bound | Upper Bound |
| LDT1 | 3.372[a] | 1.314 | .790 | 5.954 |
| LDT2 | 4.734[a] | 1.937 | .929 | 8.539 |
| LDV | 5.374[a] | .901 | 3.604 | 7.144 |

a. Evaluated at covariates appeared in the model: CO_OFF = 16.77908, AVG_SPD = 27.95300, COEM_CAT = 7.930E-02.

### Pairwise Comparisons

Dependent Variable: CO_DIFF

| | | | | | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| (I) VEHCLASS | (J) VEHCLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | Lower Bound | Upper Bound |
| LDT1 | LDT2 | -1.362 | 2.211 | .538 | -5.707 | 2.983 |
| | LDV | -2.002 | 1.450 | .168 | -4.851 | .847 |
| LDT2 | LDT1 | 1.362 | 2.211 | .538 | -2.983 | 5.707 |
| | LDV | -.640 | 2.052 | .755 | -4.671 | 3.391 |
| LDV | LDT1 | 2.002 | 1.450 | .168 | -.847 | 4.851 |
| | LDT2 | .640 | 2.052 | .755 | -3.391 | 4.671 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 353.086 | 2 | 176.543 | .953 | .386 |
| Error | 93896.679 | 507 | 185.201 | | |

The F tests the effect of VEHCLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION B
# CO Univariate Analysis of Variance
# No Local Cycle
# LDV & LDT
# All Emitter categories

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CYCLE_ID | ART | 148 |
| | FWY | 221 |
| | LA92 | 37 |
| | RAMP | 37 |
| CLASS | LDT | 156 |
| | LDV | 287 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 1316.192[a] | 5 | 263.238 | 1.328 | .251 |
| Intercept | 2454.833 | 1 | 2454.833 | 12.386 | .000 |
| CYCLE_ID | 326.043 | 3 | 108.681 | .548 | .649 |
| CO_OFF | 167.178 | 1 | 167.178 | .844 | .359 |
| CLASS | 851.774 | 1 | 851.774 | 4.298 | .039 |
| Error | 86609.227 | 437 | 198.190 | | |
| Total | 95074.518 | 443 | | | |
| Corrected Total | 87925.419 | 442 | | | |

a. R Squared = .015 (Adjusted R Squared = .004)

## Estimated Marginal Means

## 1. CYCLE_ID

**Estimates**

Dependent Variable: CO_DIFF

| CYCLE_ID | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| ART | 2.723[a] | 1.176 | .412 | 5.035 |
| FWY | 4.111[a] | .969 | 2.206 | 6.016 |
| LA92 | 2.316[a] | 2.324 | -2.251 | 6.884 |
| RAMP | 5.191[a] | 2.325 | .622 | 9.761 |

a. Evaluated at covariates appeared in the model: CO_OFF = 15.98205.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) CYCLE_ID | (J) CYCLE_ID | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] Lower Bound | 95% Confidence Interval for Difference[a] Upper Bound |
|---|---|---|---|---|---|---|
| ART | FWY | -1.388 | 1.496 | .354 | -4.328 | 1.552 |
| | LA92 | .407 | 2.588 | .875 | -4.679 | 5.493 |
| | RAMP | -2.468 | 2.588 | .341 | -7.555 | 2.619 |
| FWY | ART | 1.388 | 1.496 | .354 | -1.552 | 4.328 |
| | LA92 | 1.795 | 2.501 | .473 | -3.121 | 6.710 |
| | RAMP | -1.081 | 2.502 | .666 | -5.999 | 3.838 |
| LA92 | ART | -.407 | 2.588 | .875 | -5.493 | 4.679 |
| | FWY | -1.795 | 2.501 | .473 | -6.710 | 3.121 |
| | RAMP | -2.875 | 3.273 | .380 | -9.309 | 3.559 |
| RAMP | ART | 2.468 | 2.588 | .341 | -2.619 | 7.555 |
| | FWY | 1.081 | 2.502 | .666 | -3.838 | 5.999 |
| | LA92 | 2.875 | 3.273 | .380 | -3.559 | 9.309 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 326.043 | 3 | 108.681 | .548 | .649 |
| Error | 86609.227 | 437 | 198.190 | | |

The F tests the effect of CYCLE_ID. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# 2. CLASS

**Estimates**

Dependent Variable: CO_DIFF

| CLASS | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| LDT | 2.133[a] | 1.279 | -.381 | 4.647 |
| LDV | 5.038[a] | 1.026 | 3.022 | 7.054 |

a. Evaluated at covariates appeared in the model: CO_OFF = 15.98205.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) CLASS | (J) CLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT | LDV | -2.905* | 1.401 | .039 | -5.659 | -.151 |
| LDV | LDT | 2.905* | 1.401 | .039 | .151 | 5.659 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 851.774 | 1 | 851.774 | 4.298 | .039 |
| Error | 86609.227 | 437 | 198.190 | | |

The F tests the effect of CLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION C
# CO Univariate Analysis of Variance
# Normal Emit
# No Local Cycle

## CLASS = LDV

**Tests of Between-Subjects Effects[b]**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 11535.632[a] | 2 | 5767.816 | 46.774 | .000 |
| CO_OFF | 4320.606 | 1 | 4320.606 | 35.038 | .000 |
| AVG_SPD | 577.457 | 1 | 577.457 | 4.683 | .031 |
| Error | 33787.462 | 274 | 123.312 | | |
| Total | 45323.093 | 276 | | | |

a. R Squared = .255 (Adjusted R Squared = .249)

b. CLASS = LDV

**Parameter Estimates[a]**

Dependent Variable: CO_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| CO_OFF | .815 | .138 | 5.919 | .000 | .544 | 1.085 |
| AVG_SPD | 5.272E-02 | .024 | 2.164 | .031 | 4.759E-03 | .101 |

a. CLASS = LDV

# SECTION D
# CO Univariate Analysis of Variance
# Norm Emit LDT only
# No local

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 1798.456[a] | 1 | 1798.456 | 8.229 | .005 |
| AVG_SPD | 1798.456 | 1 | 1798.456 | 8.229 | .005 |
| Error | 28629.094 | 131 | 218.543 | | |
| Total | 30427.550 | 132 | | | |

a. R Squared = .059 (Adjusted R Squared = .052)

**Parameter Estimates**

Dependent Variable: CO_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| AVG_SPD | .104 | .036 | 2.869 | .005 | 3.230E-02 | .176 |

# SECTION E

# CO Univariate Analysis of Variance
# All Veh Classes
# High emitters only

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 10004.567[a] | 2 | 5002.283 | 11.871 | .000 |
| AVG_SPD | 5948.248 | 1 | 5948.248 | 14.115 | .001 |
| CO_OFF | 9361.556 | 1 | 9361.556 | 22.215 | .000 |
| Error | 16434.569 | 39 | 421.399 | | |
| Total | 26439.136 | 41 | | | |

a. R Squared = .378 (Adjusted R Squared = .347)

**Parameter Estimates**

Dependent Variable: CO_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| AVG_SPD | -.462 | .123 | -3.757 | .001 | -.710 | -.213 |
| CO_OFF | 9.863E-02 | .021 | 4.713 | .000 | 5.630E-02 | .141 |

# SECTION F
# CO Univariate Analysis of Variance
# High emitters only
# No Local Cycle
# Avg speed < 19

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CLASS | LDT | 6 |
| | LDV | 3 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 9718.115[a] | 4 | 2429.529 | 12.919 | .008 |
| CLASS | 518.031 | 2 | 259.015 | 1.377 | .334 |
| CO_OFF | 1.364 | 1 | 1.364 | .007 | .935 |
| AVG_SPD | 150.806 | 1 | 150.806 | .802 | .412 |
| Error | 940.329 | 5 | 188.066 | | |
| Total | 10658.444 | 9 | | | |

a. R Squared = .912 (Adjusted R Squared = .841)

# Estimated Marginal Means

# CLASS

**Estimates**

Dependent Variable: CO_DIFF

| CLASS | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| LDT | 2.167[a] | 12.164 | -29.101 | 33.435 |
| LDV | 58.091[a] | 23.003 | -1.040 | 117.223 |

a. Evaluated at covariates appeared in the model: CO_OFF = 159.63389, AVG_SPD = 14.43333.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) CLASS | (J) CLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] Lower Bound | 95% Confidence Interval for Difference[a] Upper Bound |
|---|---|---|---|---|---|---|
| LDT | LDV | -55.925 | 33.816 | .159 | -142.853 | 31.003 |
| LDV | LDT | 55.925 | 33.816 | .159 | -31.003 | 142.853 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 514.350 | 1 | 514.350 | 2.735 | .159 |
| Error | 940.329 | 5 | 188.066 | | |

The F tests the effect of CLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

## SECTION G
## CO Univariate Analysis of Variance
## Avg. Speed < 19 mph
## All Veh. Classes

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 9200.084[a] | 2 | 4600.042 | 22.080 | .001 |
| CO_OFF | 5780.609 | 1 | 5780.609 | 27.746 | .001 |
| AVG_SPD | 337.690 | 1 | 337.690 | 1.621 | .244 |
| Error | 1458.360 | 7 | 208.337 | | |
| Total | 10658.444 | 9 | | | |

a. R Squared = .863 (Adjusted R Squared = .824)

## SECTION H
## CO Univariate Analysis of Variance
## High emitters only
## No Local Cycle
## Avg. Speed < 19
## All veh. class

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 8862.394[a] | 1 | 8862.394 | 39.475 | .000 |
| CO_OFF | 8862.394 | 1 | 8862.394 | 39.475 | .000 |
| Error | 1796.050 | 8 | 224.506 | | |
| Total | 10658.444 | 9 | | | |

a. R Squared = .831 (Adjusted R Squared = .810)

**Parameter Estimates**

Dependent Variable: CO_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| CO_OFF | .154 | .024 | 6.283 | .000 | 9.738E-02 | .210 |

## SECTION I
## CO Univariate Analysis of Variance
## Local Cycle Only

# All Veh. Classes
# All Emitter Categories

**Between-Subjects Factors**

| | | N |
|---|---|---|
| VEHCLASS | LDT1 | 18 |
| | LDT2 | 8 |
| | LDV | 48 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 9881.026[a] | 6 | 1646.838 | 15.961 | .000 |
| VEHCLASS | 1154.473 | 3 | 384.824 | 3.730 | .015 |
| AVG_SPD | 76.562 | 1 | 76.562 | .742 | .392 |
| CO_OFF | 2276.352 | 1 | 2276.352 | 22.063 | .000 |
| COEM_CAT | 48.846 | 1 | 48.846 | .473 | .494 |
| Error | 7015.951 | 68 | 103.176 | | |
| Total | 16896.976 | 74 | | | |

a. R Squared = .585 (Adjusted R Squared = .548)

# Estimated Marginal Means

# VEHCLASS

**Estimates**

Dependent Variable: CO_DIFF

| VEHCLASS | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| LDT1 | 3.706[a] | 2.415 | -1.114 | 8.525 |
| LDT2 | 13.979[a] | 3.741 | 6.514 | 21.443 |
| LDV | 8.798[a] | 1.494 | 5.816 | 11.780 |

a. Evaluated at covariates appeared in the model: AVG_SPD = 10.00000, CO_OFF = 21.55046, COEM_CAT = 8.108E-02.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) VEHCLASS | (J) VEHCLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| LDT1 | LDT2 | -10.273* | 4.382 | .022 | -19.018 | -1.528 |
| | LDV | -5.093 | 2.871 | .081 | -10.823 | .637 |
| LDT2 | LDT1 | 10.273* | 4.382 | .022 | 1.528 | 19.018 |
| | LDV | 5.180 | 4.102 | .211 | -3.005 | 13.366 |
| LDV | LDT1 | 5.093 | 2.871 | .081 | -.637 | 10.823 |
| | LDT2 | -5.180 | 4.102 | .211 | -13.366 | 3.005 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 644.113 | 2 | 322.057 | 3.121 | .050 |
| Error | 7015.951 | 68 | 103.176 | | |

The F tests the effect of VEHCLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# Univariate Analysis of Variance

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CLASS | LDT | 26 |
| | LDV | 48 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 9314.064[a] | 5 | 1862.813 | 16.950 | .000 |
| AVG_SPD | 80.405 | 1 | 80.405 | .732 | .395 |
| CO_OFF | 2074.928 | 1 | 2074.928 | 18.881 | .000 |
| COEM_CAT | 9.007 | 1 | 9.007 | .082 | .776 |
| CLASS | 587.511 | 2 | 293.756 | 2.673 | .076 |
| Error | 7582.912 | 69 | 109.897 | | |
| Total | 16896.976 | 74 | | | |

a. $R^2$ Squared = .551 (Adjusted R Squared = .519)

# SECTION J
# CO Univariate Analysis of Variance
# Local Cycle only
# LDVs and LDTs
# All emit

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 6754.531[a] | 1 | 6754.531 | 48.616 | .000 |
| CO_OFF | 6754.531 | 1 | 6754.531 | 48.616 | .000 |
| Error | 10142.446 | 73 | 138.938 | | |
| Total | 16896.976 | 74 | | | |

a. R Squared = .400 (Adjusted R Squared = .392)

**Parameter Estimates**

Dependent Variable: CO_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| CO_OFF | .125 | .018 | 6.972 | .000 | 8.948E-02 | .161 |

# SECTION K
# CO Univariate Analysis of Variance
# Local cycle only
# Normal emitters only

**Between-Subjects Factors**

| | | N |
|---|---|---|
| VEHCLASS | LDT1 | 16 |
| | LDT2 | 6 |
| | LDV | 46 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 3803.884[a] | 5 | 760.777 | 8.018 | .000 |
| VEHCLASS | 835.916 | 3 | 278.639 | 2.937 | .040 |
| AVG_SPD | 3.965 | 1 | 3.965 | .042 | .839 |
| CO_OFF | 237.803 | 1 | 237.803 | 2.506 | .118 |
| Error | 5977.832 | 63 | 94.886 | | |
| Total | 9781.715 | 68 | | | |

a. R Squared = .389 (Adjusted R Squared = .340)

# Estimated Marginal Means

# VEHCLASS

**Estimates**

Dependent Variable: CO_DIFF

| VEHCLASS | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| LDT1 | 1.267[a] | 2.557 | -3.843 | 6.378 |
| LDT2 | 13.300[a] | 3.986 | 5.334 | 21.265 |
| LDV | 7.685[a] | 1.455 | 4.777 | 10.594 |

a. Evaluated at covariates appeared in the model: AVG_SPD = 10.00000, CO_OFF = 6.00891.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) VEHCLASS | (J) VEHCLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT1 | LDT2 | -12.032* | 4.781 | .014 | -21.586 | -2.478 |
| | LDV | -6.418* | 3.005 | .037 | -12.422 | -.414 |
| LDT2 | LDT1 | 12.032* | 4.781 | .014 | 2.478 | 21.586 |
| | LDV | 5.614 | 4.228 | .189 | -2.835 | 14.064 |
| LDV | LDT1 | 6.418* | 3.005 | .037 | .414 | 12.422 |
| | LDT2 | -5.614 | 4.228 | .189 | -14.064 | 2.835 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 703.835 | 2 | 351.918 | 3.709 | .030 |
| Error | 5977.832 | 63 | 94.886 | | |

The F tests the effect of VEHCLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION L
# CO Univariate Analysis of Variance
# Local Cycle only
# LDT & LDV
# Normal Emitters Only

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CLASS | LDT | 22 |
| | LDV | 46 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 3202.891[a] | 3 | 1067.630 | 10.548 | .000 |
| CO_OFF | 118.764 | 1 | 118.764 | 1.173 | .283 |
| CLASS | 1084.797 | 2 | 542.398 | 5.359 | .007 |
| Error | 6578.825 | 65 | 101.213 | | |
| Total | 9781.715 | 68 | | | |

a. R Squared = .327 (Adjusted R Squared = .296)

# Estimated Marginal Means

# CLASS

**Estimates**

Dependent Variable: CO_DIFF

| CLASS | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| LDT | 4.824[a] | 2.195 | .440 | 9.208 |
| LDV | 7.553[a] | 1.500 | 4.558 | 10.549 |

a. Evaluated at covariates appeared in the model: CO_OFF = 6.00891.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) CLASS | (J) CLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT | LDV | -2.729 | 2.698 | .315 | -8.116 | 2.659 |
| LDV | LDT | 2.729 | 2.698 | .315 | -2.659 | 8.116 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 103.579 | 1 | 103.579 | 1.023 | .315 |
| Error | 6578.825 | 65 | 101.213 | | |

The F tests the effect of CLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION M
# CO Univariate Analysis of Variance
# Local Cycly Only
# Normal Emitters only
# LDV & LDT

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 2118.094[a] | 1 | 2118.094 | 18.518 | .000 |
| CO_OFF | 2118.094 | 1 | 2118.094 | 18.518 | .000 |
| Error | 7663.622 | 67 | 114.382 | | |
| Total | 9781.715 | 68 | | | |

a. R Squared = .217 (Adjusted R Squared = .205)

**Parameter Estimates**

Dependent Variable: CO_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| CO_OFF | .678 | .158 | 4.303 | .000 | .364 | .993 |

# SECTION N
# CO Univariate Analysis of Variance
# Local Cycle only
# High emitters only

**Between-Subjects Factors**

| | | N |
|---|---|---|
| VEHCLASS | LDT1 | 2 |
| | LDT2 | 2 |
| | LDV | 2 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 7075.528[a] | 5 | 1415.106 | 35.615 | .127 |
| VEHCLASS | 980.390 | 3 | 326.797 | 8.225 | .250 |
| AVG_SPD | 945.375 | 1 | 945.375 | 23.793 | .129 |
| CO_OFF | 54.499 | 1 | 54.499 | 1.372 | .450 |
| Error | 39.733 | 1 | 39.733 | | |
| Total | 7115.261 | 6 | | | |

a. R Squared = .994 (Adjusted R Squared = .966)

# Estimated Marginal Means

# VEHCLASS

**Estimates**

Dependent Variable: CO_DIFF

| VEHCLASS | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| LDT1 | -3.500[a] | 9.341 | -122.192 | 115.192 |
| LDT2 | 8.052[a] | 8.188 | -95.982 | 112.086 |
| LDV | 69.074[a] | 15.722 | -130.699 | 268.846 |

a. Evaluated at covariates appeared in the model: AVG_SPD = 10.00000, CO_OFF = 197.68800.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) VEHCLASS | (J) VEHCLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT1 | LDT2 | -11.552 | 6.445 | .324 | -93.438 | 70.333 |
| | LDV | -72.574 | 24.125 | .204 | -379.108 | 233.961 |
| LDT2 | LDT1 | 11.552 | 6.445 | .324 | -70.333 | 93.438 |
| | LDV | -61.021 | 22.833 | .228 | -351.141 | 229.098 |
| LDV | LDT1 | 72.574 | 24.125 | .204 | -233.961 | 379.108 |
| | LDT2 | 61.021 | 22.833 | .228 | -229.098 | 351.141 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 388.354 | 2 | 194.177 | 4.887 | .305 |
| Error | 39.733 | 1 | 39.733 | | |

The F tests the effect of VEHCLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION O
# CO Univariate Analysis of Variance
# High Emitters Only
# Local Cycle Only
# LDV & LDT

**Between-Subjects Factors**

| | | N |
|---|---|---|
| CLASS | LDT | 4 |
| | LDV | 2 |

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 6947.853[a] | 4 | 1736.963 | 20.751 | .047 |
| AVG_SPD | 870.834 | 1 | 870.834 | 10.404 | .084 |
| CO_OFF | 26.455 | 1 | 26.455 | .316 | .631 |
| CLASS | 852.715 | 2 | 426.357 | 5.094 | .164 |
| Error | 167.408 | 2 | 83.704 | | |
| Total | 7115.261 | 6 | | | |

a. R Squared = .976 (Adjusted R Squared = .929)

## Estimated Marginal Means

## CLASS

**Estimates**

Dependent Variable: CO_DIFF

| CLASS | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| LDT | 5.089[a] | 11.639 | -44.990 | 55.167 |
| LDV | 63.449[a] | 22.361 | -32.763 | 159.660 |

a. Evaluated at covariates appeared in the model: AVG_SPD = 10.00000, CO_OFF = 197.68800.

**Pairwise Comparisons**

Dependent Variable: CO_DIFF

| (I) CLASS | (J) CLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT | LDV | -58.360 | 33.070 | .220 | -200.650 | 83.929 |
| LDV | LDT | 58.360 | 33.070 | .220 | -83.929 | 200.650 |

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: CO_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 260.679 | 1 | 260.679 | 3.114 | .220 |
| Error | 167.408 | 2 | 83.704 | | |

The F tests the effect of CLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# Univariate Analysis of Variance

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 6095.138[a] | 2 | 3047.569 | 11.950 | .021 |
| AVG_SPD | 35.792 | 1 | 35.792 | .140 | .727 |
| CO_OFF | 3759.501 | 1 | 3759.501 | 14.741 | .018 |
| Error | 1020.123 | 4 | 255.031 | | |
| Total | 7115.261 | 6 | | | |

a. R Squared = .857 (Adjusted R Squared = .785)

# SECTION P

# CO Univariate Analysis of Variance
# Local Cycle Only
# High Emitters Only
# LDV & LDT

**Tests of Between-Subjects Effects**

Dependent Variable: CO_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 6059.346[a] | 1 | 6059.346 | 28.692 | .003 |
| CO_OFF | 6059.346 | 1 | 6059.346 | 28.692 | .003 |
| Error | 1055.915 | 5 | 211.183 | | |
| Total | 7115.261 | 6 | | | |

a. R Squared = .852 (Adjusted R Squared = .822)

**Parameter Estimates**

Dependent Variable: CO_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| CO_OFF | .119 | .022 | 5.357 | .003 | 6.206E-02 | .177 |

**Appendix E:**

CO Graphs

## CO Graphs

Figure 1

LDV- Normal Emitters- Freeway, Arterial,

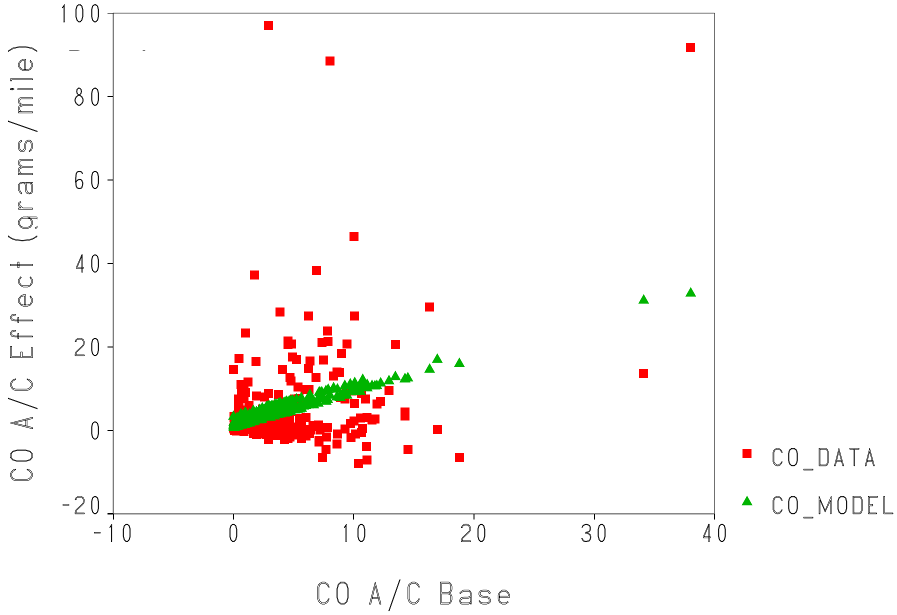


Figure 3

High Emitters- Cycles with Avg. Speed < 1

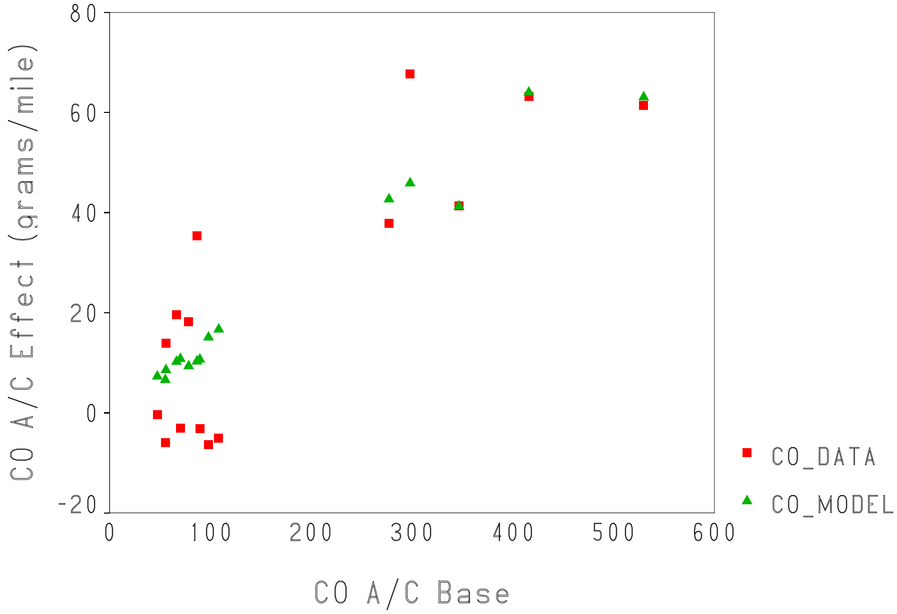
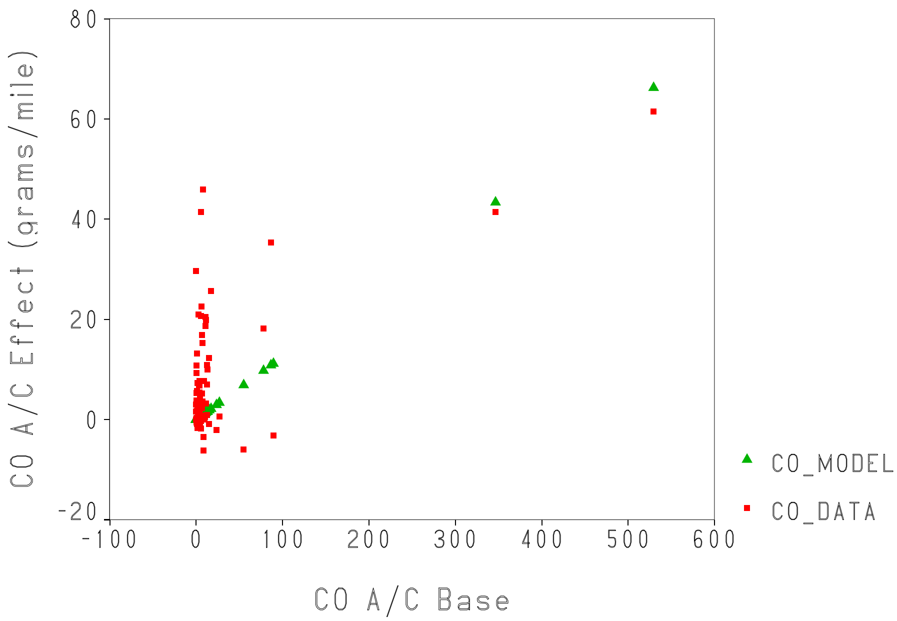


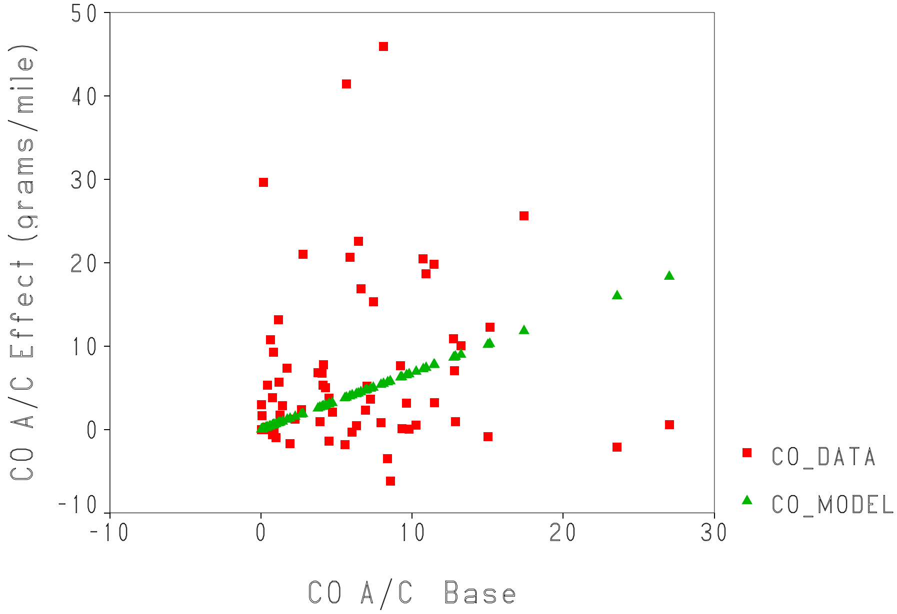

Figure 4

LOCAL



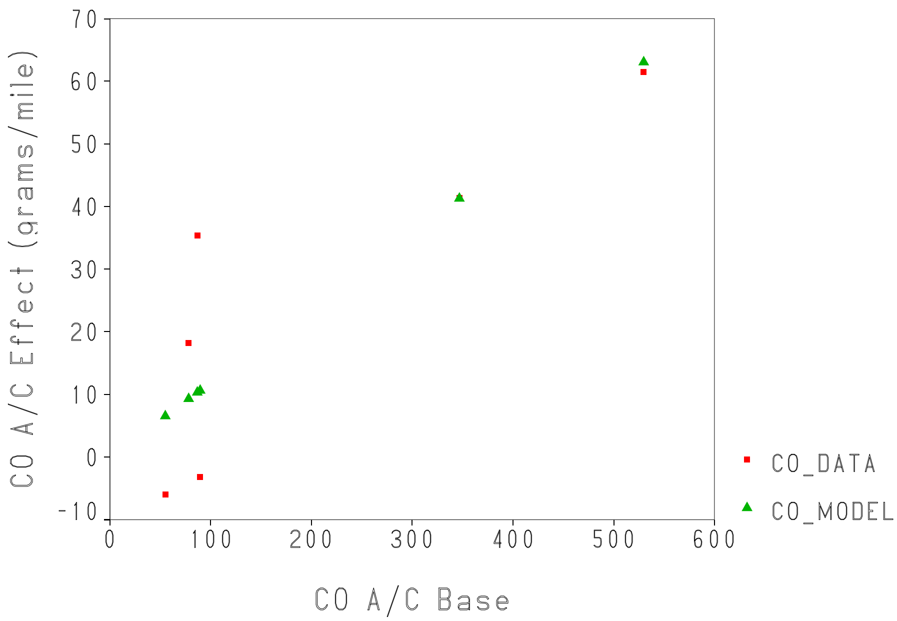
## Figure 5

Normal Emitters- Local




## Figure 6

High Emitters- Local



**Appendix F:**
NOx ANOVA Results

# SECTION A
# NOx Univariate Analysis of Variance
# All Vehicle Classes
# All Cycles

**Between-Subjects Factors**

| | | N |
|---|---|---|
| VEHCLASS | LDT1 | 126 |
| | LDT2 | 56 |
| | LDV | 335 |
| FACILITY | 1 | 111 |
| | 2 | 221 |
| | 3 | 74 |
| | 4 | 74 |
| | 5 | 37 |

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 25.912[a] | 16 | 1.620 | 11.798 | .000 |
| Intercept | 2.523 | 1 | 2.523 | 18.376 | .000 |
| NOX_OFF | 15.856 | 1 | 15.856 | 115.504 | .000 |
| AVG_SPD | 2.876 | 1 | 2.876 | 20.950 | .000 |
| VEHCLASS | 3.057 | 2 | 1.529 | 11.136 | .000 |
| FACILITY | 2.076 | 4 | .519 | 3.780 | .005 |
| VEHCLASS * FACILITY | .741 | 8 | 9.264E-02 | .675 | .714 |
| Error | 68.638 | 500 | .137 | | |
| Total | 144.847 | 517 | | | |
| Corrected Total | 94.550 | 516 | | | |

a. R Squared = .274 (Adjusted R Squared = .251)

# Estimated Marginal Means

# 1. VEHCLASS

**Estimates**

Dependent Variable: NOX_DIFF

| VEHCLASS | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| LDT1 | .169[a] | .040 | 9.094E-02 | .248 |
| LDT2 | .159[a] | .059 | 4.233E-02 | .276 |
| LDV | .362[a] | .024 | .314 | .409 |

a. Evaluated at covariates appeared in the model: NOX_OFF = .76540, AVG_SPD = 27.95300.

**Pairwise Comparisons**

Dependent Variable: NOX_DIFF

| (I) VEHCLASS | (J) VEHCLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT1 | LDT2 | 1.022E-02 | .070 | .885 | -.128 | .149 |
| | LDV | -.192* | .047 | .000 | -.284 | -.101 |
| LDT2 | LDT1 | -1.022E-02 | .070 | .885 | -.149 | .128 |
| | LDV | -.203* | .064 | .002 | -.329 | -7.640E-02 |
| LDV | LDT1 | .192* | .047 | .000 | .101 | .284 |
| | LDT2 | .203* | .064 | .002 | 7.640E-02 | .329 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NOX_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 3.057 | 2 | 1.529 | 11.136 | .000 |
| Error | 68.638 | 500 | .137 | | |

The F tests the effect of VEHCLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

## 2. FACILITY

**Estimates**

Dependent Variable: NOX_DIFF

| FACILITY | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| 1 | .277[a] | .047 | .185 | .369 |
| 2 | .274[a] | .035 | .205 | .343 |
| 3 | .386[a] | .060 | .269 | .504 |
| 4 | .167[a] | .056 | 5.719E-02 | .278 |
| 5 | 4.579E-02[a] | .080 | -.111 | .202 |

a. Evaluated at covariates appeared in the model: NOX_OFF = .76540, AVG_SPD = 27.95300.

**Pairwise Comparisons**

Dependent Variable: NOX_DIFF

| (I) FACILITY | (J) FACILITY | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| 1 | 2 | 3.012E-03 | .061 | .961 | -.117 | .123 |
| | 3 | -.109 | .072 | .131 | -.251 | 3.267E-02 |
| | 4 | .109 | .072 | .128 | -3.150E-02 | .250 |
| | 5 | .231* | .093 | .013 | 4.826E-02 | .414 |
| 2 | 1 | -3.012E-03 | .061 | .961 | -.123 | .117 |
| | 3 | -.112 | .074 | .128 | -.257 | 3.244E-02 |
| | 4 | .106 | .068 | .117 | -2.668E-02 | .239 |
| | 5 | .228* | .086 | .008 | 5.954E-02 | .396 |
| 3 | 1 | .109 | .072 | .131 | -3.267E-02 | .251 |
| | 2 | .112 | .074 | .128 | -3.244E-02 | .257 |
| | 4 | .219* | .080 | .006 | 6.207E-02 | .375 |
| | 5 | .340* | .101 | .001 | .142 | .538 |
| 4 | 1 | -.109 | .072 | .128 | -.250 | 3.150E-02 |
| | 2 | -.106 | .068 | .117 | -.239 | 2.668E-02 |
| | 3 | -.219* | .080 | .006 | -.375 | -6.207E-02 |
| | 5 | .122 | .097 | .213 | -6.998E-02 | .313 |
| 5 | 1 | -.231* | .093 | .013 | -.414 | -4.826E-02 |
| | 2 | -.228* | .086 | .008 | -.396 | -5.954E-02 |
| | 3 | -.340* | .101 | .001 | -.538 | -.142 |
| | 4 | -.122 | .097 | .213 | -.313 | 6.998E-02 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NOX_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | 2.076 | 4 | .519 | 3.780 | .005 |
| Error | 68.638 | 500 | .137 | | |

The F tests the effect of FACILITY. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION B
# NOx Univariate Analysis of Variance
# Log Space
# No Ramp Cycle
# LDV only

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 57.523[a] | 2 | 28.761 | 182.563 | .000 |
| LG10NOX1 | 26.665 | 1 | 26.665 | 169.256 | .000 |
| LG10SPD | 4.680E-02 | 1 | 4.680E-02 | .297 | .586 |
| Error | 48.681 | 309 | .158 | | |
| Total | 106.203 | 311 | | | |

a. R Squared = .542 (Adjusted R Squared = .539)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| LG10NOX1 | 1.865 | .143 | 13.010 | .000 | 1.583 | 2.148 |
| LG10SPD | -1.350E-02 | .025 | -.545 | .586 | -6.225E-02 | 3.525E-02 |

# SECTION C
# NOx Univariate Analysis of Variance
# Linear Space
# LDV only
# No Ramp Cycle

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 54.725[a] | 2 | 27.363 | 164.245 | .000 |
| AVG_SPD | 8.316E-02 | 1 | 8.316E-02 | .499 | .480 |
| NOX_OFF | 39.687 | 1 | 39.687 | 238.225 | .000 |
| Error | 51.478 | 309 | .167 | | |
| Total | 106.203 | 311 | | | |

a. R Squared = .515 (Adjusted R Squared = .512)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| AVG_SPD | -5.996E-04 | .001 | -.707 | .480 | -2.270E-03 | 1.070E-03 |
| NOX_OFF | .459 | .030 | 15.435 | .000 | .400 | .517 |

# SECTION D

# Speed Bin Approach
# Speed < 15

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 39.366[a] | 1 | 39.366 | 244.308 | .000 |
| LG10NOX1 | 39.366 | 1 | 39.366 | 244.308 | .000 |
| Error | 15.308 | 95 | .161 | | |
| Total | 54.674 | 96 | | | |

a. R Squared = .720 (Adjusted R Squared = .717)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LG10NOX1 | 2.637 | .169 | 15.630 | .000 | 2.302 | 2.971 |

# 15 < Speed < 30

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 22.324[a] | 1 | 22.324 | 157.233 | .000 |
| LG10NOX1 | 22.324 | 1 | 22.324 | 157.233 | .000 |
| Error | 20.303 | 143 | .142 | | |
| Total | 42.626 | 144 | | | |

a. R Squared = .524 (Adjusted R Squared = .520)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LG10NOX1 | 1.668 | .133 | 12.539 | .000 | 1.405 | 1.931 |

# Speed > 30

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 4.673[a] | 1 | 4.673 | 61.140 | .000 |
| LG10NOX1 | 4.673 | 1 | 4.673 | 61.140 | .000 |
| Error | 7.184 | 94 | 7.642E-02 | | |
| Total | 11.856 | 95 | | | |

a. R Squared = .394 (Adjusted R Squared = .388)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Parameter | B | Std. Error | t | Sig. | Lower Bound | Upper Bound |
| LG10NOX1 | .900 | .115 | 7.819 | .000 | .672 | 1.129 |

# SECTION E
# LDV NOx Model
# No Ramp Cycle

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 65.252[a] | 2 | 32.626 | 246.184 | .000 |
| LG10NOX1 | 18.783 | 1 | 18.783 | 141.730 | .000 |
| LGNXLGS | 7.776 | 1 | 7.776 | 58.678 | .000 |
| Error | 40.951 | 309 | .133 | | |
| Total | 106.203 | 311 | | | |

a. R Squared = .614 (Adjusted R Squared = .612)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Parameter | B | Std. Error | t | Sig. | Lower Bound | Upper Bound |
| LG10NOX1 | 4.867 | .409 | 11.905 | .000 | 4.063 | 5.672 |
| LGNXLGS | -2.296 | .300 | -7.660 | .000 | -2.886 | -1.706 |

# SECTION F
# LOG Space
# LDT only
# No Ramp Cycle

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 12.006[a] | 2 | 6.003 | 45.623 | .000 |
| LG10NOX1 | 2.289 | 1 | 2.289 | 17.398 | .000 |
| LG10SPD | 1.182E-02 | 1 | 1.182E-02 | .090 | .765 |
| Error | 23.684 | 180 | .132 | | |
| Total | 35.690 | 182 | | | |

a. R Squared = .336 (Adjusted R Squared = .329)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LG10NOX1 | .786 | .188 | 4.171 | .000 | .414 | 1.158 |
| LG10SPD | 1.247E-02 | .042 | .300 | .765 | -6.963E-02 | 9.458E-02 |

# Linear Space
# LDT Only
# No Ramp Cycle

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 10.730[a] | 2 | 5.365 | 38.690 | .000 |
| NOX_OFF | 5.232 | 1 | 5.232 | 37.729 | .000 |
| AVG_SPD | 9.585E-05 | 1 | 9.585E-05 | .001 | .979 |
| Error | 24.960 | 180 | .139 | | |
| Total | 35.690 | 182 | | | |

a. R Squared = .301 (Adjusted R Squared = .293)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| NOX_OFF | .204 | .033 | 6.142 | .000 | .138 | .269 |
| AVG_SPD | 3.132E-05 | .001 | .026 | .979 | -2.320E-03 | 2.382E-03 |

# SECTION G
# Speed Bin Approach

# Speed < 15

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 6.604[a] | 1 | 6.604 | 32.468 | .000 |
| LG10NOX1 | 6.604 | 1 | 6.604 | 32.468 | .000 |
| Error | 10.373 | 51 | .203 | | |
| Total | 16.977 | 52 | | | |

a. R Squared = .389 (Adjusted R Squared = .377)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LG10NOX1 | 1.201 | .211 | 5.698 | .000 | .778 | 1.624 |

# 15 < Speed < 31

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 4.634[a] | 1 | 4.634 | 52.617 | .000 |
| LG10NOX1 | 4.634 | 1 | 4.634 | 52.617 | .000 |
| Error | 6.782 | 77 | 8.808E-02 | | |
| Total | 11.416 | 78 | | | |

a. R Squared = .406 (Adjusted R Squared = .398)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LG10NOX1 | .820 | .113 | 7.254 | .000 | .595 | 1.046 |

# Speed > 31

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 1.798[a] | 1 | 1.798 | 16.676 | .000 |
| LG10NOX1 | 1.798 | 1 | 1.798 | 16.676 | .000 |
| Error | 5.499 | 51 | .108 | | |
| Total | 7.297 | 52 | | | |

a. R Squared = .246 (Adjusted R Squared = .232)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LG10NOX1 | .561 | .137 | 4.084 | .000 | .285 | .837 |

# SECTION H
# LDT only
# No Ramp Cycle

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 12.765[a] | 2 | 6.382 | 50.850 | .000 |
| LG10NOX1 | 2.436 | 1 | 2.436 | 19.406 | .000 |
| LGNXLGS | .735 | 1 | .735 | 5.859 | .017 |
| Error | 20.961 | 167 | .126 | | |
| Total | 33.726 | 169 | | | |

a. R Squared = .378 (Adjusted R Squared = .371)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LG10NOX1 | 1.930 | .438 | 4.405 | .000 | 1.065 | 2.795 |
| LGNXLGS | -.769 | .318 | -2.421 | .017 | -1.395 | -.142 |

# SECTION I
# NOx Univariate Analysis of Variance
# Log fit

# Ramp Cycle only

**Between-Subjects Factors**

| | | N |
|---|---|---|
| VEHCLASS | LDT1 | 9 |
| | LDT2 | 4 |
| | LDV | 24 |

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 2.147[a] | 4 | .537 | 6.391 | .001 |
| VEHCLASS | .466 | 3 | .155 | 1.850 | .157 |
| LGNOX | .663 | 1 | .663 | 7.897 | .008 |
| Error | 2.771 | 33 | 8.397E-02 | | |
| Total | 4.918 | 37 | | | |

a. R Squared = .437 (Adjusted R Squared = .368)

# Estimated Marginal Means

# VEHCLASS

**Estimates**

Dependent Variable: NOX_DIFF

| VEHCLASS | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|
| LDT1 | 8.673E-02[a] | .101 | -.118 | .291 |
| LDT2 | -6.543E-02[a] | .148 | -.366 | .236 |
| LDV | .270[a] | .061 | .146 | .395 |

a. Evaluated at covariates appeared in the model: LGNOX = .2645.

**Pairwise Comparisons**

Dependent Variable: NOX_DIFF

| (I) VEHCLASS | (J) VEHCLASS | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LDT1 | LDT2 | .152 | .174 | .389 | -.202 | .506 |
| | LDV | -.184 | .121 | .139 | -.430 | 6.299E-02 |
| LDT2 | LDT1 | -.152 | .174 | .389 | -.506 | .202 |
| | LDV | -.336* | .163 | .047 | -.667 | -4.339E-03 |
| LDV | LDT1 | .184 | .121 | .139 | -6.299E-02 | .430 |
| | LDT2 | .336* | .163 | .047 | 4.339E-03 | .667 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Univariate Tests**

Dependent Variable: NOX_DIFF

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Contrast | .438 | 2 | .219 | 2.608 | .089 |
| Error | 2.771 | 33 | 8.397E-02 | | |

The F tests the effect of VEHCLASS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

# SECTION J
# NOx Univariate Analysis of Variance
# Log format
# All veh. class
# Ramp Cycle only

**Tests of Between-Subjects Effects**

Dependent Variable: NOX_DIFF

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Model | 1.681[a] | 1 | 1.681 | 18.690 | .000 |
| LGNOX | 1.681 | 1 | 1.681 | 18.690 | .000 |
| Error | 3.237 | 36 | 8.992E-02 | | |
| Total | 4.918 | 37 | | | |

a. R Squared = .342 (Adjusted R Squared = .323)

**Parameter Estimates**

Dependent Variable: NOX_DIFF

| Parameter | B | Std. Error | t | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| LGNOX | .655 | .152 | 4.323 | .000 | .348 | .963 |

**Appendix G:**
NOx Graphs

## NOx Graphs

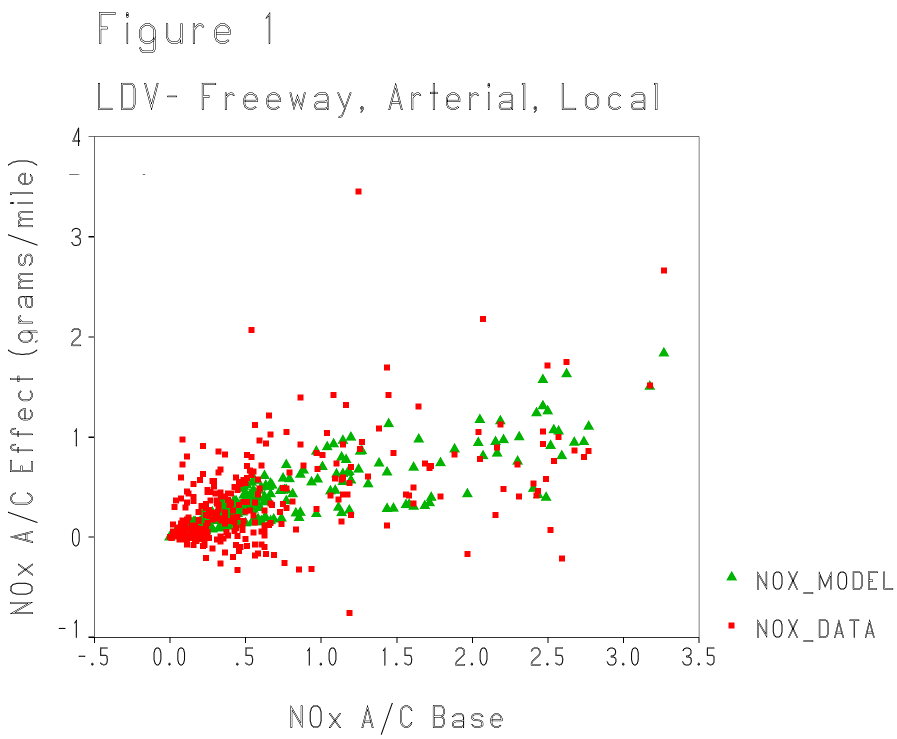
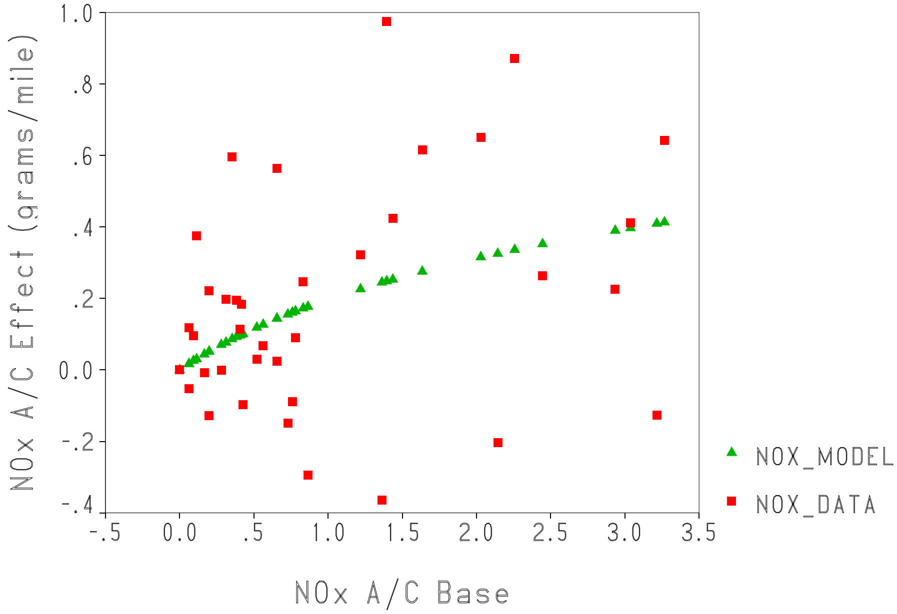


Figure 1
LDV- Freeway, Arterial, Local
NOx A/C Effect (grams/mile)
4
3
2
1
0
-1
-.5
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
NOx A/C Base
NOX_MODEL
NOX_DATA

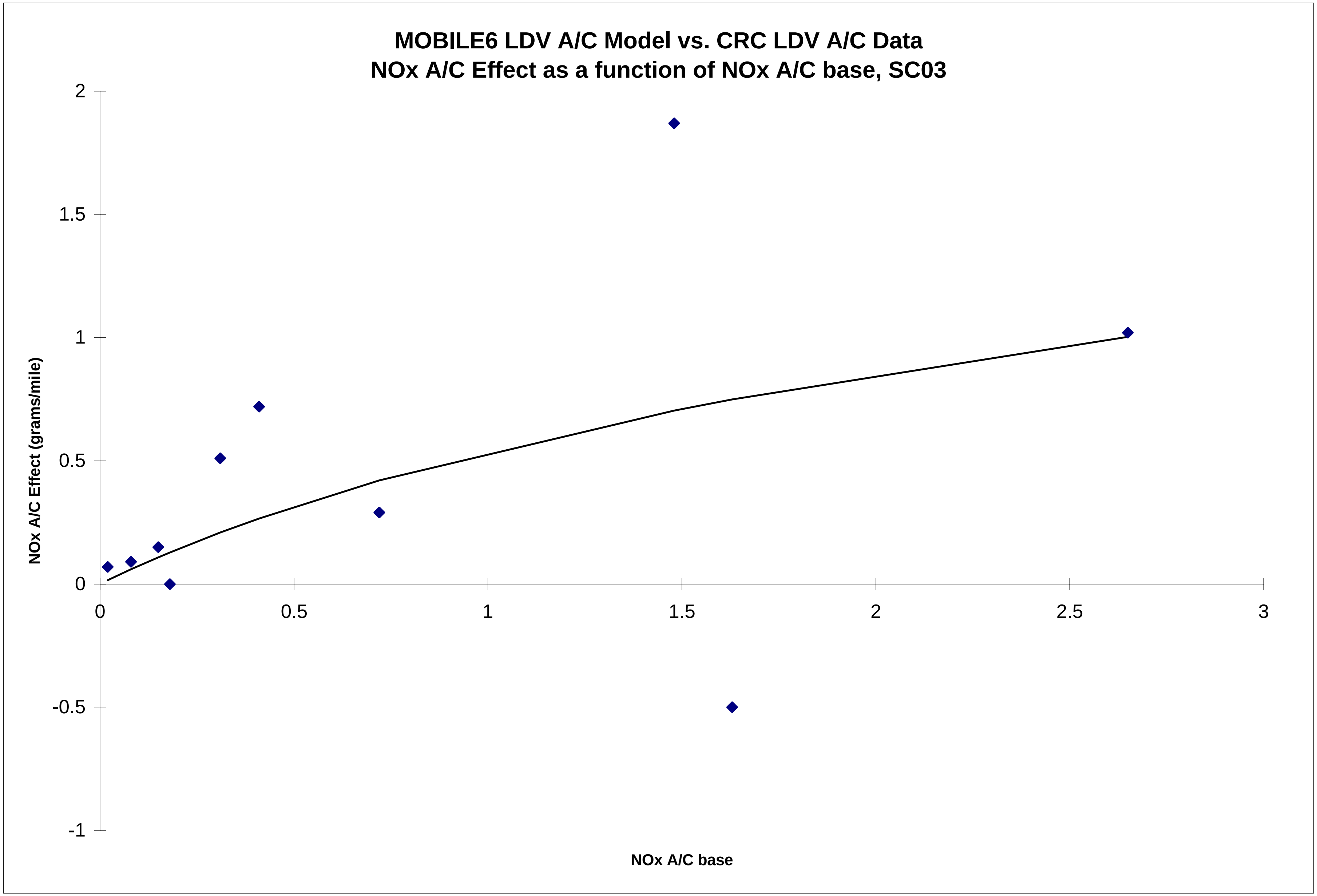
Figure 3

LDV & LDT- Ramp Cycle

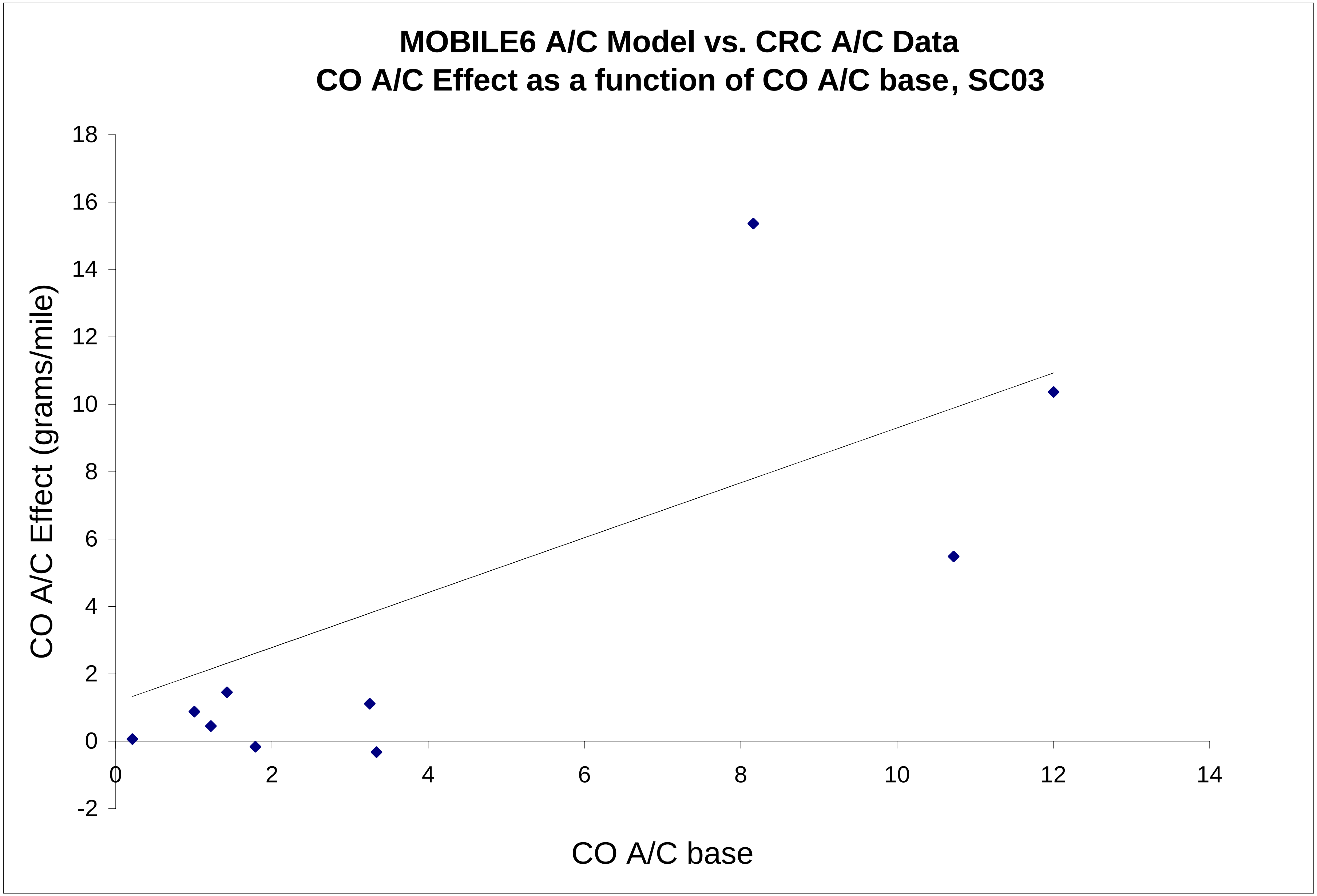


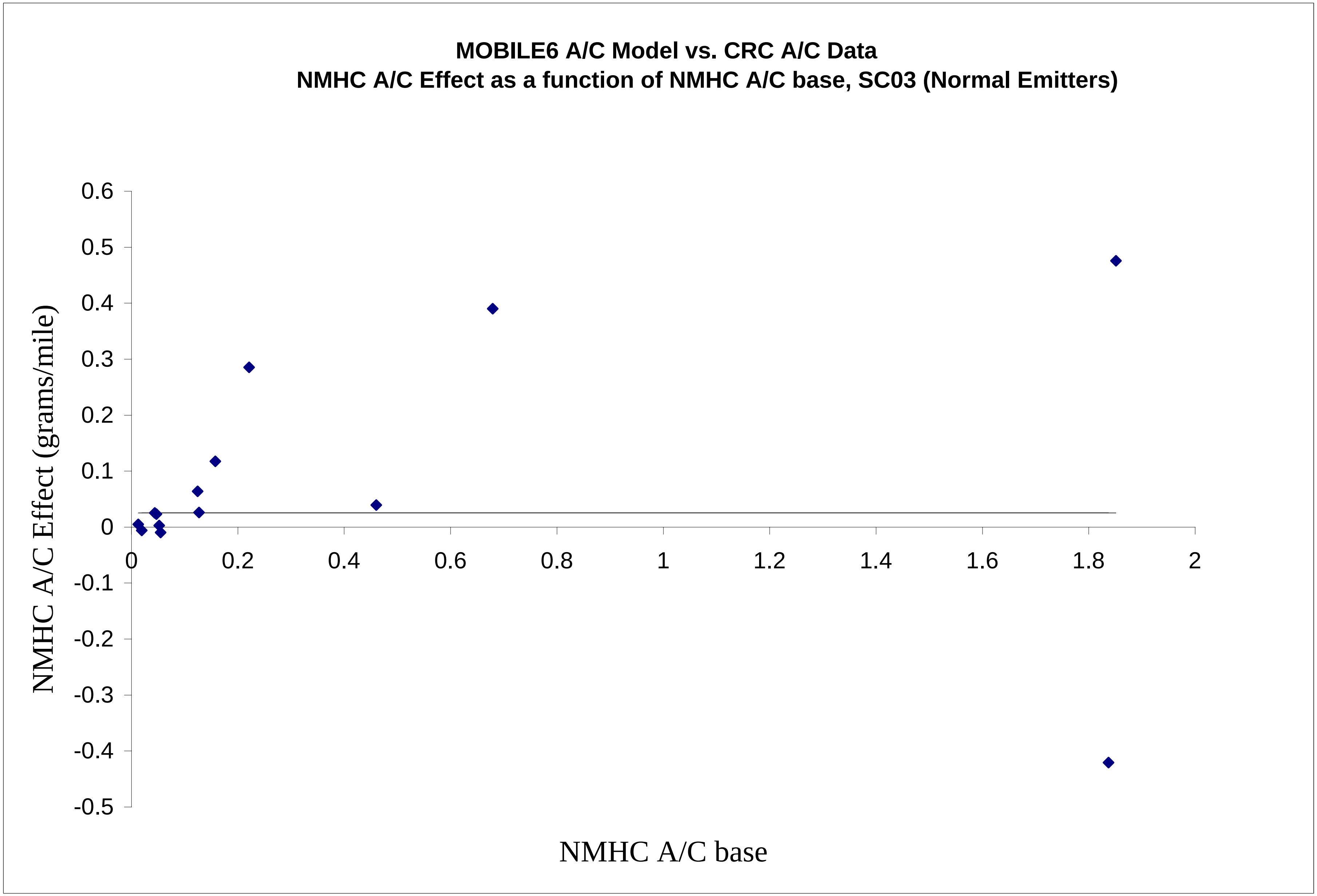
## Appendix H:

CRC Comparison Graphs



MOBILE6 LDV A/C Model vs. CRC LDV A/C Data
NOx A/C Effect as a function of NOx A/C base, SC03
NOx A/C Effect (grams/mile)
2
1.5
1
0.5
0
-0.5
-1
0
0.5
1
1.5
2
2.5
3
NOx A/C base


MOBILE6 A/C Model vs. CRC A/C Data
CO A/C Effect as a function of CO A/C base, SC03
CO A/C Effect (grams/mile)
18
16
14
12
10
8
6
4
2
0
-2
0
2
4
6
8
10
12
14
CO A/C base



MOBILE6 A/C Model vs. CRC A/C Data
NMHC A/C Effect as a function of NMHC A/C base, SC03 (Normal Emitters)
NMHC A/C Effect (grams/mile)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
NMHC A/C base

**Appendix I:**

Cold Start Ratios

**Table 1 -** Cold Start ST01 A/C Ratios
(average cycle speed = 20.2 mph)

| | **LDV** | | **LDT** | |
|---|---|---|---|---|
| | **Normal** | **High** | **Normal** | **High** |
| ***Fuel*** | 1.17 | n/a | 1.13 | n/a |
| ***NOx*** | 1.24 | n/a | 1.19 | n/a |
| ***NMHC*** | 0.96 | 1.29 | 1.05 | 0.97 |
| ***CO*** | 0.95 | 1.60 | 1.17 | 0.99 |

**Appendix J:**

SFTP Benefits

| TABLE 1<br>TIER 1 SFTP BENEFITS FROM<br>OFF-CYCLE OPERATION and AIR CONDITIONING* | |
|---|---|
| POLLUTANT | SFTP BENEFIT |
| HC | 100% |
| CO | Fuel Consumption Increase |
| NOx | 50% |
| *EPA rule estimated benefits of Tier 1 SFTP standards, in terms of percent reduction of uncontrolled "excess" emissions. | |

**TABLE 2**
**WORKSHEET FOR DEVELOPING LEV NOX BENEFITS**

| | **Tier 1 (50K Miles)** | | | | **LEV (4K Miles)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **LDV/ T1** | **LDT2** | **LDT3** | **LDT4** | **LDV/ T1** | **LDT2** | **LDT3** | **LDT4** |
| **(1) Average FTP Certification Level** | 0.17 | 0.19 | 0.24 | 0.30 | 0.07 | 0.11 | 0.13 | 0.16 |
| **(2) Estimated "Running" Certification Level** | 0.15 | 0.17 | 0.21 | 0.27 | 0.06 | 0.10 | 0.11 | 0.14 |
| **(3) Estimated NOx 4K Standard (ARB)** | | | | | 0.17 | 0.23 | 0.27 | 0.38 |
| **(4) Estimated NOx 50K Standard (EPA)** | 0.58 | 0.90 | 0.90 | 1.32 | | | | |
| **(5) US06 Standard / Running Certification Level** | | | | | 2.67 | 2.32 | 2.35 | 2.70 |
| **(6) Additional Stringency of ARB Standard** | | | | | 40% | 69% | 59% | 56% |
| **(7) EPA SFTP Benefit (%)** | 50 | 50 | 50 | 50 | | | | |
| **(8) ARB Benefit (%)** | | | | | **70%** | **85%** | **79%** | **78%** |

| TABLE 3<br>LEV SFTP BENEFITS FROM A/C OPERATION | | | | |
|---|---|---|---|---|
| | LDV/LDT1 | LD2 | LD3 | LD4 |
| HC | 100% | 100% | 100% | 100% |
| CO | 20% Remain | 20% Remain | 20% Remain | 20% Remain |
| NOx | 70% | 85% | 79% | 78% |
| *EPA rule estimated benefits of LEV SFTP standards, in terms of percent reduction of uncontrolled "excess" emissions. | | | | |

**Appendix K:**

Peer Review Comments

This section summarizes comments from the two formal peer reviews the original draft report underwent after publication in March 1998.

**Commentor 1:**

The comment text is verbatim from the commentor, minus editorial corrections to maintain the confidentiality of the commentor. Because the report was significantly modified after these comments were received, many of the detailed comments are no longer applicable. The overarching recommendations in the "general comment" section were addressed through the change in approach from a multiplicative air conditioning correction factor to an additive correction factor.

General comment:

You are using the ratios (with a/c)/(without a/c). Perhaps early in the paper it would be helpful to indicate reason for using pollutant ratios instead of increments (so it will apply to large cars as well as small; high emitters as well as low?). Such ratios for pollutants seem more logical than for engine power. The power increment needed by the a/c compressor is more easily modeled as an absolute number than a ratio. This observation is the basis for many comments that follow. Basically, a/c power requirement is almost linearly proportional to engine rpm at a given compressor suction and discharge pressure. These pressures depend, in turn, on the indoor and outdoor temperature and airflow condition, which apparently are identical for the vehicle testing program discussed in the draft report. Therefore improvements might be obtained by adding the a/c power directly to the (large or small) engine power first, and then perhaps employ the assumption that emissions are directly proportional to the total engine power (for drivetrain plus compressor).

Page 2

"It should be noted that the correction factors presented in this report apply to vehicles which do not comply with the SFTP requirement." We would add some comment or hint indicating why it does not apply. What would be needed to comply? What are the effects on non-compliance? Answers are well-known to those familiar with the issues, but probably not to many readers.

Page 3, para 1

Define "standard cooling"; it is not clear whether it refers to an engine cooling or a/c setting. Explain rationale for the "driver window down" criterion: to ensure that the interior of the car does not cool, so the indoor coil sees high temperature air. The justification for the "max a/c, recirc" setting is not clear. By recirculating air that has already been dehumidified instead of using 100% fresh air, the open window and the recirculation are working at cross purposes. Small differences in wind outside the driver's window will therefore affect the amount of mixing (of recirculated and fresh air) and therefore cause the evaporator to see different inlet conditions in different tests. This might explain some of the differences observed for the same vehicle at different test sites.

Page 3, para 3

Apparently the numerator of the correction factor is *measured* on the 95° test, while the denominator is a *calculated* (corrected) 75° test value. Next time such tests are done, a more accurate correction factor might be obtained by testing a/c off at 95° so both figures are measured in the same facility at the same time.

<u>pp 2-3</u>
The relative humidity in the 75° test is about 38%, and it is about 20% in the 95° test. The dew point of the air in the 95° test is 48°F, so the evaporator is probably removing sensible heat only. The coil will be wet and dehumidify the air only if the fan speed is low enough that the temperature of the exiting air drops below 48°. The report provides no information on exit air temperatures, so it is not possible to know whether closeness to the dewpoint might explain some of the variance between results obtained at different laboratories. At any rate, dry-coil conditions are not very common in actual operation. Under "full load" conditions (95°, relative humidity = 40%) the dewpoint is 67° so the coil will become wet and latent loads will appear when the air is cooled below that temperature.

<u>Page 5, para 1</u>
Notes the difference between high and low emitters for HC and CO. This raises the possibility, on cycles where compressor cycles on/off every few seconds, that different cars' air-fuel mixture controls might not be well-programmed to account for time constants as short as these. In other words, by the time the mixture adjusts to the step function input due to compressor power, the compressor cycles off.

<u>Page 5 para 4</u>
Typo on line 3: "is"

<u>Page 5, para 4</u>
It is surprising that the compressor was on for 97% of the time "on each of the cycles". Clarify here that only 4 of the cycles were tested, or the whole list shown in Table 2? Was compressor on full-time during the other cycles as well? On most cars the compressor shuts off when the suction pressure falls to the level where the refrigerant evaporating temperature reaches 32° (about 42 psia, or 28 psig). Since Table 4 says simply "psi", we suspect that it is a gage pressure and that explains why the compressor never shut off. The description of Table 4 is hard to understand without more knowledge of the differences between the test cells. For example if GM reported gage pressures and EPA reported absolute evaporating pressures, that could account for the differences noted.

<u>Page 6, para 1</u>
Implies that the GM test cell used a variable speed fan. Such differences between test cells should be explained more fully. For example would the fan affect the functioning of the open driver's window as well as the condenser face velocity? Are there any other differences, e.g. humidity? WEagree that more research might be required to fully explain differences, but my point is that a better partial explanation might be drawn from available data if the differences in test conditions were better documented. Similar comments arose when looking at Table 3; here are some comments prompted by it:

Table 3.

Discrepancies in this table should be better addressed; more explanations should be attempted. There could be four possible causes:

a)instruments used in each test laboratory are not equal or calibrated
b)the test conditions are not identical
c)the test procedure (measurement) is not identical
d)the vehicle was not identically adjusted prior to each test

The report does not describe what attempts, if any, were made to identify the reasons for nonrepeatability of measurements. In that respect, it would be good to document:

a)types of instruments, year of production, date calibrated and where, accuracy, repeatability, range, etc. In what part of the instruments range were measurements?
b)test conditions (for vehicle and a/c system) are not exactly described. What are possible differences? What are tolerances?
c)Did operators have the same instructions? What are tolerances? Did technician repeat the test at one location at the same vehicle to demonstrate repeatability?
d)What were the time periods (and maybe miles) between two tests? Was vehicle hauled or driven from one location to another?

Figures 5 to 10 and associated discussion

"Average Cycle Speed" is a term of art they will confuse mobile a/c experts who use the term “cycling” to describe the on/off operation of the compressor, and speak of the speed or frequency at which this occurs. It may be useful in this report to use the term "Vehicle speed" since the cycle is identified in the same Figure.

We would question the selection of the parabolic form of the regression line. We would expect that the influence of a/c system will decline as vehicle speed increases because engine power increases nonlinearly with vehicle speed (with the cube of engine rpm in a given gear?) while compressor power increases only linearly (or slightly less due to effect of ram air reducing condensing pressure), so the relative influence of compressor power is therefore reduced. In other words we would expect an asymptotic regression curve with ratio just above one at higher speeds. Such behavior seems consistent with the data shown on Figures 5, 6, 8, and 10.

Figures 7 and 9 show little or no influence of vehicle speed, or high scatter around whatever trend exists. This is not unexpected, because “vehicle speed” is a highly aggregated parameter. Perhaps we should not even be concerned about explaining whether speed or something else is the determining variable; this would be the case if we were interested only in emissions per cycle. If in the future it is necessary to try to eliminate some of this scatter in order to better understand the factors affecting emission variations among cycles, one could break the cycles into “speed bins” and calculate a mileage-weighted average of emissions. This might provide a more solid foundation when one wants to tie backwards to the emission standards which are expressed in grams/mile on a given cycle, or forwards to application of these correction factors to facility types having different average speeds. However even such a technique would fail to capture effects of acceleration differences between cycles. Therefore it might be wise to examine ways to model emissions based on cycle testing alone, rather than using vehicle speed as an intermediate variable. However if the correlation approach is needed and must be improved, it might be worth trying adding two additional variables from the cycles: average acceleration and percent idle time.

Page 7 para 3
Typo on line 2: "vehicles were"

Page 8, para 3
We would not make too much of the dip at middle speeds; we would view it as scatter until considering how speeds and accelerations are distributed within cycles.

**Commentor 2:**

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Verbatim comments not available electronically. Hard copies available upon request. As with the first set of comments, because the report was significantly modified after these comments were received, many of the detailed comments are no longer applicable.

**Comment:**The general recommendation was to be more systematic in how to determine what effects are important for generating correction factors, while at the same time acknowledging that factors such as technical judgement may play as important a role as statistical significance; in general, statistical significance should not be the sole judge of determining correction factors.

**Response:** the current approach represents a good balance between technical judgement in the absence of data, but statistical approach for determining correction factors where merited by data