CRC Report No. E-74b

EFFECTS OF VAPOR PRESSURE, OXYGEN CONTENT, AND TEMPERATURE ON CO EXHAUST EMISSIONS

May 2009

COORDINATING RESEARCH COUNCIL, INC.

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Report No. SR2009-05-03

Effects of Vapor Pressure, Oxygen Content, and Temperature on CO Exhaust Emissions

prepared for:

Coordinating Research Council

May 18, 2009

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1. EXECUTIVE SUMMARY

In response to the Clean Air Act Amendments of 1990, both Phoenix, Arizona and Las Vegas, Nevada areas were designated as being in nonattainment with the National Ambient Air Quality Standard (NAAQS) for carbon monoxide (CO). Both areas implemented regulations requiring winter gasolines to contain 3.5 percent oxygen by weight and limiting Reid Vapor Pressure (RVP) to 9 psi in order to reduce CO emissions from on-road motor vehicles. However, the regulations also created fuel property requirements that differed from those in place throughout the rest of the southwest, including California, and this tended to reduce the flexibility of the fuel supply and distribution system to provide gasoline in Phoenix and Las Vegas during the winter. Despite the fact that ambient CO concentrations have not exceeded the NAAQS in either area for a number of years, both areas continue to enforce these fuel regulations. One reason why the regulations remain in place is that the U.S. Environmental Protection Agency (EPA)'s MOBILE6.2 emission factor model predicts that the elimination of the oxygenate requirements and RVP restrictions will result in large increases in CO emissions from on-road mobile sources.

In 2003, Sierra Research (Sierra) reviewed the adjustment methodology used in MOBILE6, a predecessor to MOBILE6.2, to account for the impacts of oxygenate and RVP on CO emissions under winter conditions.[*] Sierra found that the oxygenate adjustment methodology had been recently updated using data from 1988 and later model-year vehicles certified to Tier 1 exhaust emission standards and concluded that it was reasonable. In contrast, Sierra found that the RVP methodology was originally developed for use in the now outdated MOBILE4 and MOBILE5 models using data acquired from early 1980s model-year vehicles and that it appeared to overpredict the increase in CO emissions associated with an increase in RVP relative to alternative correction factors developed by Sierra that included more recent data. The oxygenate and RVP adjustment methodologies that Sierra reviewed in MOBILE6 have been carried over by U.S. EPA into MOBILE6.2.

Since the last time either the U.S. EPA oxygenate and RVP adjustment methodologies were revisited by the agency and Sierra's 2003 study, vehicles certified to much more stringent exhaust and evaporative emission control standards have entered the fleet in large numbers and their populations will continue to expand. Given this, and the fact that the U.S. EPA methodologies generally rely on data from older vehicles, the Coordinating Research Council (referred to here as Sponsors) funded the E-74b vehicle testing

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[*] Heirigs, P.L., and Lyons, J.M, "Review of Current and Future CO Emissions from On-Road Vehicles in Selected Western Areas," Sierra Research Report No. SR03-01-01, January 28, 2003.

program. The E-74b program was designed primarily to evaluate the effects of RVP and oxygenate content on exhaust CO emissions under conditions similar to those found in the Phoenix and Las Vegas areas during the winter on recent model-year vehicles. Therefore, test vehicles selected for the E-74b program were certified to Tier 1 and more stringent exhaust emission standards and both enhanced and so-called “zero” evaporative emissions standards. Similarly, the test fuel matrix included fuels with RVP levels varying from 9 to 13.3 psi and oxygenate content ranging from zero to 3.5 weight percent, and emissions testing was performed at both 75°F and 50°F. In addition to the RVP and oxygenate matrix, an E20 test fuel was included in the test fuel matrix to examine the emission effects of increasing gasoline ethanol content beyond the current E10 limit.

A complete statistical analysis of the vehicle emissions and fuel property data was conducted. The results of this analysis revealed statistically significant relationships between test variables and CO, THC, and NOx emissions. These relationships are summarized in Table ES-1 in terms of the directional change in the test variable and the directional impact on emissions. Note that the same directional changes in primary test variables are also applicable to the four combinations of test variables.

Table ES-1
Summary of Statistically Significant Relationships[a] Observed Between FTP Composite Emissions and Test Variables

Variables	CO	THC	NOx
Temperature (decreasing from 75°F)	+[b]	+	+
Oxygen Content (increasing from 0 wt%)	-[c]	-	+
RVP (increasing from 9 psi)	+		+
Temperature and Oxygen Content		+	
RVP and Oxygen Content			
RVP and Temperature	-		
Oxygen Content Squared	+		

[a]At 95% or greater confidence level.
[b]+ Indicates increasing emissions.
[c]- Indicates decreasing emissions.

Based on the results of the statistical analysis, updated adjustments for RVP, oxygenate and temperature impacts under moderate winter conditions were developed from the E-74b data. These updated adjustments were substituted for those used in MOBILE6.2, and the impacts of this substitution were evaluated on the wintertime CO inventory for the Las Vegas area.* The results of this evaluation indicate that, for late-model vehicles operating under wintertime conditions, MOBILE6.2 currently:

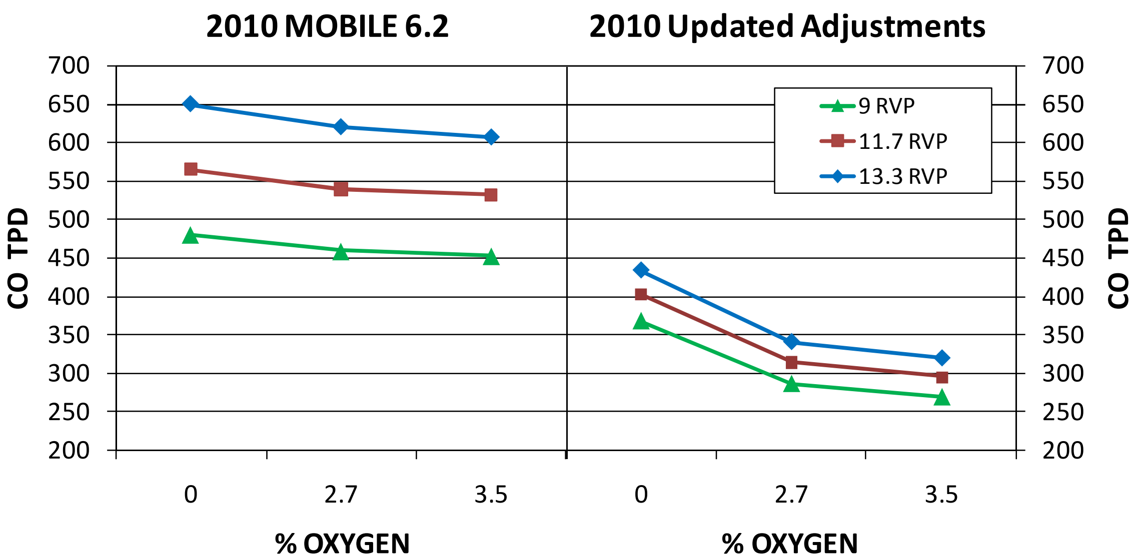
1. Overestimates CO emissions;

2. Underestimates the impact of increasing oxygenate content in reducing CO emissions; and

3. Overestimates the impact of increasing RVP in increasing CO emissions.

The magnitude of the differences between the current MOBILE6.2 adjustments and those developed based on the data collected in this project can be seen in Figure ES-1.

Figure ES-1
2010 Winter On-Road CO Emission Inventory for Clark County, Nevada as a Function of Oxygenate Level



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*The Las Vegas area was selected for this comparison for several reasons. First, it, along with the Phoenix, Arizona area, represents one of the two major urban areas where regulations requiring winter gasoline to contain 3.5 percent oxygen by weight and limiting RVP to 9 psi were implemented in order to reduce CO emissions from on-road vehicles. Next, because limited project resources precluded comparisons in both areas, it was selected over Phoenix due to the availability of the emission inventory data required to perform the comparison.

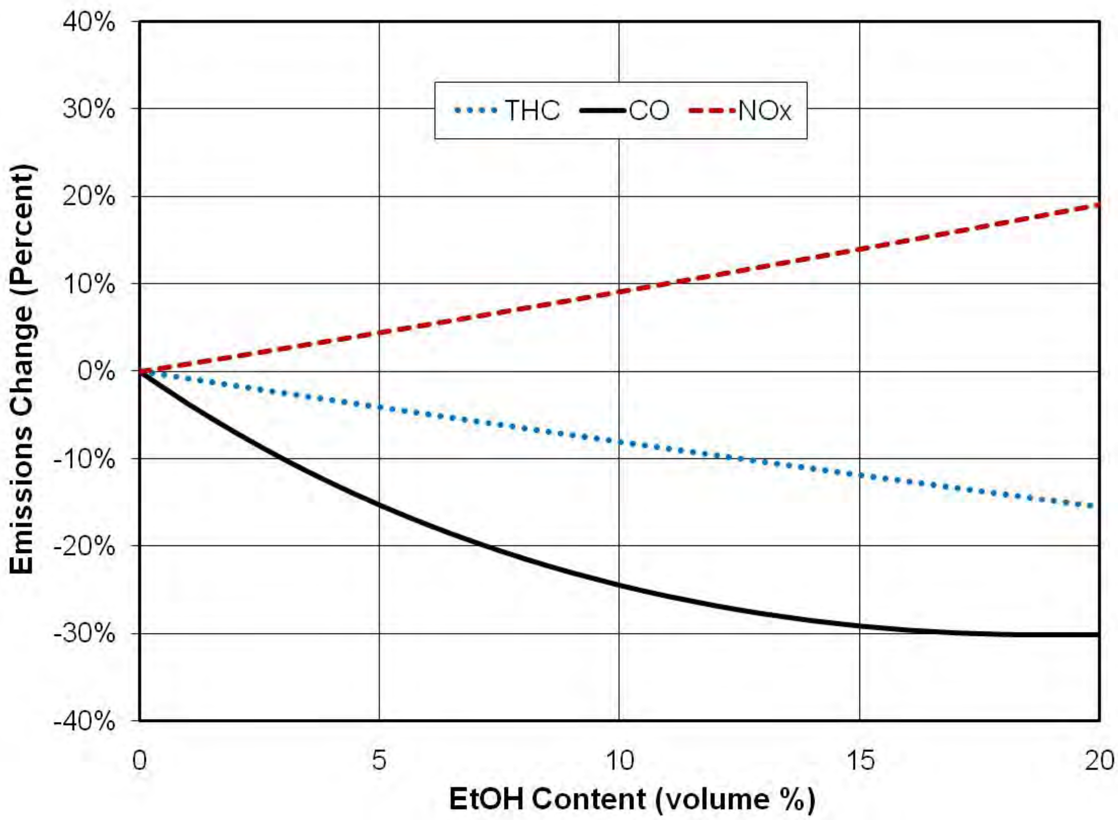
Figure ES-1 shows the 2010 winter CO emission inventory for Clark County (Las Vegas), Nevada as a function of RVP and fuel oxygen content estimated using MOBILE6.2 with the existing oxygen, RVP and temperature adjustment factors and those developed under this study. The general overestimation of CO emissions by MOBILE6.2 relative to the results of this study can be seen by the displacement of the constant RVP lines on the right and left sides of the figure. Most notably, with the updated adjustment factors, even the highest estimated CO emissions under the 13.3 RVP and no oxygen case are lower than those estimated by MOBILE6.2 for the lowest CO emissions case at 9 RVP and 3.7 weight percent oxygen.

Next, as can be seen by the space between the constant RVP lines, for an RVP increase from 9 to 13.3 psi the updated adjustment factors predict an increase in CO emissions of about 15%, which is less than one-half of the 35% increase currently predicted by MOBILE6.2. Finally, as can also be seen from the slopes of the constant RVP lines as oxygenate content is increased, the updated adjustment factors predict a much greater reduction in CO emissions with increasing oxygenate content than that currently predicted by MOBILE6.2. Moving from 9 RVP and no oxygen to 9 RVP and 3.5 percent oxygen by weight, the updated adjustments show about a 23% reduction in the CO inventory. Using MOBILE6.2, this same change in oxygen content would be estimated to reduce the CO inventory by only about 8%. Overall, the results of this study show that (1) CO emissions in Las Vegas are considerably lower than estimated by MOBILE6.2; (2) removal of the RVP limit in Las Vegas would have a smaller effect in terms of the percentage increase in CO emissions than predicted by MOBILE6.2; and (3) elimination of the winter oxygenate requirements in Las Vegas would have a larger effect, again in terms of the percentage increase in CO emissions, than predicted by MOBILE6.2. Although CO emissions in the Phoenix area were not explicitly evaluated, similar findings would be made using the updated adjustments developed from the E-74b data.

As noted above, in addition to allowing for the evaluation of the RVP and oxygen adjustment factors under winter conditions in the Las Vegas and Phoenix areas, the data collected during the E-74b test program provide insight with respect to another important question—the effect of increasing the ethanol content of gasoline above 10% by volume on exhaust emissions. This was possible because of the inclusion of an E20 test fuel in the test fuel matrix. However, the results may be confounded to some degree because of variation in the distillation properties of the E20 test fuel relative to the other test fuels in the project.

Figure ES-2 shows the estimated change in exhaust emissions of total hydrocarbons (THC), CO, and oxides of nitrogen (NOx) as a function of oxygen content at 75°F and 9 RVP. As shown in the figure, analysis of emissions data from the late-model vehicles tested in the E-74b project indicates that increasing ethanol (and therefore oxygen) content leads to reduced exhaust emissions of THC and CO and increased emissions of NOx. For THC and NOx, the relationships between changes in emissions and ethanol content found in the E74b data are linear. In contrast, for CO the relationship is non-linear, with diminishing changes in CO emissions resulting from increasing the amount of ethanol added.

Figure ES-2
Effects of Ethanol Content on Composite FTP Emissions in the E-74b Project



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2. INTRODUCTION

The effects caused by changes in gasoline RVP and oxygen content on exhaust emissions have been of concern for quite some time and adjustments to account for these effects were incorporated into the U.S. EPA's MOBILE series of emission factor models during the 1980s and 1990s. In general, the MOBILE adjustments for RVP and oxygenate effects are based on older model-year vehicles and have not been updated with data obtained from newer model-year vehicles certified to more stringent exhaust and evaporative emissions standards. As a consequence of these MOBILE adjustments, Phoenix, Arizona and Las Vegas, Nevada areas implemented regulations requiring winter gasolines to contain 3.5 percent oxygen by weight and limiting Reid Vapor Pressure to 9 psi in order to reduce CO emissions from on-road motor vehicles. As noted previously, these regulations also created fuel property requirements that differed from those in place throughout the rest of the southwest, including California, and this tended to reduce the flexibility of the fuel supply and distribution system to provide gasoline in Phoenix and Las Vegas during the winter.

Given the above, the Coordinating Research Council (referred to here as Sponsors) funded the E-74b vehicle testing program designed primarily to evaluate the effects of RVP and oxygenate content on exhaust CO emissions under conditions similar to those experienced in the Las Vegas and Phoenix areas during winter months. Given their prevalence in the in-use vehicle fleet, this testing focused on recent model-year vehicles certified to Tier 1 and more stringent exhaust emission standards and both enhanced and so-called "zero" evaporative emissions standards. This project involved vehicle testing, a complete statistical analysis of the data, and the development of updated adjustment factors for RVP and oxygenate effects on exhaust emissions. In addition, because an E20 fuel was added to the test fuel matrix, the results of the E-74b project provide insight into the exhaust emission impacts that would be associated with an increase in the allowable ethanol content of gasoline beyond the current limit of ten percent by volume.

The subsequent sections of this report describe the test program, data analysis, statistical analysis and development of adjustments, and evaluation of the updated RVP and oxygenate adjustments on the wintertime CO emission inventory in the Las Vegas area. The catalyst sulfur removal protocol used in the project is presented in Appendix A and all vehicle test data collected during the project are presented in Appendix B. Finally, an assessment of test-to-test variability in the E-74b project is presented in Appendix C.

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3. TEST PROGRAM

3.1 Test Vehicles

Detailed vehicle fleet specifications were provided by the sponsors of the E-74b program. The vehicle definition included make, model year, engine size, and exhaust and evaporative emission certification classes. The vehicles tested exactly met the requested vehicle specifications.

Test vehicles were purchased from local Arizona dealers and private parties specifically for use in this program. They were selected to include representative high sales volume samples based on emission control system/manufacturer/engine size categories. Accumulated odometer mileages were appropriate for the model year procured, ranging from 28,000 miles to 104,000 miles. The vehicle model years ranged from 1994 to 2006.

A detailed under hood visual inspection was performed prior to purchase. Vehicles that had been modified, or that showed signs of extensive damage and repair, were not to be procured. In particular, the catalytic converter and engine emission control systems were inspected to ensure they were intact, and that their apparent age and condition were appropriate for the candidate vehicle. The operation of the vehicle's brakes and transmission was verified to ensure testability. Table 3-1 describes the test vehicles in the program. Table 3-2 provides additional detail regarding the certification standards applicable to the test vehicles selected.

As shown in Table 3-2, the test vehicles were certified to either federal Tier 1, National Low Emission Vehicle (NLEV), or Tier 2 exhaust emission standards. In addition, most of the vehicles were certified as being in compliance with the federal Cold Temperature CO requirements. With respect to evaporative emissions, test vehicles were certified to either the pre-enhanced (e.g., one-hour diurnal), enhanced, or near-zero emission standards.

Table 3-1
Test Vehicle Descriptions

Veh No	MY	Make	Model	Type	Trans	Displacement (l)	Odometer	Tank Volume (gal)
001	1994	Chevrolet	Lumina	PC	Auto	3.1	81,512	16.0
002	1996	Ford	Taurus	PC	Auto	3.0	86,538	16.0
003	1995	Jeep	Cherokee	LDT	Man/5	4.0	98,668	20.0
004	1999	Honda	Accord	PC	Auto	2.3	100,414	17.1
005	2001	Toyota	Corolla	PC	Auto	1.8	92,047	13.2
006	2002	Nissan	Altima	PC	Auto	2.5	104,712	20.0
007	2001	Dodge	Caravan	LDT	Auto	3.3	92,740	20.0
008	2002	Chevrolet	Trail Blazer	LDT	Auto	4.2	58,618	18.6
009	2004	Dodge	Stratus	PC	Auto	2.4	63,184	16.0
010	2004	Chevrolet	Impala	PC	Auto	3.4	57,604	17.0
011	2004	Toyota	Camry	PC	Auto	3.0	42,592	17.2
012	2006	Ford	Taurus	PC	Auto	3.0	28,354	18.0
013	2004	Dodge	Ram 1500 SLT	LDT	Auto	4.7	96,119	35.0
014	2004	Ford	Escape	LDT	Auto	3.0	40,188	16.0
015	2004	Toyota	Highlander	LDT	Auto	3.3	88,693	19.1

Table 3-2 **Test Vehicle Emission Certification Classes**						
Veh No	Model Year	Make	Exhaust Standard	Standards [a] (g/mile)	Cold CO Standards (g/mile)	Evap Standard
001	1994	Chevrolet	Tier 1 LDV	.31/4.2/.6	N/A	Pre Enhanced
002	1996	Ford	Tier 1 LDV	.31/4.2/.7	10.0	Enhanced
003	1995	Jeep	Tier 1 LDT2	.40/5.5/0.97	N/A	Pre Enhanced
004	1999	Honda	NLEV LEV	.09/4.2/.3	10.0	Enhanced/ORVR
005	2001	Toyota	NLEV LEV	.09/4.2/.3	10.0	Enhanced/ORVR
006	2002	Nissan	NLEV ULEV	.055/2.1/.3	10.0	Enhanced/ORVR
007	2001	Dodge	NLEV LEV LDT2	.13/5.5/.5	12.5	Enhanced/ORVR
008	2002	Chevrolet	NLEV LEV LDT2	.13/5.5/.5	12.5	Enhanced/ORVR
009	2004	Dodge	Tier 2 Bin 5	.09/4.2/.07	10.0	Enhanced/ORVR
010	2004	Chevrolet	Tier 2 Bin 5	.09/4.2/.07	10.0	Enhanced/ORVR
011	2004	Toyota	Tier 2 Bin 9	.09/4.2/.30	10.0	Near Zero/ORVR
012	2006	Ford	Tier 2 Bin 5	.09/4.2/.07	10.0	Near Zero/ORVR
013	2004	Dodge	Tier 2 Bin 10 LDT	.23/6.4/.60	12.5	Enhanced/ORVR
014	2004	Ford	Tier 2 Bin 9	.09/4.2/.30	10.0	Near Zero/ORVR
015	2004	Toyota	Tier 2 Bin 5	.09/4.2/.07	10.0	Near Zero/ORVR

[a] Standards are given as NMHC/CO/NOx

3.2 Pretest Procedures

All exhaust emission testing in this project was performed using the U.S. EPA's standard "Federal Test Procedure" (FTP). An FTP exhaust emission test was performed to assess vehicle condition upon arrival at the testing laboratory. The results were reviewed with Harold Haskew and Associates before continuing. The in-use compliance of the vehicles with their very stringent certification standards was notable. No emissions-related repairs were required prior to testing.

The fuel tank temperatures encountered during vehicle operation strongly influence the rate of fuel vapor generation. Emission testing is performed on a chassis dynamometer. Left uncontrolled, fuel tank temperatures occurring during dynamometer operation can be unrepresentatively high or low. Exhaust emission CO levels encountered with Tier 0 vehicles were believed to be influenced by fuel vapors purged by the engine from the evaporative emission control canister. The temperature of the gasoline during FTP testing in this program was therefore monitored and controlled.

An on-road fuel tank temperature profile appropriate for FTP testing at 50° and 75°F was measured. Each test vehicle was instrumented with external fuel tank thermocouples, drained and filled to 40% tank capacity, preconditioned with one LA4 road equivalent, and soaked overnight. The vehicle was then operated on the road through the equivalent of the dynamometer FTP cycle while fuel tank temperatures were monitored. These temperature data were used to develop fuel temperature targets for use during dynamometer emission testing.

A special preconditioning cycle was performed before the first test fuel cycle to minimize the effect of residual catalyst sulfur deposits resulting from operation with uncontrolled commercial fuels. A description of the sulfur preconditioning is provided in Appendix A.

Individual random test orders were created for each vehicle prior to the start of testing. The various combinations of fuel RVP, ethanol level, and ambient temperatures were performed in the predetermined order. The detailed test results, provided in Appendix B, include the run number for the individual tests.

3.3 Test Procedures

Vehicles received extensive preconditioning prior to each test. The preconditioning served to normalize both the exhaust emission control adaptive learning function and fuel carryover effects in the evaporative emission control charcoal canister.

Vehicle preconditioning began with canister normalization. The canister received a 300 bed volume purge with room air at a nominal flow rate of 0.4 cfm. The vehicle evaporative service port (or a tee installed for the purpose) was used for the purge. One liter of the fuel type to be used for the emission test was then placed in a sealed container. The container was mounted on a laboratory digital scale. Nitrogen was bubbled through the fuel, and the saturated vapor was directed to the service port and canister of the vehicle being tested. Canister loading continued until the weight of the fuel sample had been reduced by an amount equal to 25% of the vehicle canister capacity. For example, a canister with a 120-gram working capacity was loaded with 30 grams of fuel vapor. The rate of nitrogen flow was controlled to maintain a nominal rate of fuel weight change of 40 grams/hour. Rates were adjusted to maintain a purge/load cycle within a two-hour limit.

The vehicle was then drained and refueled with as-received tank fuel to 40% capacity with the fuel specified for the upcoming test. The vehicle was operated over three cycles of a 7.6-mile road course. The operation included mixed city street and expressway driving, with an average speed similar to the dynamometer LA4 cycle used for FTP testing. The vehicle was then parked in the laboratory at a nominal temperature of 75°F. A final drain and 40% fill with the same fuel was performed. The dynamometer test cell and soak area were set at the temperature specified for the upcoming test. The final LA4 preconditioning was performed and the vehicle was placed in the controlled temperature soak area.

Soak time between the end of the preconditioning and the start of the FTP was maintained between 18 and 22 hours. At the end of the soak period, the vehicle was transferred to the emission test cell. An FTP test was performed in accordance with new vehicle certification procedures. Enhancements included use of an INNOVA analyzer to measure ethanol in the exhaust and second-by-second emissions measurements before and after the catalytic converter. The cell temperature was set at 50° or 75°F, as specified in the randomized testing schedule. Emissions of CO, THC, non-methane hydrocarbons (NMHC), NOx, and carbon dioxide (CO_2) were measured and reported in grams and grams/mile. The ethanol component of the hydrocarbon emissions was handled as specified in the California Air Resources Board (CARB) procedures[*] cited in the federal regulations.

Fuel temperatures were controlled during the final LA4 and FTP tests. The temperature rise observed during the initial road test would be applied to the ambient temperatures maintained during each test on a vehicle. An 8°F fuel temperature rise observed during the initial road LA4 would translate to a rise from 50° to 58°F during a 50°F dynamometer test. Under-vehicle air flow was adjusted to maintain the fuel temperature profile observed during road operation.

Data from each preconditioning and test series were carefully reviewed for completeness and conformance to all quality specifications. The test vehicle would be scheduled for the next randomly selected test in the series following test acceptance.

[*]California Non-Methane Organic Gas Test Procedures, July 12, 1991, amended July 30, 2002, California Air Resources Board, Monitoring and Laboratory Division.
http://www.arb.ca.gov/msprog/levprog/cleandoc/clean_nmogtps_final.pdf

3.4 Test Fuels

The test fuels were specifically prepared for this program. The RVP of the finished fuels was targeted at levels of 7.0, 9.0, and 13.0 psi. Ethanol contents of E0, E10, and E20 were specified. The base stocks for the E10 and E20 fuels were intended to yield appropriate RVP and other properties following addition of the ethanol.

The fuels were prepared by Haltermann Products of Channelview, Texas. The average inspection properties of winter-grade conventional gasoline blended with ethanol, as reported in the 2002-2003 Northrop Grumman (formally NIPER) gasoline survey,[*] were supplied as targets. Table 3-3 displays the survey results. Initially only two batches of fuel were to be tested, and all properties, except RVP, were to be "closely matched." Both fuels were to contain 10% ethanol. The program was later expanded to include seven different combinations of fuel RVP and ethanol content. As a result, the fuel properties at the highest RVP and highest ethanol contents were no longer as "close" as those of the lower RVP and ethanol fuels.

The fuels were to be blended from standard refinery streams. Samples of the finished fuels were analyzed by several of the test sponsors. Table 3-4 displays the results of the analyses performed by the sponsors. Table 3-5 displays additional analysis performed by the fuel blender.

Table 3-3
Original Fuel Blending Targets

Property	Limits	Test Method
Gravity, °API	Report	ASTM D 287
DVPE	9.0, 13.0	ASTM D 5191
T10	Varies w/DVPE	ASTM D 86
T50	158-168 F	ASTM D 86
T90	315-325 F	ASTM D 86
FBP	< 437 F	ASTM D 86
RON	91-95	ASTM D 2699
MON	83-87	ASTM D 2700
(R+M)/2	87-91	
Aromatics	21-25 vol%	ASTM D 1319 (Vol %), or D 5580 (Wt %)
Benzene	0.9-1.1 vol %	ASTM D 5580 or D 3606
Olefins	7-11 vol%	ASTM D 1319 (Vol %), or D 6550 (Wt %)
Sulfur	25-30 ppm	ASTM D 2622
Ethanol	10 vol%	ASTM D 4815

[*] "Motor Gasolines, Winter 2002-03," Cheryl Dickson, August 2003, Northrop Grumman, Bartlesville, OK, NGMS-230 PPS 2003/3

Table 3-4
Fuel Properties (Average from sponsors)

Inspection	Units	Fuel 6	Fuel 3	Fuel 5	Fuel 7	Fuel 1	Fuel 2	Fuel 4
API Gravity	°API	60.2	63.3	64.1	58.5	58.8	59.7	57.0
Relative Density	60/60°F	0.7381	0.7262	0.7231	0.7447	0.7435	0.7399	0.7506
DVPE	psi	6.95	9.10	12.76	7.30	8.79	13.30	8.47
Oxygenates--D4815								
MTBE	vol %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ETBE	vol %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EtOH	vol %	0.00	0.00	0.00	9.54	9.42	9.03	20.38
Oxygen	wt %	0.00	0.00	0.00	3.53	3.49	3.36	7.49
HC Composition								
Aromatics	vol %	22.1	23.4	24.2	24.4	23.6	22.5	21.5
Olefins	vol %	8.0	9.6	9.5	8.8	9.6	9.6	10.9
Saturates	vol %	70.0	67.1	66.4	57.3	57.5	59.0	46.8
D86 Distillation								
IBP	°F	99.9	88.8	82.0	104.0	97.2	83.7	103.3
10%	°F	142.4	122.4	106.4	133.0	125.1	107.9	131.2
50%	°F	197.9	191.0	189.1	195.0	189.8	165.4	159.6
90%	°F	313.6	316.5	316.3	317.0	319.0	322.1	313.7
EP	°F	361.0	353.7	353.7	360.0	357.2	352.4	342.0
Recovery	vol %	97.8	97.6	96.6	97.8	97.9	96.7	98.3
Residue	vol %	1.3	1.6	1.3	1.0	1.1	1.4	1.1
Loss	vol %	1.0	0.8	2.1	1.2	1.0	1.7	0.7
Drivability Index	-	1120.7	1073.2	1043.2	1101.5	1075.9	979.9	989.1

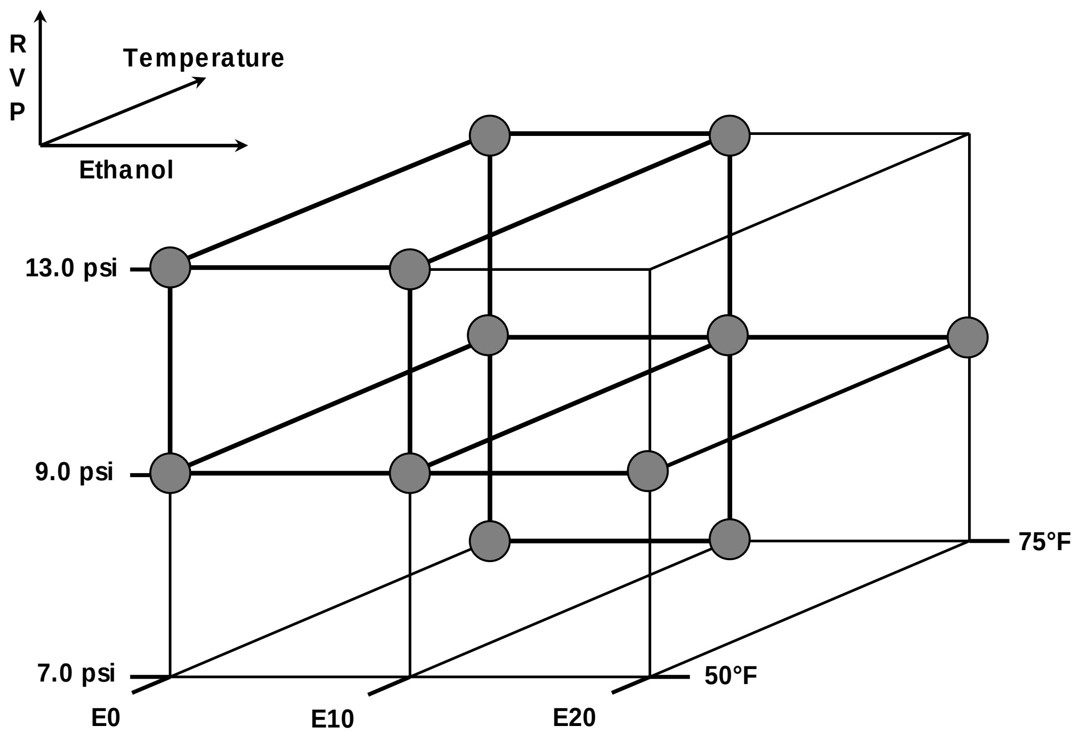
Table 3-5
Additional Fuel Properties (from Haltermann)

Inspection	Units	Fuel 6	Fuel 3	Fuel 5	Fuel 7	Fuel 1	Fuel 2	Fuel 4
DVPE	psi	6.95	9.10	12.76	7.30	8.79	13.30	8.47
EtOH	vol %	0.00	0.00	0.00	9.54	9.42	9.03	20.38
Sulfur Content	ppm	29	28	26	27	29	27	27
Benzene	vol %	0.90	1.00	1.00	1.00	1.00	0.98	0.96
Research Octane Number		93.2	94.4	94.6	94.0	92.9	94	94.6
Motor Octane Number		83.8	84.5	83.5	83.8	84.1	83.4	83.4
(R+M)/2		88.5	89.5	89.0	88.9	88.5	88.7	89.0
Benzene	vol %	0.89	1.05	1.05	1.06	1.10	0.94	0.97
C/H Ratio		6.200	6.196	6.170	6.092	6.106	6.143	5.835
Net Heat of Combustion	btu/lb	18,703	18,733	18,758	18,016	17,973	18,000	17,160
Oxygen	wt. %	0.008	0	0	3.396	3.609	3.488	7.733
C+H	wt. %	99.99	100.00	100.00	96.60	96.39	96.51	92.27
H	wt. %	13.89	13.90	13.95	13.62	13.56	13.51	13.50
C	wt. %	86.10	86.10	86.05	82.98	82.83	83.00	78.77
Net Heat of Combustion D3338	Btu/lb	18,573	18,592	18,580	18,514	18,516	18,521	18,513

Fuels were produced at three vapor pressure levels (7.0, 9.0, and 13.0 psi) with three levels of ethanol (0%, 10%, and 20%). The E0 and E10 fuels were produced at all three vapor pressure levels. The E20 fuel was produced only at the 9.0 psi level.

Tests were performed at two temperatures (50° and 75°F) with each of the 9.0 psi and 13.0 psi fuels. The 7.0 psi fuels were tested only at 75°F. Figure 3-1 summarizes the combinations included in the test program.

Figure 3-1
Fuel Ethanol, Vapor Pressure, and Temperature Combinations Tested



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4. DATA ANALYSIS

4.1 Overview of Experimental Design

As was shown in Figure 3-1, the test program included 12 combinations of RVP (3 levels), ethanol content (3 levels), and ambient temperature (2 levels). The design is unbalanced because only 12 of the possible 18 combinations of three variables were tested.

To obtain the greatest insight into the effects of RVP, oxygenate, and ambient temperature, the analysis in this section considers the dataset as if it involved the four individual experiments outlined below.

- An experiment on the effect of oxygenate (ethanol content) conducted at a temperature of 75°F and at RVP 9. This experiment consists of the three test points E0, E10, and E20 in the background plane of the experimental matrix shown in Figure 3-1 at RVP 9. The emissions effect of varying oxygenate levels can be directly observed in this subset of the program test data.

- An experiment on the effect of low RVP at FTP conditions of 75°F. This experiment consists of the five test points in the background plane spanning E0, E10, and E20, and RVP 7 and 9 fuels. This experiment combines the effect of RVP 7 fuel (compared to a baseline of RVP 9 fuel), with two non-zero levels of oxygenate. As a result, the oxygenate effect must be controlled for in order to observe the emissions effect of low RVP fuel.

- An experiment on the effects of high RVP at FTP conditions of 75°F. This experiment consists of the five data points in the background plane spanning E0, E10, and E20, and RVP 9 and 13 fuels. Because this experiment also combines oxygenate with RVP effects, statistical controls must be employed to observe the emissions effect of high RVP fuel.

- A final experiment on the effects of high RVP at an ambient temperature of 50°F. This experiment consists of the five data points in the foreground plane spanning E0, E10, and E20, and RVP 9 and 13 fuels. After appropriate controls for the effect of oxygenate at low temperature, the effect of RVP at lower ambient temperatures can be observed in this experiment.

The benefit of this approach is that the major trends in the data can be easily seen and understood without relying on complex statistical models to infer the trends. In addition, the only variable for which statistical control is required is that of added oxygen content in the experiments dealing with RVP effects. This control can be easily implemented in simple statistical models that are unlikely to risk misfitting the data. The results of the individual analyses are then combined in Section 5 in a complete statistical analysis of the data and the estimation of correction factor equations for use in the MOBILE model.

4.2 Vehicle Technology Groups

The first step in the data analysis involved dividing the test vehicles into four groups based on the sophistication of their emission control technology:

1. Group 1 – Test vehicles No. 1, No. 2, and No. 3. This group includes the oldest vehicles, certified to Tier 1 exhaust emission standards. Two of the vehicles (Nos. 1 and 3) were not certified to enhanced evaporative emission or to cold CO standards.

2. Group 2 – Test vehicles No. 4 through No. 8. These vehicles were certified to NLEV exhaust emission, enhanced evaporative emission, and cold CO standards.

3. Group 3 – Test vehicles Nos. 9, 10, and 13. This group consists of three vehicles certified to Tier 2 exhaust emission, enhanced evaporative emission, and cold CO standards.

4. Group 4 – Test vehicles Nos. 11, 12, 14, and 15. This group consists of four vehicles certified to Tier 2 exhaust, near-zero evaporative emission, and cold CO standards.

In addition to the above, all of the vehicles in Groups 2 through 4 were equipped with on-board refueling vapor recovery systems.

The average FTP composite and bag emission rates by technology group are shown in Table 4-1.

Many of the vehicles in Groups 3 and 4 had emission levels, particularly for Bag 3, that were reported as zero because they fell below the minimum detectable levels of the emission analyzers when recorded to two decimal places. In order to include these data in the statistical analysis where logarithmic models were used for the dependent emission variable, a *de minimus* emission level of one-half of the smallest non-zero measurement recorded for the pollutant was substituted for zero readings. At such low levels, the difference in logarithms of emissions can be subject to large fluctuations due to small values in the denominator. Thus, it should come as no surprise that estimating emission effects with high statistical confidence is sometimes problematic for these vehicles.

Table 4-1 Average Emission Rates by Technology Group (g/mile) (At 75°F, RVP = 9 psi, E0 fuel)												
	Group 1			Group 2			Group 3			Group 4		
	NMHC	CO	NOx	NMHC	CO	NOx	NMHC	CO	NOx	NMHC	CO	NOx
FTP	0.39	4.88	0.94	0.08	1.31	0.17	0.07	0.68	0.05	0.04	0.23	0.05
Bag 1	0.89	9.13	1.56	0.27	2.97	0.47	0.22	2.37	0.18	0.14	1.03	0.13
Bag 2	0.21	1.56	0.56	0.03	0.83	0.05	0.04	0.26	0.01	0.02	0.01	0.03
Bag 3	0.34	0.89	1.19	0.04	0.96	0.18	0.03	0.19	0.02	0.02	0.06	0.04

4.3 Test Fuels

As shown previously in Table 3-4, the T50 temperatures for Fuels 2 and 4 differed markedly from those of the other test fuels. The other test fuels were controlled to have T50 values within the range 189°F to 198°F, while Fuels 2 and 4 had T50 values 24°F and 30°F below this range, respectively. Further, review of Summer and Winter Alliance of Automobile Manufacturers (AAM) Fuel Survey Data indicated that the T50 values of these fuels were substantially lower than the lowest values observed in commercial California gasolines. This raised a concern in light of the findings of the CRC E-67 study[*] regarding emission impacts associated with T50 itself and with interactions between T50 and ethanol content.

In regard to T50 and ethanol content, the CRC E-67 study observed that ethanol content and T50 interacted in such a way that, at high levels of T50 (above 220°F), raising ethanol content to high levels was associated with increased CO emissions, an effect not seen at lower T50 levels. However, the high T50 level in the CRC E-67 study was well above the values in the test fuels for this project. In addition, the CRC E-67 study noted the presence of diminishing returns in the overall effect of ethanol content on CO emissions, such that the reduction in CO emissions due to oxygenation was primarily observed at low to mid levels, with little or no incremental benefit observed at high levels. This finding guided the conduct of this analysis and led to the characterization of a non-linear oxygenate effect for CO emissions.

In regard to the representativeness of Fuels 2 and 4, a Principal Components Analysis (PCA) was conducted on the fuel property data to gain insight on whether the low T50 values were anomalies or merely represented blending effects associated with meeting the experimental targets for RVP. PCA is a useful tool in many real-world problems

[*]Durbin, T.D., et al., "Effects of Ethanol and Volatility Parameters on Exhaust Emissions," CRC Project No. E-67. College of Engineering – Center for Environmental Research and Technology, University of California, Riverside. January 2006.

where variables display a high degree of correlation among themselves. When the correlations are inherent—i.e., result from the underlying physical reality—PCA can yield valuable insight to the causal factors at work in the data. PCA decomposes the correlation matrix describing the linear relationships among the variables into eigenvectors that represent the distinct patterns by which the variables covary in the data. The vectors themselves form an orthogonal basis and provide an independent (uncorrelated) set of variables that can be used as an alternative expression of the data. What is usually seen in PCA is that most of the variance in the data is explained by a small subset of eigenvectors, so that a reduction in the dimensionality of the problem is achieved. It is not uncommon for 3 to 5 vector variables to represent 90% or more of the variation present in a dataset that contains 10 or more variables.

In this case, PCA revealed four primary eigenvectors that represent 96% of the variation in the fuels. Vectors 1 and 2 represent the blending methods used to form the experimental fuels and can be explained as follows:

- <u>Vector 1 (49% of the variation in fuels)</u>: An oxygenation index representing the blending of EtOH along with associated effects, including a tendency to increase RVP. This blending strategy appears to substitute aromatics and olefins for saturates in oxygenated fuels, possibly as a strategy to offset the direct RVP effect of added EtOH and to maintain target RVP levels.

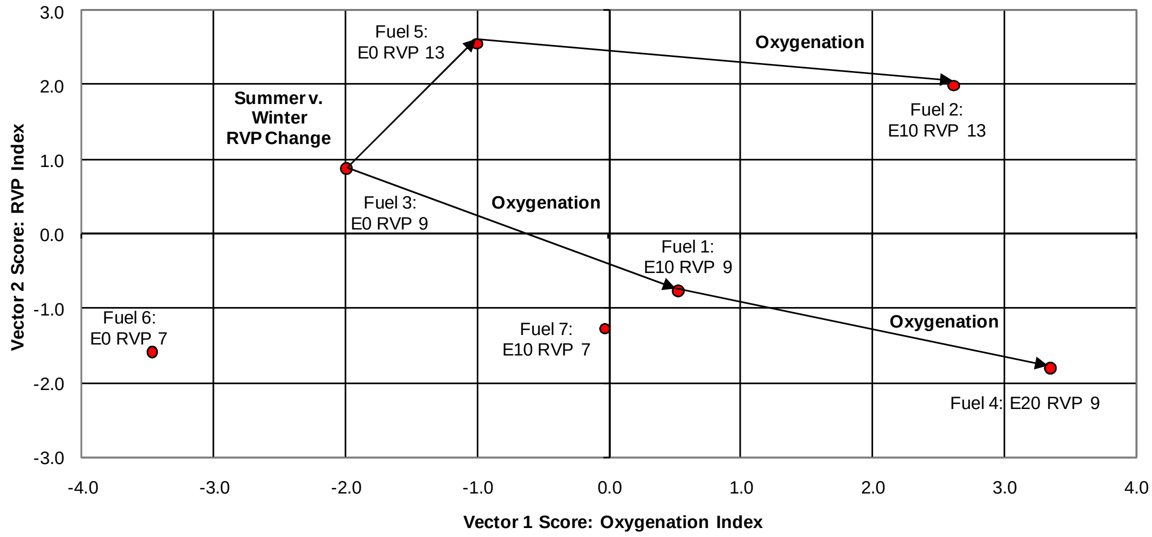
- <u>Vector 2 (27% of the variation in fuels)</u>: An RVP index representing the reformulation of the base fuel to meet varying RVP targets, including a tendency for increased RVP to be associated with lower specific gravities and lower T10 distillation points. This blending strategy appears to raise RVP primarily by selecting lighter components within each of the hydrocarbon classes, so that the overall mix of aromatics, olefins, and saturates is relatively unchanged.

Together, Vector 1 and 2 account for 76% of the total variation in fuels. The two additional eigenvectors (Vectors 3 and 4) appear to represent final blending steps taken to control research octane number (RON) and motor octane number (MON), respectively, to near-constant levels.

Figure 4-1 diagrams the relationships between RVP and oxygen content in the experimental fuels as revealed by PCA. In the figure, each experimental fuel has been scored[*] to determine the extent to which it expresses the characteristics described by Vectors 1 and 2. A shift in the base RVP level is seen as a movement predominantly up and to the right on the formulation diagram, as seen between Fuels 3 and 5. A change in

[*]The scoring process is similar to computation of an index value from known properties to assess a characteristic in the absence of direct measurement. As an example, Diesel fuel can be scored for cetane quality using the ASTM cetane index method as an alternative to the actual measurement of cetane in a test engine.

Figure 4-1
Experimental Fuel Formulation for RVP and Oxygen Content



the oxygenation level is seen as a movement down and predominantly to the right, as seen between Fuels 3, 1, and 4.*

In this diagram, neither Fuel 2 (RVP 13) nor Fuel 4 (RVP 9) appears to be anomalous, in that each creates nearly parallel fuel reformulation lines representing the blending to increase oxygenation. What is distinctive is that Fuels 2 and 4 are the rightmost fuels in the diagram, and most strongly express the fuel reformulation represented by Vector 1. This vector represents not only fuel oxygen content, but also associated changes in the hydrocarbon composition of fuels with resulting effects on specific gravity and the distillation curve. Vector 1 is strongly correlated with T50 (r = -0.89), and it should be no surprise that Fuels 2 and 4, with the highest Vector 1 scores, have the lowest T50 values.

Whether the two fuels in question are fully representative of gasolines in the market, we conclude that they are logical outcomes of the blending strategies used to create the experimental fuels and should be retained in the analysis. A larger issue is whether the T50 effects that occurred in the blending of Fuels 2 and 4 are representative of those observed in commercial gasolines at these RVP and oxygenate levels. There is, unfortunately, no definitive answer to this question, particularly for E20 blends where standardized fuel specifications do not exist.

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*Fuels 6 and 7, which are not of direct concern here as their T50 values do not differ significantly, also show that oxygenation leads predominantly to movement down and to the right, while RVP *reductions* lead to movement down and to the *left*.

The depression of T50 in Fuels 2 and 4 below the range of the other fuels has significant consequences for the interpretation of the data generated in this project. If the lower T50 level of these fuels leads to an emission effect in its own right, then Fuels 2 and 4 confound that T50 effect to some degree with effects of oxygenate content and RVP. Confounding means that two or more variables are correlated to such an extent that it becomes difficult or impossible to separate their individual contributions.

In this dataset, the consequences of confounding are as follows:

- Fuel 4 is the only test fuel containing more than 10% ethanol. If Fuel 4 were removed from the dataset, the analysis would necessarily be restricted to the range of E0 to E10. By retaining Fuel 4, the analysis can assess whether the emissions effect due to the higher oxygen content is in proportion to that observed at lower levels, *but it cannot determine whether the result is due to higher oxygen levels or to a much lower T50 or to some combination of the two effects.*

- Fuel 2 is one of two test fuels at RVP 13 and the only such test fuel that also contained oxygen. Removing Fuel 2 from the dataset would leave the analysis dependent on only one test fuel for the determination of RVP effects and would make it impossible to test whether there was an interaction between increased RVP and oxygen content. By retaining Fuel 4, the analysis can test for the presence of an interaction between RVP and oxygen content, *although it cannot determine the extent to which such an interaction is caused by RVP and Oxygen or by T50 or by a combination of the variables.*

In addition, estimates of the effect of RVP itself and in interaction with ambient temperature will be partially confounded by emissions effects caused by T50. Such partial confounding is termed *aliasing* and occurs in regression analysis when the coefficient estimated for a variable such as RVP is changed in value by the inclusion of effects actually caused by another variable (such as T50), which is correlated with the predictor but not included in the regression model. The presence of aliasing means that the coefficient does not estimate the effect associated with the predictor alone. As a result, the coefficient estimate is biased with respect to the true (but unknown) value. The depression of T50 values in two of the test fuels poses a major problem in the analysis due to the confounding with design effects and the potential for aliasing to change estimated coefficient values.

It was determined that there was no potential for separating the imbedded T50 effect by the application of statistical controls. This is because T50 is exactly confounded with the high oxygenation level (E20) and with the interaction between RVP and oxygen content at the E10 level.* Instead, the analysis was conducted twice in order to attempt to assess the import of the T50 effects.

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*The confounded terms are the quadratic term in OxPct, which represents the extent to which emissions of the E20 fuel differ from what would be expected from extrapolating the E10 effect to E20, and the term RVP · OxPct.

- The first (and primary) analysis used data for all of the test fuels and regression terms formed from the variables T, RVP, OxPct, and their two-way interactions. This analysis contains an embedded T50 effect of the kind introduced by Fuels 2 and 4 and ascribes those effects to terms involving RVP and OxPct. Its results can be used reliably and without bias to the extent that T50 depression is generally observed in fuels blended to these RVP and oxygenate levels.

- A second (sensitivity) analysis in which the two terms that are exactly confounded by T50 are dropped from consideration and replaced by a term measuring the T50 depression below a reference level of 190°F. This analysis contains an explicit T50 effect, but it will ascribe to T50 any incremental effects that are related to the E20 oxygen level or to the interaction between RVP and oxygen content (at the E10 level). Its results serve to bracket quantitatively the limitations of the first analysis and of predictions based on it. It may prove possible to use the results of this sensitivity analysis to adjust predictions (at least approximately) if T50 depression does not occur in fuels blended to the RVP and oxygenate levels reflected in Fuels 2 and 4.

4.4 Statistical Analysis Methodology

As discussed above, the test program data can be viewed as a series of experiments in which selected fuels and tests examine the response of the test vehicles to changes in fuel oxygen content and RVP at test temperatures of 75°F and 50°F. The analyses of these individual experiments are presented below. In general, the methodology involved fitting simple statistical models to subsets of the data to estimate the effects of oxygenation and RVP on CO emissions. Only CO emissions are examined in this stage, because the objective of the test program was to evaluate oxygenate, RVP, and temperature effects on CO emissions. Questions related to the presence and magnitude of emission effects by FTP phase and by vehicle technology group are considered, and estimated emission changes are presented in both tabular and graphical form.

Based on the trends established in these individual analyses, an overall model is formulated for emission adjustment factors as a function of ambient temperature, RVP, and fuel oxygen content. A complete statistical analysis, including the development of the new correction factor equations for CO, NOx, and HC emissions by FTP phase, is presented in Section 5.

The analysis reported here was conducted using the general linear models procedure (PROC GLM) of the Statistical Analysis System (SAS) to fit general linear models involving temperature, RVP, and oxygen content to exhaust emissions. In some instances, an alternative SAS regression package (PROC REG) was used when it was desired to produce datasets containing residuals, predicted values, and confidence limits. Conventional regression techniques were used to fit and evaluate models in order to test the statistical significance of differing formulations and to conduct tests on whether terms differed significantly by technology group or vehicle type. The logarithm of exhaust emissions was used in all cases as the dependent variable.

Because the purpose of the analysis is to measure the response of vehicles to temperature, RVP, and oxygen content, a statistical technique known as absorption was used to remove the effect of varying emissions levels by vehicle. This technique is numerically equivalent to including dummy variables in the model to represent the mean emission levels of N-1 vehicles, but it is generally easier to specify such models using absorption. If emissions data on vehicles with varying emission levels are pooled for analysis without absorption or the use of dummy variables, the estimated response coefficients will often be dominated by the vehicles with the highest emissions levels. That is, in cases where the response is proportional to a base emission level, high emission vehicles will tend to show large responses and will create an upward bias in the response coefficients that are estimated.

Unlike the fitting of dummy variables, absorption removes the effect of varying emission levels by first normalizing all data (both dependent and independent variables) to remove the corresponding mean values for each vehicle. That is, log emissions ln(E) is replaced by the logarithm of the emissions ratio $\ln(E/E_0)$ relative to the mean emissions level E_0 for the vehicle, ambient temperature is replaced by the deviation of temperature from the average temperature for each vehicle, and RVP and oxygen content are similarly replaced by their deviations from the mean. As a result, the data are cast in the form of deviations from a reference point for each vehicle that has been removed from the data. When the resulting normalized data are pooled in the analysis, each vehicle is given equal weight in estimating the response coefficients. This choice of reference point (the mean values) is mathematically equivalent to any other choice of reference point, such as the vehicle emission level at FTP conditions.

The varying emission levels of the individual vehicles are by far the largest contributor to the total variance in the data. PROC GLM counts this contribution to the sum of squares reduction in computing the regression R^2 statistic, as does PROC REG count the sum of squares reduction due to dummy variables for vehicles. As a result, all of the regression models fit in this analysis approach or exceed R^2 values of 0.90. R^2 is at best a simplistic measure of goodness-of-fit in regression modeling and, in this case, where all R^2 values are very high, it is of little utility. As a result, R^2 statistics are not reported in the discussion of the statistical results.

4.5 Analysis of Oxygenate Effects on CO Emissions

The starting point for the analysis is the examination of oxygenate effects on CO emissions. Tests at FTP conditions of 75°F and RVP 9 on Fuels 3, 1, and 4 (E0, E10, and E20, respectively) were selected to isolate the effect of oxygenation from changes in RVP or ambient temperature. While the fuels are described by their nominal ethanol content, the actual measured oxygen content is used as the independent variable. Values given as "percent CO reductions per percent" refer to percent oxygen content.

For reference, the MOBILE6.2 adjustment factors for Tier 1 and later vehicles use these values:

- Normal emitters: no effect from oxygenate.
- High emitters: -5.3 percent per percent oxygen.

None of the vehicles in this project would be classified as high emitters (defined as CO emissions exceeding 3 times the 50,000 mile CO standard), with Vehicle 2 being closest to a high emitter at 2 times the 50,000 mile standard. As a result, the analysis can determine the emissions effect of oxygenation for normal emitters only.

The analysis of oxygenate effects uses a log emissions model to estimate the sensitivity of CO emissions to oxygen content by vehicle technology group and FTP test phase. The regression model is of the mathematical form:

$$\ln[CO \cdot (OxPct)/CO_0] = C_1 \cdot OxPct \qquad \text{(Eq. 4-1)}$$

where OxPct is the oxygen content stated as a weight percent (not decimal fraction). The model assumes a linear response of CO emissions to oxygen content, and CO_0 is the CO emissions at FTP conditions of 75°F, RVP 9, and E0. The model is fit in log space as a simple equation of the form $Y = A + B \cdot OxPct$, and the reference emissions level CO_0 is computed from the regression intercept A.

The results of the analysis are summarized in Table 4-2, which shows the estimated coefficient C_1, along with standard errors and significance levels, and two measures of the oxygenate effect:

- The estimated reduction in CO emissions at 3.7 percent oxygen content typical of E10 gasoline; and

- The estimated percent change in CO emissions per percent oxygen content.

Estimates reported with prob>|t| of 0.05 or less are statistically significant at a 95 percent confidence level or better, while estimates with prob>|t| in the range 0.10 to 0.05 can be accepted as being statistically significant at reduced confidence levels (in the range of 90 to 95 percent).

As seen clearly in Table 4-2, an oxygenate effect is present in all technology groups and FTP phases, with CO emissions declining with increasing oxygen content. The magnitude of the effect is also relatively consistent (within the error of the estimates) across technology groups and FTP phases, with CO emissions being reduced in most instances by 5 to 9% per percent oxygen content. The observed oxygenate effect is

Table 4-2 **Effect of Fuel Oxygen Content on CO Emissions** (FTP Conditions of 75°F, RVP 9)							
Vehicle Group	N	FTP Phase	lnCO Model (E0, E10, E20)			CO Benefit For E10	Percent CO Change per % Oxygen
			C_1	Std Err	Prob >|t|		
All	15	Composite	-0.072	0.012	0.0001	-23%	-6%
		Bag 1	-0.054	0.009	0.0001	-18%	-5%
		Bag 2	-0.198	0.052	0.0003	-52%	-14%
		Bag 3	-0.084	0.042	0.0497	-27%	-7%
1	3	Composite	-0.079	0.022	0.0037	-25%	-7%
		Bag 1	-0.064	0.014	0.0006	-21%	-6%
		Bag 2	-0.117	0.027	0.0012	-35%	-10%
		Bag 3	-0.049	0.032	0.1608	-16%	-4%
2	5	Composite	-0.076	0.024	0.0054	-25%	-7%
		Bag 1	-0.044	0.011	0.0010	-15%	-4%
		Bag 2	-0.248	0.102	0.0244	-60%	-16%
		Bag 3	-0.099	0.040	0.0218	-31%	-8%
3	3	Composite	-0.047	0.008	0.0001	-16%	-4%
		Bag 1	-0.043	0.012	0.0035	-15%	-4%
		Bag 2	-0.103	0.052	0.0747	-32%	-9%
		Bag 3	-0.065	0.045	0.1796	-21%	-6%
4	4	Composite	-0.080	0.029	0.0137	-26%	-7%
		Bag 1	-0.068	0.027	0.0232	-22%	-6%
		Bag 2	-0.267	0.145	0.0828	-63%	-17%
		Bag 3	-0.107	0.148	0.4795	-33%	-9%

generally as large as, or larger than, the -5.3% per percent oxygen effect used in MOBILE6.2 for high emitters, and it obviously exceeds the MOBILE6.2 assumption of no effect for normal emitters.

The oxygenate effect is statistically significant for the FTP Composite, Bag 1, and Bag 2 tests, both overall (all vehicles) and in all technology groups, in spite of low CO emission levels for Groups 1 and 2 and very low CO emission levels for Groups 3 and 4. For Bag 3, the effect is statistically significant overall and for Group 2 vehicles. The effect appears to be present in other technology groups, but fails the test of statistical significance in those groups at conventionally accepted levels of statistical significance.

Figure 4-2 presents bar charts by FTP phase and vehicle technology group that are similarly scaled on the vertical axis to facilitate a visual comparison of the trends. The bars are shown below the zero line to emphasize that the oxygenate effect reduces CO emissions. Error bars (vertical lines) are shown in the graphs as ± 1 standard errors (σ);

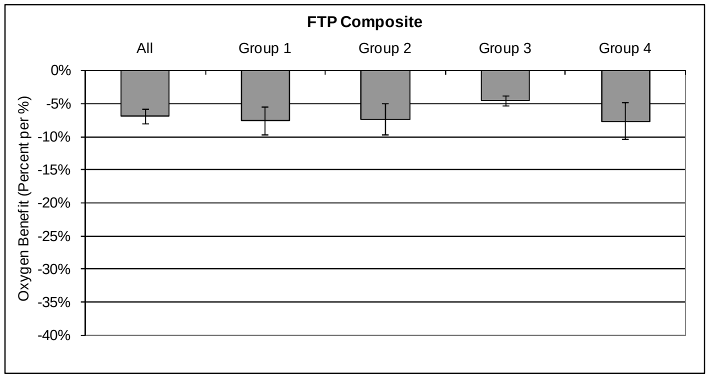
the 95 percent confidence limits would be twice as wide. An approximate test of the significance of observed differences can be based on these 1 σ error bars: two estimates are not significantly different if their 1 σ error bars overlap.

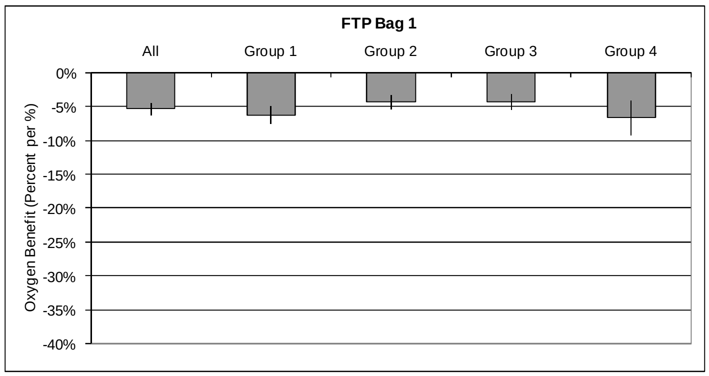
As seen in Figure 4-2, the oxygenate effect is smaller (in percentage terms) in Bag 1 than in Bag 2. The Bag 1 to Bag 2 difference is statistically significant, and this is true in all four technology groups. The effect in Bag 3 appears to be intermediate in size between Bags 1 and 2, but the error bars are generally large enough that it is not statistically different from the Bag 1 effect.

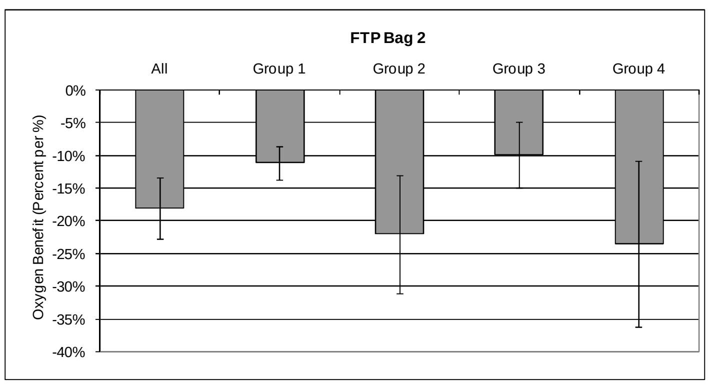
The oxygenate effect is very consistent across technology groups. Depending on the FTP phase, the graphs may suggest that the Group 4 vehicles have a somewhat smaller effect than other technology groups. However, formal tests for the existence of technology-related differences find no evidence that the oxygenate effect (by Phase) differs among the four primary technology groups, among exhaust or evaporative technology groups, or between passenger cars (PC) and light-duty trucks (LDT). The oxygenate effect appears to be homogenous with respect to vehicle technology, in spite of the progressively lower levels of CO emissions of newer vehicles.

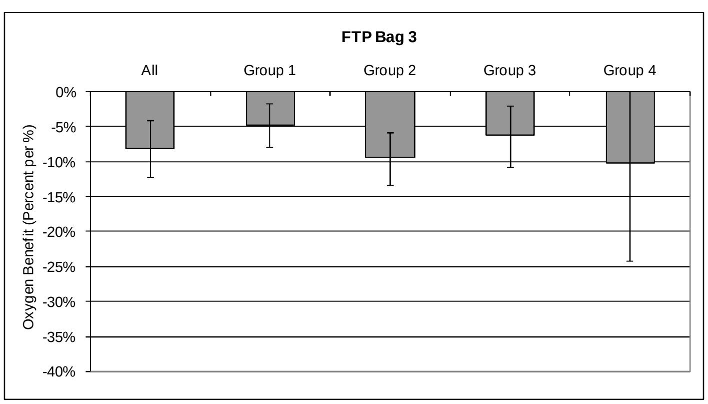
The key conclusions of this analysis are that the data indicate clearly a substantial oxygenate effect in late-model motor vehicles (at least at the FTP conditions of 75°F and RVP 9), and that its magnitude appears to be consistent across the vehicle technology groups. The oxygenate effect varies by FTP phase, ranging from about -5% per percent oxygen in Bag 1, to -14% per percent oxygen in Bag 2, and to -7% per percent oxygen in Bag 3. As will be seen in the following sections, the emissions data obtained with the oxygenated fuels used in the RVP testing at both 50°F and 75°F support these conclusions.

Figure 4-2
Oxygenate Effect by FTP Phase and Technology for RVP 9 Fuels at 75°F





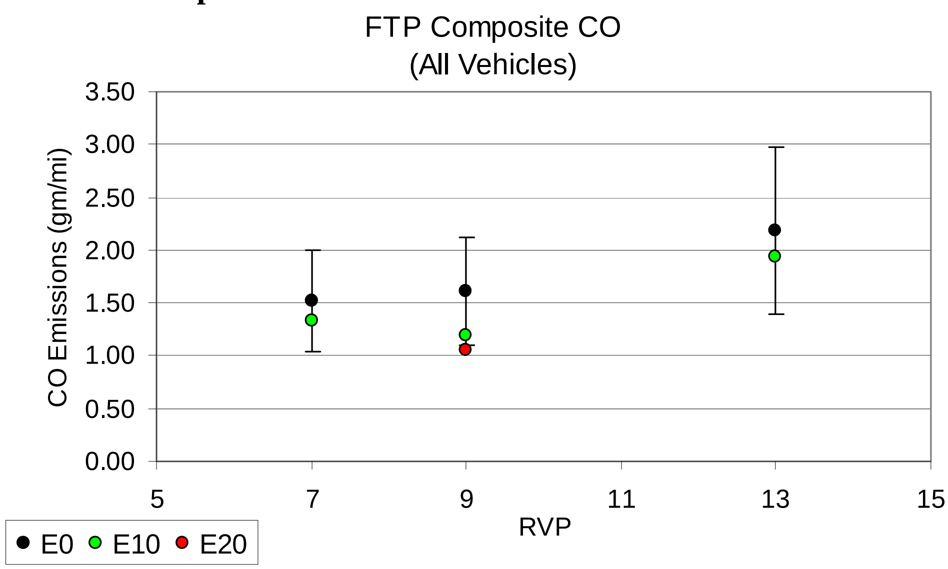




4.6 Analysis of RVP Effects Between 7 and 9 psi at 75°F

A previous study of RVP effects on CO emissions based on CRC research* using vehicle certification data concluded, "Fuel volatility increases between 7 RVP and 9 RVP have little effect on CO emissions at 75°F. This is consistent with the MOBILE6 model, because the MOBILE model predicts CO increases only at volatilities above 9 RVP." As suggested by Figure 4-3, and supported by the analysis in this section, the data from this project are consistent with the conclusion of the earlier study. It is possible that a small CO emissions increase occurs between 7 and 9 RVP, but the magnitude of such increase (if it exists) is small compared to the normal variation in the test data. The data from this project show no statistically significant evidence that CO emissions increase between 7 and 9 RVP.

Figure 4-3
Example of CO Emissions Trends with RVP at 75°F



Note: The error bars are ± 1 standard error ranges.

An analysis was conducted of CO emission changes between 7 and 9 RVP using five fuels tested at 75°F, including Fuels 6 (E0) and 7 (E10) and Fuels 3 (E0), 1 (E10), and 4 (E20). The analysis uses a log emissions model to estimate the sensitivity of CO emissions to RVP changes by vehicle technology group and FTP test phase at 75°F:

$$\ln[CO \cdot (RVP)/CO_0] = C_{RVP} \cdot (RVP - 9) + C_1 \cdot OxPct \qquad \text{(Eq. 4-2)}$$

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*_Examination of Temperature and RVP Effects on CO Emissions in EPA's Certification Database_. Final Report CRC Project No. E-74a. Prepared by Air Improvement Research, Inc., Novi, Michigan. April 2005.

where RVP is in units of psi and OxPct is the fuel oxygen content as a weight percent (not decimal fraction).* CO_0 is the CO emissions at FTP conditions of 75°F, RVP 9, and E0. This model assumes a linear response of CO emissions to variation in RVP at a constant ambient temperature of 75°F. The actual measured RVP value is used as the independent variable, not the nominal RVP level planned in the experimental design. The OxPct term is included as a control for the oxygenate effect in three of the fuels. While the oxygenate effects are displayed graphically, the estimated C_1 coefficients are not tabulated.

Table 4-3 summarizes the effect of increasing RVP from 7 to 9 at 75°F and E0. In general, the analysis is unable to detect a meaningful effect on CO emissions with an acceptable degree of statistical confidence. For Groups 1 and 2, the analysis estimates a small CO emission decrease at 7 RVP in some cases, ranging from reductions of 7 to perhaps as much 20%. In other cases, however, the analysis estimates a CO emission increase, and none of the estimates reach a conventionally accepted level of statistical significance. For Groups 1 and 2, only two of the estimates could be considered weakly

Table 4-3
Effect of Low Gasoline RVP on CO Emissions
(FTP Conditions of 75°F)

Vehicle Group	N	FTP Phase	lnCO Model (RVP 7-9, E0, E10, E20)			CO Benefit For RVP 7 Gasoline
			C_{RVP}	Std Err	Prob >|t|	
All	15	Composite	0.018	0.027	0.51	7%
		Bag 1	-0.019	0.024	0.41	-7%
		Bag 2	0.321	0.145	0.03	262%
		Bag 3	-0.110	0.122	0.37	-35%
1	3	Composite	-0.017	0.043	0.70	-7%
		Bag 1	-0.062	0.033	0.09	-22%
		Bag 2	0.071	0.088	0.44	33%
		Bag 3	-0.051	0.038	0.22	-18%
2	5	Composite	0.086	0.046	0.08	41%
		Bag 1	0.000	0.030	0.99	0%
		Bag 2	0.756	0.343	0.04	1961%
		Bag 3	0.085	0.082	0.31	41%
3	3	Composite	0.000	0.029	0.99	not measurable
		Bag 1	0.000	0.032	0.99	not measurable
		Bag 2	0.066	0.129	0.62	not measurable
		Bag 3	-0.007	0.123	0.96	not measurable
4	4	Composite	-0.027	0.078	0.73	not measurable
		Bag 1	-0.026	0.075	0.73	not measurable
		Bag 2	0.157	0.311	0.62	not measurable
		Bag 3	-0.474	0.443	0.30	not measurable

*As before, the model is fit in log space as a simple equation of the form Y = A + B · OxPct, and the reference emissions level CO_0 is computed from the regression intercept A.

significant (Group 1 Bag 1, and Group 2 Composite). For Groups 3 and 4, the confidence level of the estimates is so low that the CO benefit is reported as being not measurable. Only the estimate for Group 2 Bag 2 reaches the 95% confidence level in significance, and this result gives an implausibly large emissions effect. (This result is also responsible for the Bag 2 estimate for all vehicles showing a comparably large and implausible emissions effect.)

A review of the individual test data strongly suggests that one vehicle is primarily responsible for this outcome, although no formal outlier test was performed given the exploratory nature of the analysis in this section. Vehicle 7 produced CO emissions of 0.82 g/mile when tested at FTP conditions (RVP 9, E0) and 0.09 g/mile and 0.00 g/mile when tested on E10 and E20 fuels at 9 RVP. Both of its tests at 7 RVP reported CO emissions of 0.00 g/mile. As a result, the change from 7 to 9 to RVP (at zero oxygen content) is associated with a 100% reduction in CO emissions. Other vehicles showed CO emission changes ranging from -18% to +19% in the same circumstances. It is unknown whether the specific test results for Vehicle 7 represent a marked sensitivity to RVP (and fuel oxygenation) or reflect a change in vehicle condition after the baseline test on Fuel 3. However, it is clear that the apparent response to reduced RVP is not characteristic of the other vehicles. The implausible result for Group 2 Bag 2 has been discounted for the purposes of this section, but Vehicle 7 has been retained in the dataset. In the analysis of the following section, Vehicle 7 is shown to have a response to RVP 7 fuel that is both statistically significant and different from the responses of other vehicles, which fail to reach the threshold of statistically significance.

In all other respects, there is no evidence in the dataset that RVP changes between 7 and 9 RVP have statistically significant effects on CO emissions at 75°F, although the presence of an RVP effect smaller than the normal test variation cannot be ruled out. This conclusion is true whether vehicles are pooled to increase the sample size for analysis or divided into technologically homogenous groups. These trends are illustrated in the bar charts of Figure 4-4, which is individually scaled on the vertical axis to display the estimates for each FTP phase. Error bars (vertical lines) represent ± 1 standard error (σ); the 95% confidence limit of the estimates would be twice as wide. Two estimates are not significantly different if their 1 σ error bars overlap (approximately).

On the other hand, the dataset indicates the presence of an oxygenate effect for 7 and 9 RVP fuels in each FTP phase and vehicle technology group. The observed oxygenate effect at 7 RVP varies in magnitude by FTP phase and is present across all technology groups (if not always statistically significant). These trends are illustrated in the bar charts of Figure 4-5, which is scaled on the vertical axis to facilitate a visual comparison of the trends. Error bars (vertical lines) are shown as ± 1 standard error (σ); the 95 percent confidence limit of the estimates would be twice as wide. Two estimates are not significantly different if their 1 σ error bars overlap (approximately).

Figure 4-4
7 RVP Effect by FTP Phase and Technology
at 75°F Compared to 9 RVP Fuels

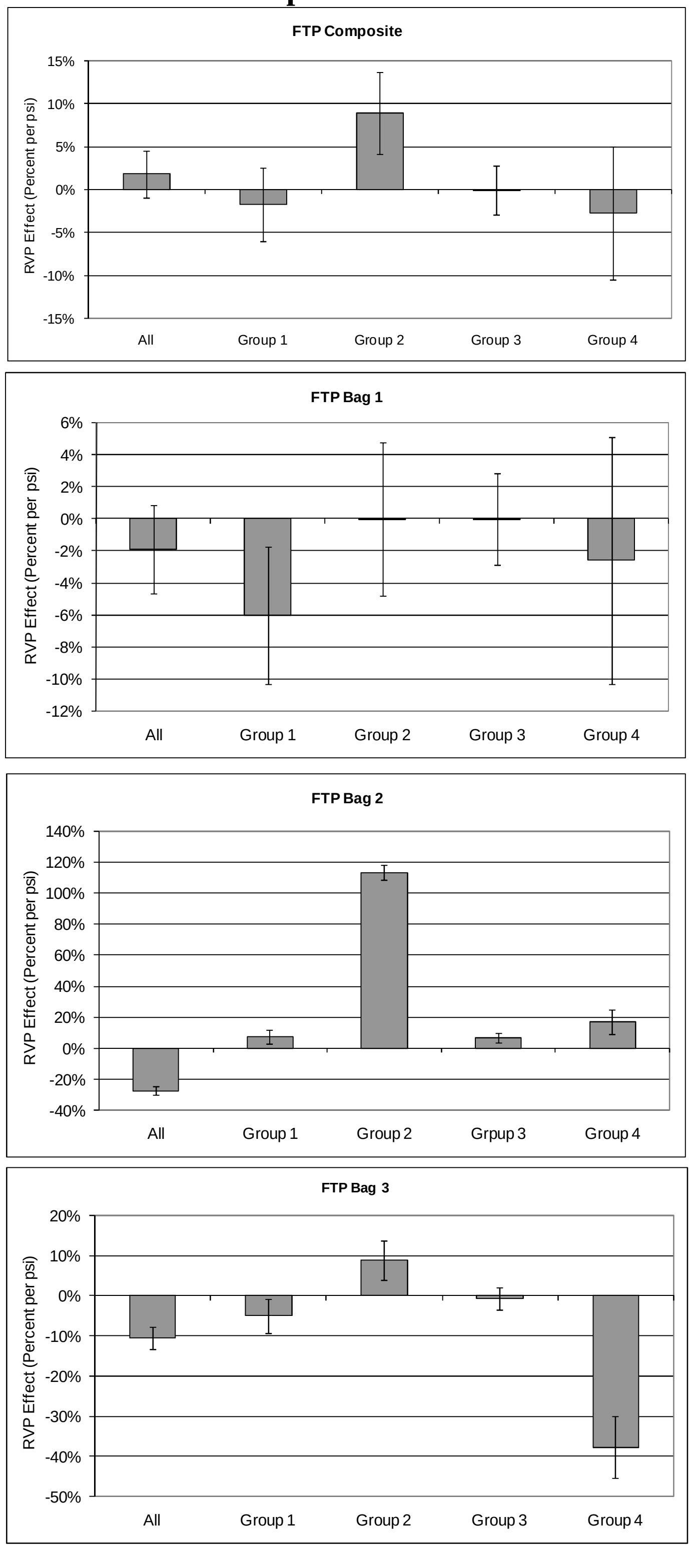
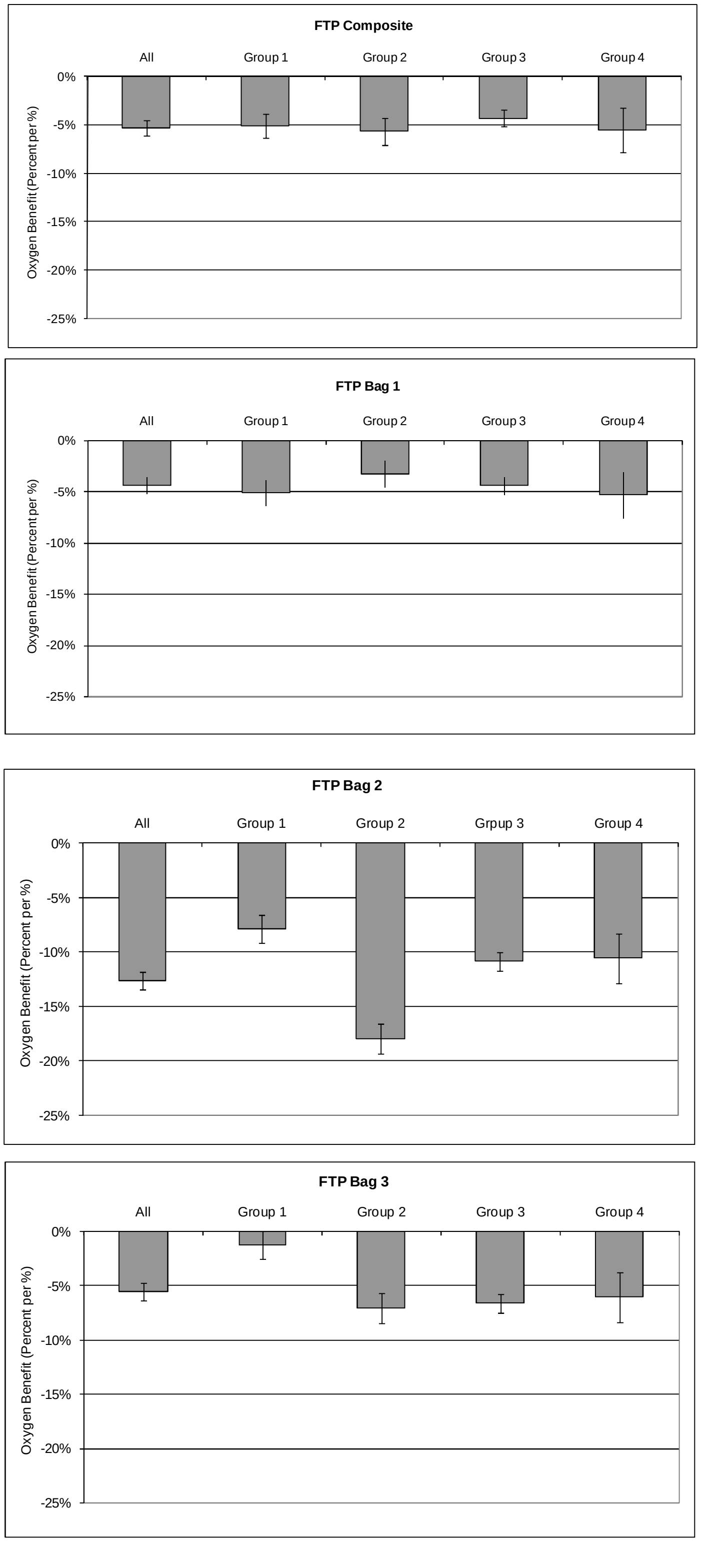


Figure 4-5
Oxygenate Effect by FTP Phase and Technology for RVP 7 to 9 Fuels at 75°F



4.7 Analysis of the Effect of Increasing RVP from 9 psi to 13 psi at 75°F

Another RVP analysis was conducted at 75°F using the test data for the three Fuels 3, 1, and 4 (E0, E10, E20, respectively) at 9 RVP and the two Fuels 5 and 2 (E0 and E10, respectively) at 13 RVP. The analysis uses the log emissions model described previously to estimate the sensitivity of CO emissions to RVP changes by vehicle technology group and FTP test phase. The model is of the form:

$$\ln[CO \cdot (RVP)/CO_0] = C_{RVP} \cdot (RVP - 9) + C_1 \cdot OxPct \qquad \text{(Eq. 4-3)}$$

where RVP is in units of psi and OxPct is a wt percent oxygen content (not decimal fraction).* CO_0 is again the CO emissions at FTP conditions of 75°F, 9 RVP, and E0. As before, the actual measured RVP value is used as the independent variable, and the OxPct term is included as a control for the oxygenate effect in three of the fuels.

The results of the analysis show that as RVP increases from 9 psi to 13 psi, increases in CO emissions are observed. In addition, the data again demonstrate the presence of a oxygenate effect in all FTP Phases and for all vehicle technology groups.

For reference, MOBILE6.2 CO uses the following factors to adjust CO emissions for RVP levels about 9 psi for vehicles certified to Tier 1 and more stringent standards:

Bag 1: +4.2 percent per psi
Bag 2: +30.0 percent per psi
Bag 3: +26.1 percent per psi

Table 4-4 summarizes the results of the analysis. For Groups 1 and 2, increasing RVP from 9 to 13 at 75°F consistently increases CO emissions by amounts on the order of 5% per psi in Bag 1, 10 to 35% per psi in Bag 2, and 15 to 20% in Bag 3. These estimated RVP effects are comparable in magnitude to those assumed in MOBILE6.2 for Bag 1, but are somewhat smaller in magnitude than the MOBILE6.2 effects for Bags 2 and 3. The RVP effects are statistically significant at the 95 percent confidence level (or better) for Group 1 vehicles, but are both smaller and of weaker significance for Group 2 vehicles.

For Groups 3 and 4, the estimated RVP effect is always smaller than for Groups 1 and 2 and is of inconsistent algebraic sign (positive and negative), with the one exception of the Bag 2 effect in Group 4. All of the estimated effects display such poor statistical significance that they are reported as not measurable. The best level of significance achieved in any bag for Groups 3 and 4 could still occur by chance with a probability of nearly 1 in 3 (28%). No one vehicle (or subset of vehicles) appears to be responsible for this outcome. Instead, the variance in the data is simply large enough that, at the low emission levels of these vehicles, there is no statistical significance to the estimated effects.

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*As before, the model is fit in log space as a simple equation of the form $Y = A + B \cdot OxPct$, and the reference emissions level CO_0 is computed from the regression intercept A.

Table 4-4
Effect of High Gasoline RVP on CO Emissions
(FTP Conditions of 75°F)

Vehicle Group	N	FTP Phase	lnCO Model (RVP 9-13, E0-E20)			CO Impact of 13 RVP Gasoline	Percent CO Change per Psi
			C_{RVP}	Std Err	Prob >|t|		
All	15	Composite	0.062	0.015	0.000	28%	6.4%
		Bag 1	0.024	0.012	0.054	10%	2.5%
		Bag 2	0.146	0.073	0.052	79%	15.7%
		Bag 3	0.053	0.061	0.385	24%	5.5%
1	3	Composite	0.080	0.021	0.003	38%	8.3%
		Bag 1	0.041	0.016	0.026	18%	4.2%
		Bag 2	0.085	0.031	0.021	41%	8.9%
		Bag 3	0.113	0.033	0.007	57%	12.0%
2	5	Composite	0.099	0.028	0.002	49%	10.4%
		Bag 1	0.017	0.016	0.320	7%	1.7%
		Bag 2	0.221	0.141	0.134	142%	24.8%
		Bag 3	0.140	0.049	0.010	75%	15.0%
3	3	Composite	0.005	0.011	0.688	not measurable	
		Bag 1	-0.006	0.018	0.725	not measurable	
		Bag 2	0.035	0.078	0.662	not measurable	
		Bag 3	-0.039	0.067	0.572	not measurable	
4	4	Composite	0.046	0.041	0.280	not measurable	
		Bag 1	0.044	0.039	0.272	not measurable	
		Bag 2	0.180	0.209	0.403	not measurable	
		Bag 3	-0.031	0.220	0.891	not measurable	

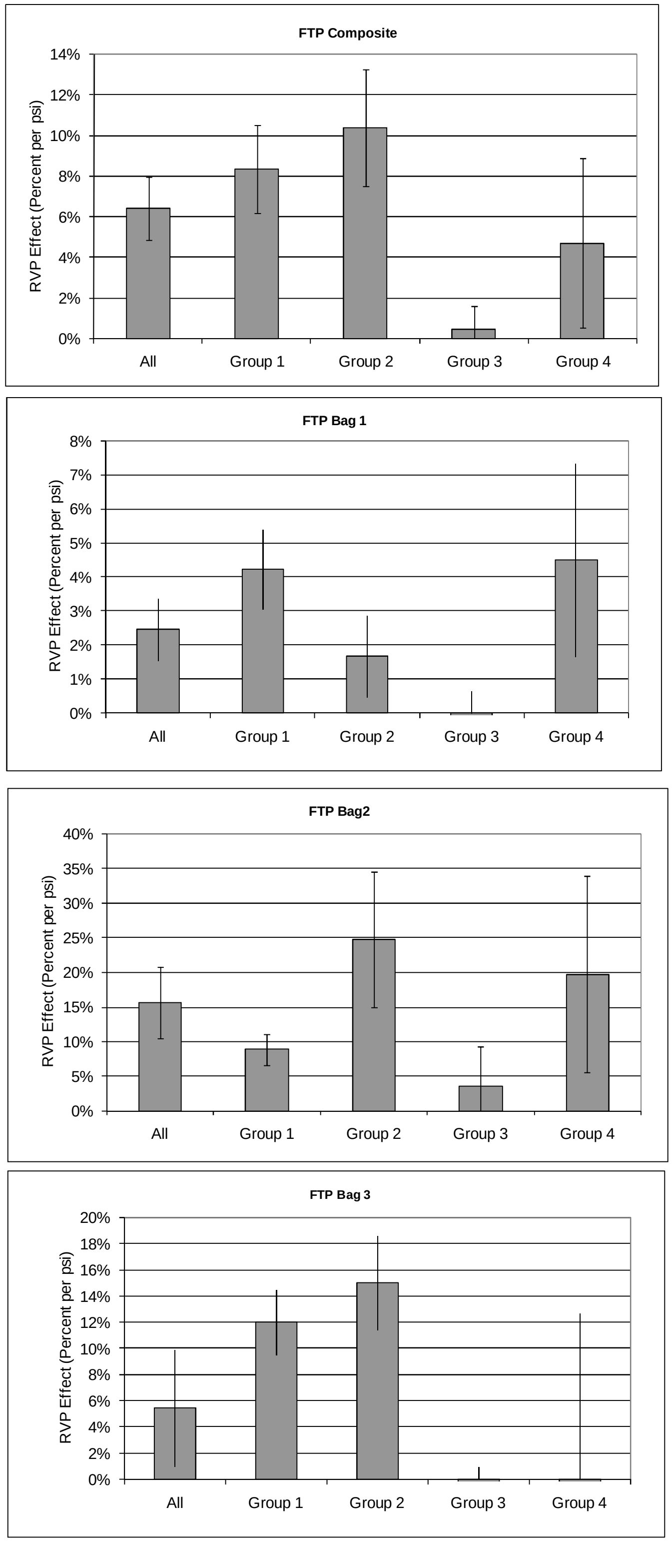
Figure 4-6 shows the trend in RVP effects by FTP phase and technology group in the format used in prior sections to facilitate the visual comparison of trends by FTP phase and vehicle technology group. Error bars (vertical lines) are shown as ± 1 standard errors (σ); the 95 percent confidence limit of the estimates would be twice as wide. Two estimates are not significantly different if their 1 σ error bars overlap (approximately).

The key conclusions to draw for increasing RVP from 9 to 13 psi at 75°F are as follows:

- A statistically significant RVP effect exists in Groups 1 and 2. This is of comparable size (or perhaps somewhat smaller, depending on FTP phase) to the effect assumed in MOBILE6.2 An effect may not exist in Groups 3 and 4, or it may be too small to detect with acceptable statistical significance.

- For Groups 1 and 2, the RVP effect is smaller in Bag 1 than in Bag 2. The Bag 3 effect appears to be intermediate in magnitude, but may not be significantly different from the values in the other Phases.

Figure 4-6
Impacts of 13 RVP Fuel by FTP Phase and Vehicle Group at 75°F Relative to 9 RVP Fuel



Formal tests for differences by technology indicate that Groups 1 and 2 can be combined for the estimation of RVP effects. The formal tests find no evidence that RVP effects at 75°F differ by evaporative control technology or between PCs and LDTs for vehicles in Groups 1 and 2.

Figure 4-7 shows the effect of fuel oxygenation on CO emissions that was estimated in conjunction with the RVP effect. The sizes of the effect by FTP phase are similar (within the error bars of the data) to those seen in 9 RVP fuels in the prior analysis. Formal tests for whether the RVP effect varies by technology indicate that no such differences can be detected, whether by exhaust or evaporative control technology or between PC and LDT.

4.8 Analysis of Impact of Increasing RVP from 9 psi to 13 psi at 50°F

The effect of RVP and oxygen content at 50°F was assessed using a regression model of the form found in Eq. 4-3. However, the CO_0 term in the equation is now measured relative to CO emissions at 50°F, 9 RVP, and E0. Put another way, the underlying effect of cold ambient temperature on CO emissions is incorporated in the baseline CO value.

Table 4-5 summarizes the results of the RVP analysis at 50°F. There is evidence that increasing RVP from 9 to 13 psi reduces CO emissions in Bag 1. This effect is highly significant when all vehicles are grouped together, and the RVP coefficient has a consistent (negative) sign in all technology groups, even when not statistically significant.

In the other FTP phases, increasing RVP from 9 to 13 at 50°F may have small upward effects on CO emissions, but the result is at best of weak statistical significance. Groups 3 and 4 show directionally similar results, of similar or smaller magnitude, but the results fail to reach an acceptable level of statistical significance. An effect may well be present, but it may be difficult to detect at the low emission levels of these vehicles.

Figure 4-7
Oxygenate Effects by FTP Phase and Technology
9 to 13 RVP Fuels at 75°F

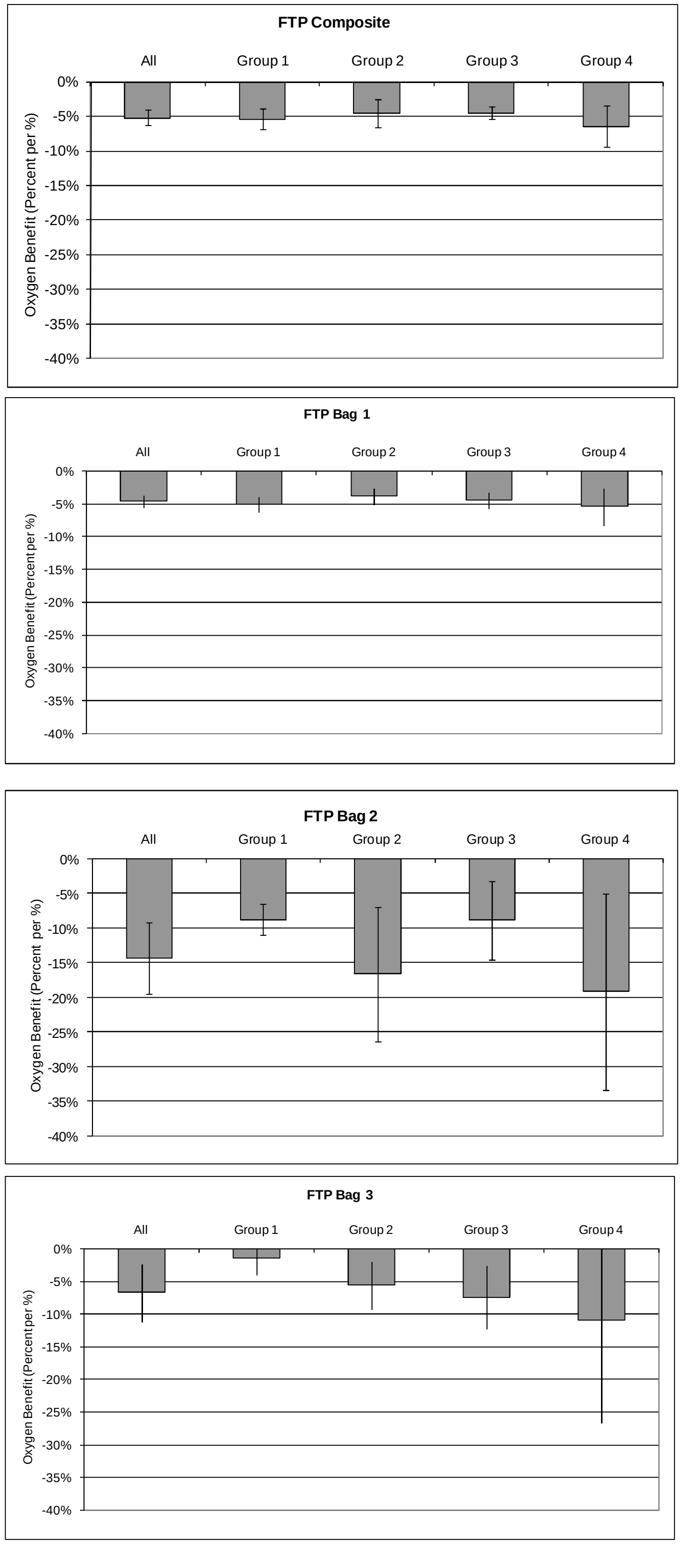


Table 4-5 **Effect of High Gasoline RVP on CO Emissions** (Cold-Ambient Temperature of 50°F)							
Vehicle Group	N	FTP Phase	lnCO Model (RVP 9-13, E0-E20)			CO Impact of 13 RVP Gasoline	Percent CO Change per psi
			C_{RVP}	Std Err	Prob >|t|		
All	15	Composite	-0.026	0.016	0.107	-10%	-2.6%
		Bag 1	-0.020	0.018	0.009	-8%	-2.0%
		Bag 2	0.038	0.038	0.374	16%	3.9%
		Bag 3	0.032	0.072	0.663	13%	3.2%
1	3	Composite	0.004	0.024	0.873	2%	0.4%
		Bag 1	-0.008	0.023	0.732	-3%	-0.8%
		Bag 2	0.075	0.034	0.050	35%	7.8%
		Bag 3	0.007	0.025	0.778	3%	0.7%
2	5	Composite	-0.016	0.022	0.472	-6%	-1.6%
		Bag 1	-0.070	0.018	0.001	-24%	-6.7%
		Bag 2	0.043	0.065	0.519	19%	4.4%
		Bag 3	0.040	0.024	0.115	17%	4.0%
3	3	Composite	-0.032	0.023	0.195	-12%	-3.1%
		Bag 1	-0.048	0.027	0.104	-17%	-4.7%
		Bag 2	0.036	0.053	0.503	16%	3.7%
		Bag 3	0.067	0.077	0.405	31%	6.9%
4	4	Composite	-0.056	0.047	0.252	-20%	-5.5%
		Bag 1	-0.074	0.056	0.209	-25%	-7.1%
		Bag 2	0.005	0.135	0.971	2%	0.5%
		Bag 3	0.013	0.275	0.962	5%	1.3%

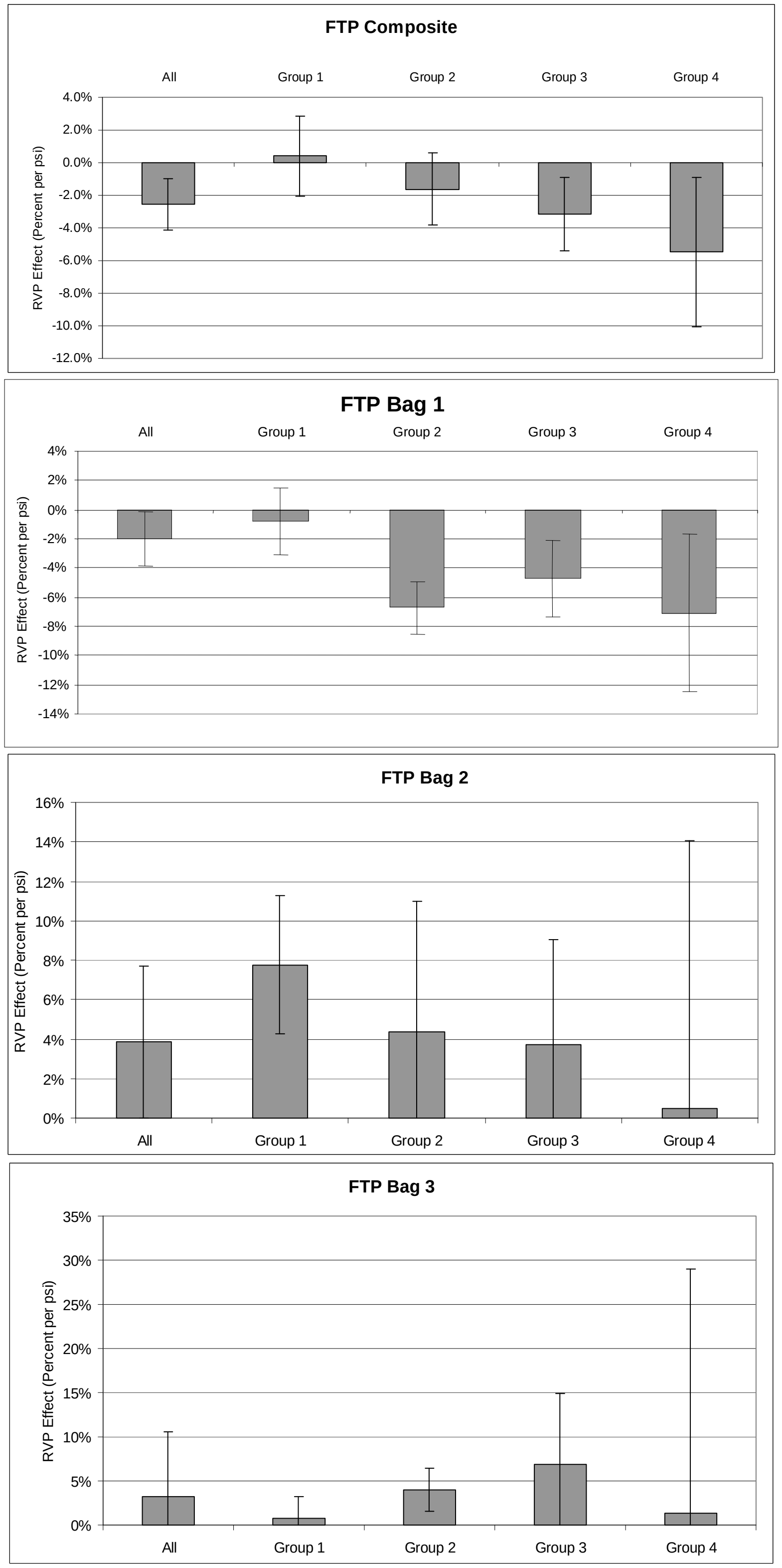
Figure 4-8 shows the trend in RVP effects by FTP phase and technology group. Error bars (vertical lines) are shown as ± 1 standard errors (σ); the 95 percent confidence limit of the estimates would be twice as wide. Two estimates are not significantly different if their 1 σ error bars overlap (approximately).

The key conclusions drawn from the RVP analysis at 50°F are as follows:

- There is clearly a reduction in Bag 1 CO emissions at low temperature resulting from increasing RVP to 13 psi. The effect appears to exist in all technology groups, although it cannot be estimated in three of them with acceptable statistical significance.

- There appears to be a consistent, but small, adverse effect on CO emissions in Bags 2 and 3, but it is too small to estimate with any degree of statistical significance using the 50°F subset of the data.

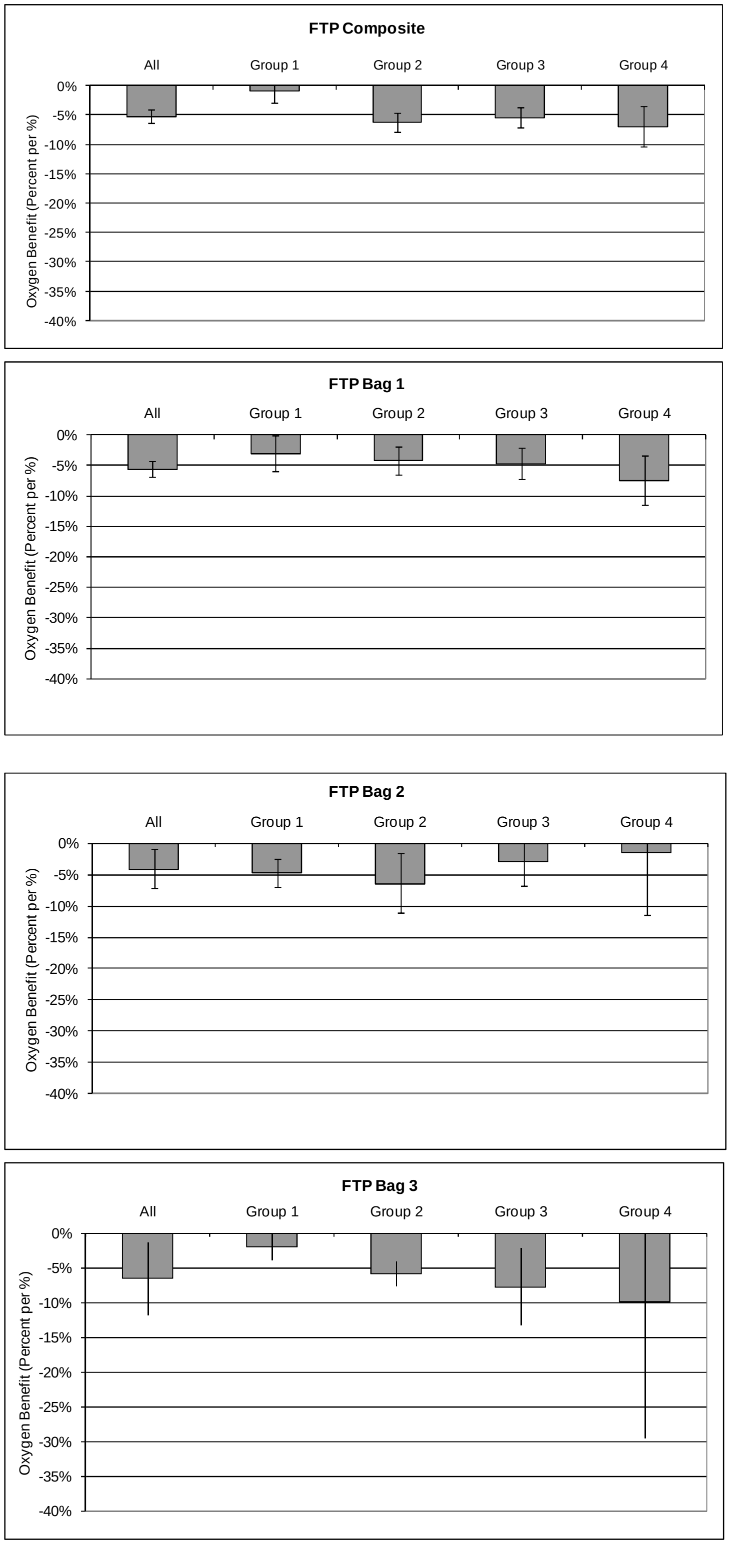
Figure 4-8
Effects of 13 RVP Fuel by FTP Phase and Technology at 50°F Relative to RVP 9 Fuels



As noted previously, Section 5 presents the results of a complete statistical analysis of the test data and uses the results of the analysis to estimate RVP correction equations as a function of ambient temperature; these correction equations account for the likely presence of a small RVP effect at 50°F.

Figure 4-9 shows the effect of fuel oxygenation on CO emissions that was estimated in conjunction with the RVP effect. The sizes of the effect by FTP phase are directionally consistent with those seen in previous sections, but of generally smaller magnitude at 50°F than at 75°F. The oxygenate effect again appears to be present and relatively consistent across all technology groups.

Figure 4-9
Oxygenate Effects by FTP Phase and Technology for 9 to 13 RVP Fuels at 50°F



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5. STATISTICAL ANALYSIS AND DEVELOPMENT OF EMISSION CORRECTION FACTORS

5.1 Overview

This section presents a statistical analysis of the E-74b THC, CO, and NOx emissions data. The results of the analysis are presented in detail and then summarized in the form of correction factor equations for use at temperatures below 75°. While subsets of the data were examined in Section 4, the analysis discussed in this section is based on all of the fuels tested in the E74-b program, with RVP values ranging from 7 to 13 psi and oxygen content ranging from E0 to E20. However, not all combinations of temperature, RVP, and oxygen content were tested. The E20 oxygenation level was tested only for RVP 9 fuels (but at both 50°F and 75°F), while the RVP 7 fuels (at E0 and E10) were tested only at 75°F.

As described below, the statistical analysis has been conducted twice to address the potential impacts of variation in T_{50} in test fuels 2 and 4 relative to the other test fuels. The primary analysis presented in Section 5.3 is based on the E-74b design variables: temperature, RVP, and oxygen content. This formulation of the analysis will include, in the coefficients estimated for the RVP and oxygen terms, the emission effects (if any) caused by variations in T_{50} for test fuels 2 and 4. The second analysis, described in Section 5.4, was conducted to test the sensitivity of the primary results by including a T_{50} term in models that are otherwise similar, except for the statistically confounded terms that must be excluded.

Lastly, the development of the correction factor equations is described and the results are compared with the correction factors incorporated into MOBILE6.2 and with correction factors previously developed by Sierra.*

5.2 Methodology

5.2.1 Mathematical Formulation

The effects of ambient temperature, RVP, and oxygen content on emissions are represented in MOBILE6.2 in the form of equations that adjust emission factors at FTP conditions to reflect emission rates at non-FTP conditions. For temperatures above 75°F,

*Heirigs, P.L., and Lyons, J.M, "Review of Current and Future CO Emissions from On-Road Vehicles in Selected Western Areas," Sierra Research Report No. SR03-01-01, January 28, 2003.

the MOBILE6.2 correction factor equations take the form of a statistical response surface, including linear terms in temperature, RVP, and oxygen content and a number of their two-way interactions. A simplified form is implemented for temperatures below 75°F.

The statistical analysis conducted here uses the most complete, second-order response surface in the design variables temperature, RVP, and oxygen content that can be estimated for the data, including all linear terms, all two-way interactions, and a quadratic term in oxygen content (the only variable tested at three levels). This formulation is very similar to that used in MOBILE6.2 for temperatures above 75°F.

The mathematical form of the general second-order response surface used here is given in Eq. 5-1:

$$\begin{aligned}\ln E = \ln E_0 &+ C_T \cdot T + C_{T,O2} \cdot T \cdot OxPct \\ &+ C_{RVP\text{-}L} \cdot RVP_L \\ &+ C_{RVP\text{-}H} \cdot RVP_H + C_{RVP\text{-}H,T} \cdot RVP_H \cdot T + C_{RVP,O2} \cdot RVP \;\; OxPct \\ &+ C_{1,O2} \cdot OxPct + C_{2,O2} \cdot OxPct^2 \qquad \text{(Eq. 5-1)}\end{aligned}$$

where: $T = T - 75°F$
$RVP_L = \min(0, RVP – 9\text{ psi})$
$RVP_H = \max(0, RVP – 9\text{ psi})$
$RVP = RVP – 9\text{ psi}$
OxPct = Oxygen content (as a weight percent, not decimal fraction)

This formulation provides separate slopes for the effect of RVP below and above 9 psi to accommodate the evidence that RVP effects differ between these regimes. One regime is that of RVP values between 7 and 9 psi in which vehicles must demonstrate compliance with federal and California certification standards. Vehicle performance in this regime is constrained by the certification process. The second regime is that of RVP values above 9 psi, in which vehicle certification does not directly constrain vehicle performance. In this regime, fuels are formulated on a seasonal basis (primarily for winter) with RVP levels selected to achieve satisfactory vehicle startup and driveability.

RVP values below 9 psi are measured by the variable RVP_L, which is zero for fuels with RVP above 9 psi. The RVP_L slope is included in the statistical models to provide a test for whether emissions differ between 7 and 9 psi. The slope is retained in all models without regard to statistical significance to distinguish emissions between the two regimes. The earlier CRC E74-a program demonstrated that there is no statistically significant difference in vehicle certification emissions between 7 and 9 psi, and the exploratory analysis in the preceding section showed that there is no statistically significant difference in in-use vehicle CO emissions in the current program. The *a priori* hypothesis is that the RVP_L slope will fail to be statistically significant.

RVP values above 9 psi are measured by the variable RVP_H, which is zero for fuels with RVP below 9 psi. The RVP_H slope is included in the model to measure the extent to which RVP values in excess of 9 psi have an effect on vehicle emissions compared to emissions at the RVP = 9 psi value used for certification. Based on prior research, the *a priori* hypothesis is that higher fuel volatility will, in some cases, have an adverse effect on HC and CO emissions at 75°F, but may have no effect, or possibly a beneficial effect, at colder temperatures. NOx emissions effects are expected to counter the HC/CO trends.

The response surface is linear with respect to T, RVP_L, and RVP_H. It includes all two-way interaction terms between the variables that can be tested, including interactions between T and RVP_H, RVP and OxPct, and T and OxPct. Because oxygen content was tested at three levels, a non-linear response surface is fit with respect to OxPct, from which the potential for changes in oxygenate response rates over the range from E0 to E20 can be evaluated. The interaction terms $T \cdot OxPct$ and $T \cdot RVP_H$ represent the potential for the oxygen and RVP effects to differ between 50°F and 75°F. The term $RVP \cdot OxPct$ represents the potential interaction of RVP and OxPct, such that the observed emissions change differs from what would be expected from the two variables alone.

The functional form of Eq. 5-1 measures temperature and RVP as departures from the FTP conditions (75°F, RVP = 9 psi, 0% oxygen content), so that the intercept term E_0 estimates emissions at FTP conditions. Because the emissions intercept term is vehicle-specific, and is either absorbed (removed from the analysis) or specified as dummy variables, it is of no direct interest in the understanding of emissions changes relative to FTP conditions. Therefore, intercept terms are not reported in the results of the analysis.

These key trends described in Section 4 for CO are incorporated, along with corresponding trends for HC and NOx, in the statistical analysis and the updated correction factor equations developed here:

- A widespread oxygenate effect in which CO emissions are reduced with increasing gasoline oxygen content by an amount that varies by FTP phase but is relatively consistent in size across technology groups. This effect may show evidence of diminishing returns for CO, in which the marginal benefit of further oxygenation decreases as oxygen content rises.

- Little or no effect on CO emissions at 75°F for fuel RVP values below 9 psi.

- An effect of increasing CO emissions with gasoline RVP between 9 and 13 psi that is substantially larger at 75°F than at 50°F. The effect varies by FTP phase and by vehicle technology group. However, the effect is restricted to RVP values in excess of 9 psi, based on the absence of statistically significant evidence for emission effects at 7 psi.

- For cold ambient temperatures (50°F), there is evidence that increasing gasoline RVP to 13 psi causes a reduction in CO emissions during Bag 1. This “cold-temperature benefit" is not detected in the other FTP phases or for the other pollutants. This effect is represented in the analysis as an RVP · T interaction that reverses sign and becomes an emissions benefit at temperatures below 75°F.

- In addition to these fuel effects, the adjustment factor analysis estimates cold-temperature emissions offsets by FTP phase for the testing at 50°F.

5.2.2 Conduct of the Analysis

5.5.2.1 Overall Fleet – The analysis was conducted in a standardized sequence for each of the 12 analysis cells formed from the intersection of pollutant (CO, HC, NOx) and FTP test phase (Composite, Bag 1, Bag 2, Bag 3). To begin the analysis for each cell, the full response surface was estimated using ordinary least squares regression analysis applied to the data for all vehicles. Its key results (coefficient estimates and p values) are reported under the heading *Full Model* in the tables found in Section 5.3. As will be seen, the second-order response surface is over-specified in general—meaning that it contains more terms than are needed to represent the trends in the data. Because many of the terms have correlations of non-negligible size, there is a tendency for the terms in the Full Model to show poor or no statistical significance. Thus, there is a need to reduce the model to include only those terms that represent meaningful and statistically significant effects.

The second stage of the analysis involved the use of stepwise regression techniques to choose among the terms in Eq. 5-1 to find those that are statistically significant. Both forward- and backward-selection techniques were used. In forward selection, one starts with a model containing only the intercept and RVP_L terms; the terms with strongest statistical significance are then added one by one until no remaining term achieves at least p=0.10. In backward selection, all terms are initially introduced in the model, and those terms not achieving p=0.10 are removed one by one until all terms remaining achieve at least p=0.10. In this, the RVP_L term is required to remain in the model. Because stepwise regression cannot be counted on to always find the "best" choice of terms, the results of the two selection methods were compared and judgment was applied in the instances where the methods disagreed. The results of the final models are reported in the tables under the heading *Reduced Model*.

An *Outlier Assessment* was conducted based on the residuals from the Reduced Model. In this assessment, the observed value for each emissions test was compared to the 99% confidence limits for the value predicted by the regression model. A "good" data point has 1 chance in 100 of lying outside the prediction confidence limits merely by chance, and in a data set of 180 tests it is likely that a few tests will do so in each instance. The tests flagged as potential outliers by this method were then examined to determine if they should be excluded from the data. Only tests substantially outside the confidence limits and appearing to diverge from the predicted trends would be excluded. After other adjustments made to the data to include certain vehicles or categories of tests (identified below), no individual tests were excluded on this basis as outliers.

<u>5.2.2.2 Technology Groups</u> – A second round of analysis was conducted to identify terms that take on different values in one or more of the four vehicle technology groups. Stepwise regression techniques were again used to select among an enlarged pool of model terms, including all of the individual terms shown in Eq. 5-1 plus additional terms that allowed the coefficients to differ in any of the four groups. The form of the Reduced Model, the form and statistical significance of terms in the technology-based models selected by stepwise regression, and analyst judgment were combined to select final *Technology Models* reported in the tables. No statistically significant differences were found for any of the four technology Groups individually, perhaps due to the small sample of vehicles in each group, but it was determined that effects sometimes displayed statistical differences when divided into two groups (Groups 1 and 2 combined, and Groups 3 and 4 combined). However, the analysis more often finds a technologically uniform response, at least when measured on a percentage basis and within the sample size limits of the dataset.

Given the form selected for the final Technology Models, the outlier analysis was repeated for individual tests, and a further analysis of residuals was conducted to determine if the emissions response to T, RVP, RVP · T, or OxPct varied to a statistically significant extent with respect to any of the following distinctions:

- By the four vehicle technology groups;
- By the three exhaust technology groups;
- By the three evaporative technology groups;
- By PC and LDT groups; or
- By individual vehicle.

The further residual analyses employed the F test to determine if there was sufficient evidence to conclude that one or more of the several (to many) levels in each distinction were different from the rest. Statistically significant differences were investigated, leading either to decisions to adjust the statistical models or to exclude divergent data until such differences were resolved. The adjustments are discussed below.

1. The FTP Bag 3 CO emissions of many vehicles are reported as 0.00 gm/mi, as a consequence of the inherently low emission levels of new vehicles that employ sophisticated exhaust and evaporative emission controls. Although the emission readings were reset to a *de minimus* level of 0.005 to permit inclusion in the log models, the response coefficients estimated for the Tier 2 Groups in the technology analysis were often weak and sometimes counter-intuitive. A decision was made to exclude all data points with FTP Bag 3 CO = 0.00 gm/mi from the Bag 3 CO analysis, reducing the number of total data points to N = 156. Bag 3 CO emissions are so low for vehicles in Groups 3 and 4 that it is doubtful whether temperature or RVP effects would be large enough to be meaningful in inventory analysis, if they could be detected with statistical significance in a larger dataset of vehicle testing.

2. The analysis of FTP Bag 2 CO emissions demonstrated that Vehicle 7 (2001 Dodge Caravan) had a distinctive response to RVP 7 fuels, as had been noted in the exploratory analysis of the prior section, in which its Bag 2 CO emissions were measured as 0.00 gm/mi on both RVP fuels. Rather than exclude the two Vehicle 7 tests from the dataset, a separate term was introduced to allow a different RVP_L response for this vehicle alone.

3. The analysis of FTP Bag 1 THC emissions indicated that the performance of Vehicle 11 (2004 Toyota Camry) was consistently different from that of other vehicles. Specifically, it had higher THC emissions at 50°F (by 25%, p=0.00) and higher emissions at 50°F on RVP 13 fuel (by 29%, p=0.03) in comparison to other Tier 2 vehicles under comparable conditions. Because the results suggest the possibility of engine or emission controls operating improperly at cold start under low ambient temperature, the data for this vehicle were dropped entirely from the analysis of the FTP Composite and Bag 1. The vehicle's data were retained for Bags 2 and 3, for which there was no indication of a significant difference compared to other vehicles.

4. FTP Bag 1 NOx emissions were found to vary significantly between PCs and LDTs with respect to the response to RVP (p=0.03) and to the interaction of RVP and temperature (p=0.03). A final technology model was fit to capture this difference in the correction factor equations. It shows that PC NOx emissions have no measurable sensitivity to RVP in FTP Bag 1, but that LDT NOx emissions are increased by a statistically significant amount when using high RVP fuel. Although FTP Composite emissions are computed from the bag-specific emissions, the PC/LDT difference for Bag 1 NOx is not detected with statistical confidence in FTP Composite NOx emissions.

Except for the adjustments itemized above, no other deletions were made for outliers. In general, the data points identified by the outlier test most often lie at low emission values, where they are flagged as potential outliers because they show large percentage differences from the log-emissions regression line. However, even large percentage differences applied to a very small emissions estimate may amount to no more than a few tenths of 1 gm/mi and, therefore, are not of substantive concern.

5.3 Statistical Analysis Results (Primary)

The results of the statistical analysis are reported in Tables 5-1 through 5-12, in a format that should be easily understood from the preceding discussion of the analysis methodology. The analysis reported in this section is the primary statistical analysis, in which only design effects are included in the model formulation. As explained previously, the presence of a much lower T_{50} temperature in two of the test fuels causes the analysis to face the problem of statistical confounding. The results of a sensitivity analysis are presented in Section 5.4 as an alternative to this primary analysis.

5.3.1 FTP Composite CO Emissions

The results of the statistical analysis for FTP Composite CO (Table 5-1) are briefly described to ensure understanding of the results shown in Tables 5-1 through 5-12. The coefficient values given in the tables pertain to the Eq. 5 model of log emissions; the corresponding percentage effect on emissions can be calculated as exp(coefficient)-1.

A first round of analysis examined the data as a whole, without consideration of technology differences. The *Full Model* section of the table reports the results for the fit of the complete second-order response surface. Of the eight possible terms (excluding the intercept), there is no evidence that the effect of oxygen content on Composite CO emissions varies with temperature (the interaction term T · OxPct). Further, there is no evidence that RVP values below 9 psi have an effect on Composite CO (the RVP term) or that the effect of oxygen content varies with respect to RVP (the RVP · OxPct term). All other terms are statistically significant at acceptable confidence levels or better.

The *Reduced Model* reports the results for the statistically significant effects once the T · OxPct and RVP · OxPct interaction terms are omitted. The RVP term is retained in the Reduced Model, even though it lacks statistical significance, to distinguish emission levels between the two RVP regimes. As shown for the outlier assessment**,** only three tests lie outside the 99% confidence intervals for the predictions of the reduced model. The number of such tests is only slightly greater than the 1.8 tests that would be expected in a sample of N=180 tests. After inspection of a graphical display of the data, no points were excluded as outliers.

The *Technology Model* section of the table reports the results of a second round of analysis to determine whether any of the terms in Eq. 5-1 vary by vehicle technology group. In the analysis, each term (including terms not found to be statistically significant in the first round of analysis) is tested for inclusion in the model in seven different forms:

- As a uniform coefficient applicable to all vehicles;
- As coefficients that differ in one or more of the four vehicle technology groups; and
- As coefficients that differ between two composite groups consisting of Groups 1 and 2 combined (Tier 1/NLEV) and Groups 3 and 4 combined (the two Tier 2 Groups).

The technology model is then built from the terms that are found to fit the data with an acceptable level of statistical significance (p=0.10 or better). Correction factor equations for use in MOBILE6.2 are derived from the technology models, as will be summarized in Section 5.5.

For FTP Composite CO, the technology analysis finds that the T and RVP effects and the RVP · T interaction differ between the composite Groups 1 and 2 and the composite Groups 3 and 4 to a statistically significant degree. Groups 3 and 4 (vehicles certified to Tier 2 exhaust emission standards) have a slightly larger temperature sensitivity (on a percentage basis), but they have a substantially smaller RVP response and a smaller RVP · T interaction term.

The oxygenate effect is found to be uniform across all technology groups and of the same size at both 50°F and 75°F ambient temperatures and at all three RVP levels. The data clearly indicate that the CO emissions benefit of oxygenated gasoline is subject to diminishing returns as the oxygen content increases beyond E10. The quadratic form $(C_1 + C_2) \cdot OxPct$ is shown to be statistically significant at the p=0.01 level or better. The maximum point (the point of maximum CO benefit) is computed by the formula:

$$OxPct_{max} = -C_1 / (2 \cdot C_2) \qquad \text{(Eq. 5-2)}$$

For the values C_1 and C_2 estimated here, the maximum benefit is reached at an oxygen content of 6.9% or E18.8. The emissions benefit of oxygenation is subject to significantly diminished returns as oxygen content is increased beyond E10. At the E10 level oxygenation is estimated to reduce FTP Composite CO emissions by 26%, but increasing oxygenation to E18.8 extends the CO reduction to only 30%.

Although the quadratic form changes direction beyond the maximum point, the analysis does not provide a definitive answer on the trend of emissions with oxygen content *beyond* the maximum point—i.e., whether emissions are constant beyond the maximum or turn back up to follow the trend of reduced benefit (increased emissions) that is predicted by the quadratic beyond the maximum point. Further, no information is available in the E74-b data for oxygen content beyond that of E20. What is clear is that oxygenation of gasoline is subject to diminishing returns as the oxygen content is increased and that oxygenation of gasoline beyond the maximum point is not likely to carry appreciable incremental emissions benefit. As a practical matter, the estimated maximum benefit should be held constant at higher oxygenation levels in applying the results of this analysis.

Because only Fuel 4 was blended with an oxygenate level of E20, the observed non-linearity in the oxygenate effect is dependent on the emission performance of Fuel 4. As indicated in Section 4, Fuel 4 was blended with a T_{50} level some 30°F below the range of the five closely controlled fuels, so that the observed non-linearity of the oxygenate effect may be due, in whole or in part, to the low T_{50} temperature of Fuel 4.

5.3.2 Summary of Statistical Analysis Results

Tables 5-1 through 5-12 summarize the results of the primary statistical analysis. With one exception, the technology models summarized in the tables are the final models from which the correction factor equations were developed. For FTP Bag 1 NOx, the test data show a clear difference in the RVP_H and $RVP_H \cdot T$ response between passenger cars (PCs) and light-duty trucks (LDTs). An expanded model was fit for the purpose of estimating PC and LDT correction factors, and its coefficients are tabulated in Section 5.4. All terms in the model achieve p=0.05 values or better.

Table 5-1
Model Summary for CO FTP Composite
(N=180, 15 Vehicles)

		Coefficient	Prob>|t|
Full Model			
	Intercept	--	--
	T (T-75)	-0.01857	0.00
	T · OxPct	0.00006	0.93
	RVP_L (RVP-9)	0.00013	1.00
	RVP_H (RVP-9)	0.07946	0.00
	RVP_H · T	0.00370	0.00
	RVP · OxPct	-0.00360	0.60
	OxPct	-0.09466	0.00
	OxPct · OxPct	0.00640	0.09
Reduced Model			
	T (T-75)	-0.01879	0.00
	RVP_L (RVP-9)	0.00001	1.00
	RVP_H (RVP-9)	0.07271	0.00
	RVP · T	0.00373	0.00
	OxPct	-0.10337	0.00
	OxPct · OxPct	0.00746	0.02
Outlier Assessment			
	Tests with $p<0.01$ [a]	3	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	-0.01315	0.00
	Groups 3+4	-0.02519	0.00
RVP_L (RVP-9)	All	-0.00025	0.99
RVP_H	Groups 1+2	0.10843	0.00
	Groups 3+4	0.03396	0.12
RVP · T	Groups 1+2	0.00474	0.00
	Groups 3+4	0.00276	0.03
OxPct		-0.10312	0.00
OxPct · OxPct [b]		0.00743	0.01

[a] Expected tests with $p<0.01$ = 1.8
[b] Asymptote for OxPct = 6.9% or E18.8

Table 5-2
Model Summary for CO FTP Bag 1
(N=180, 15 Vehicles)

		Coefficient	Prob>|t|
Full Model			
	Intercept	--	--
	T (T-75)	-0.02751	0.00
	$T \cdot OxPct$	0.00035	0.57
	RVP_L (RVP-9)	-0.03644	0.31
	RVP_H (RVP-9)	0.05231	0.01
	$RVP_H \cdot T$	0.00315	0.00
	$RVP \cdot OxPct$	-0.00717	0.25
	OxPct	-0.09410	0.00
	$OxPct \cdot OxPct$	0.00754	0.03
Reduced Model			
	T (T-75)	-0.02623	0.00
	RVP_L (RVP-9)	-0.02974	0.39
	RVP_H (RVP-9)	0.03591	0.02
	$RVP \cdot T$	0.00299	0.00
	OxPct	-0.11536	0.00
	$OxPct \cdot OxPct$	0.00950	0.00
Outlier Assessment			
	Tests with $p<0.01$ [a]	4	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	-0.02377	0.00
	Groups 3+4	-0.02896	0.00
RVP_L (RVP-9)	All	-0.02967	0.38
RVP_H	Groups 1+2	0.03599	0.02
	Groups 3+4	Same	
$RVP \cdot T$	Groups 1+2	0.00300	0.00
	Groups 3+4	Same	
OxPct		-0.11523	0.00
$OxPct \cdot OxPct$ [b]		0.00949	0.00

[a] Expected tests with $p<0.01$ = 1.8
[b] Asymptote for OxPct = 6.3% or E16.9

Table 5-3
Model Summary for CO FTP Bag 2
(N=180, 15 Vehicles)

		Coefficient	Prob>|t|
Full Model			
	Intercept	--	--
	T (T-75)	0.01718	0.20
	T · OxPct	-0.00473	0.07
	RVP_L (RVP-9)	0.33022	0.03
	RVP_H (RVP-9)	0.13600	0.11
	RVP_H · T	-0.00486	0.20
	RVP · OxPct	0.00041	0.99
	OxPct	-0.10208	0.35
	OxPct · OxPct	-0.00514	0.72
Reduced Model			
	T (T-75)	--	--
	RVP_L (RVP-9)	0.03584	0.74
	dVeh07 · RVP_L	3.32832	0.00
	RVP_H (RVP-9)	0.16848	0.00
	RVP_H · T	0.00705	0.00
	OxPct	-0.08735	0.00
	OxPct · OxPct	--	--
Outlier Assessment			
	Tests with p<0.01 [a]	6	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	--	--
	Groups 3+4	--	--
RVP_L (RVP-9)	All	0.03584	0.74
dVeh07 · RVP_L		3.32832	0.00
RVP_H	Groups 1+2	0.16848	0.00
	Groups 3+4	Same	
RVP · T	Groups 1+2	0.00705	0.00
	Groups 3+4	Same	
OxPct		-0.08735	0.00
OxPct · OxPct		n/a	

[a] Expected tests with p<0.01 = 1.8

Table 5-4 Model Summary for CO FTP Bag 3 (N = 156, excluding Tests with CO_{Bag3} = 0.000)			
		Coefficient	**Prob > |t|**
Full Model			
	Intercept	--	--
	T (T-75)	0.00307	0.66
	T · OxPct	0.00022	0.87
	RVP_L (RVP-9)	0.02292	0.76
	RVP_H (RVP-9)	0.10408	0.02
	RVP_H · T	0.00138	0.49
	RVP · OxPct	-0.01126	0.40
	OxPct	-0.10838	0.05
	OxPct · OxPct	0.00905	0.22
Reduced Model			
	T (T-75)	--	--
	RVP_L (RVP-9)	0.00248	0.97
	RVP_H (RVP-9)	0.06640	0.01
	RVP · T	--	--
	OxPct	-0.13783	0.00
	OxPct · OxPct	0.01191	0.06
Outlier Assessment			
	Tests with $p<0.01$[a]	4	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	--	--
	Groups 3+4	--	--
RVP_L (RVP-9)	All	0.02253	0.71
RVP_H	Groups 1+2	0.14635	0.00
	Groups 3+4	None	
RVP_H · T	Groups 1+2	0.00527	0.00
	Groups 3+4	None	
OxPct		-0.13279	0.00
OxPct · OxPct [b]		0.01105	0.06

[a] Expected tests with $p<0.01$ = 1.6
[b] Asymptote for OxPct = 6.0% or E16.2

Table 5-5
Model Summary for THC FTP Composite
(N = 168, excluding Vehicle 11)

		Coefficient	Prob>|t|
Full Model			
	Intercept	--	--
	T (T-75)	-0.01164	0.00
	$T \cdot OxPct$	-0.00058	0.11
	RVP_L (RVP-9)	0.00022	0.99
	RVP_H (RVP-9)	0.01679	0.15
	$RVP_H \cdot T$	0.00059	0.26
	$RVP \cdot OxPct$	-0.00075	0.83
	OxPct	-0.02045	0.18
	$OxPct \cdot OxPct$	0.00006	0.98
Reduced Model			
	T (T-75)	-0.01026	0.00
	$T \cdot OxPct$	-0.00071	0.04
	RVP_L (RVP-9)	0.01840	0.29
	RVP_H (RVP-9)	--	--
	$RVP_H \cdot T$	--	--
	OxPct	-0.02281	0.00
	$OxPct \cdot OxPct$	--	--
Outlier Assessment			
	Tests with $p<0.01$ [a]	3	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	-0.00812	0.00
	Groups 3+4	-0.01301	0.00
$T \cdot OxPct$		-0.00072	0.03
RVP_L (RVP-9)	All	0.01850	0.27
RVP_H	Groups 1+2	--	--
	Groups 3+4	--	--
$RVP_H \cdot T$	Groups 1+2	--	--
	Groups 3+4	--	--
OxPct		-0.02279	0.00

[a] Expected tests with $p<0.01$ = 1.7

Table 5-6
Model Summary for THC FTP Bag 1
(N = 168, excluding Vehicle 11)

		Coefficient	Prob>|t|
Full Model			
	Intercept	--	--
	T (T-75)	-0.01760	0.00
	T · OxPct	-0.00074	0.08
	RVP_L (RVP-9)	-0.00613	0.80
	RVP_H (RVP-9)	0.01549	0.25
	RVP_H · T	0.00080	0.19
	RVP · OxPct	-0.00087	0.83
	OxPct	-0.02842	0.11
	OxPct · OxPct	0.00069	0.76
Reduced Model			
	T (T-75)	-0.01579	0.00
	T · OxPct	-0.00092	0.02
	RVP_L (RVP-9)	0.00909	0.65
	RVP_H (RVP-9)	--	--
	RVP_H · T	--	--
	OxPct	-0.02634	0.00
	OxPct · OxPct	--	--
Outlier Assessment			
	Tests with $p<0.01$ [a]	4	
	Tests Excluded	None	
Technology Model			
T	Groups 1+2	-0.01379	0.00
	Groups 3+4	-0.01835	0.00
T · OxPct		-0.00092	0.02
RVP_L (RVP-9)		0.00919	0.64
RVP_H	Groups 1+2	--	--
	Groups 3+4	--	--
RVP · T	Groups 1+2	--	--
	Groups 3+4	--	--
OxPct		-0.02633	0.00

[a] Expected tests with $p<0.01$ = 1.7

Table 5-7 Model Summary for THC FTP Bag 2 (N=180, 15 Vehicles)			
		Coefficient	**Prob>|t|**
Full Model			
	Intercept	--	--
	T (T-75)	0.00410	0.23
	T · OxPct	-0.00079	0.24
	RVP_L (RVP-9)	0.02665	0.49
	RVP_H (RVP-9)	0.00926	0.97
	RVP_H · T	-0.00086	0.38
	RVP · OxPct	0.00177	0.79
	OxPct	0.02271	0.42
	OxPct · OxPct	-0.00510	0.16
Reduced Model			
	T (T-75)	--	--
	T · OxPct	--	--
	RVP_L (RVP-9)	0.02654	0.37
	RVP_H (RVP-9)	--	--
	RVP_H · T	--	--
	OxPct		
	OxPct · OxPct		
Outlier Assessment			
	Tests with p<0.01 [a]	1	
	Tests Excluded	None	
Technology Model			
T	Groups 1+2	--	--
	Groups 3+4	--	--
T · OxPct		--	--
RVP_L (RVP-9)	All	-0.00258	0.93
RVP_H	Groups 1+2	0.06932	0.00
	Groups 3+4	0.00230	0.02
RVP · T	Groups 1+2	--	--
	Groups 3+4	--	--
OxPct		--	--

[a] Expected tests with p<0.01 = 1.8

Table 5-8
Model Summary for THC FTP Bag 3
(N=180, 15 Vehicles)

		Coefficient	Prob>|t|
Full Model			
	Intercept	--	--
	T (T-75)	0.00613	0.02
	T · OxPct	-0.00072	0.17
	RVP_L (RVP-9)	0.00241	0.93
	RVP_H (RVP-9)	0.02259	0.18
	RVP_H · T	-0.00020	0.79
	RVP · OxPct	-0.00448	0.38
	OxPct	-0.00362	0.87
	OxPct · OxPct	-0.00135	0.63
Reduced Model			
	T (T-75)	0.00387	0.01
	T · OxPct	--	--
	RVP_L (RVP-9)	-0.00662	0.81
	RVP_H (RVP-9)	0.01942	0.03
	RVP_H · T	--	--
	OxPct	--	--
	OxPct · OxPct	--	--
Outlier Assessment			
	Tests with p<0.01 [a]	2	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	0.00039	0.01
	Groups 3+4	same	
RVP_L (RVP-9)		-0.00662	0.81
RVP_H	Groups 1+2	0.01942	0.03
	Groups 3+4	same	
RVP · T	Groups 1+2	--	--
	Groups 3+4	--	--
OxPct		--	--

[a] Expected tests with p<0.01 = 1.8

Table 5-9
Model Summary for NOx FTP Composite
(N=180, 15 Vehicles)

		Coefficient	Prob>|t|
Full Model			
	Intercept	--	--
	T (T-75)	-0.00397	0.16
	T · OxPct	-0.00069	0.22
	RVP_L (RVP-9)	-0.01120	0.73
	RVP_H (RVP-9)	0.03777	0.04
	RVP_H · T	-0.00026	0.75
	RVP · OxPct	-0.00411	0.46
	OxPct	0.01520	0.52
	OxPct · OxPct	0.00056	0.85
Reduced Model			
	T (T-75)	-0.00644	0.00
	T · OxPct	--	--
	RVP_L (RVP-9)	-0.01831	0.53
	RVP_H (RVP-9)	0.03134	0.00
	RVP_H · T	--	--
	OxPct	0.02362	0.00
	OxPct · OxPct	--	--
Outlier Assessment			
	Tests with $p<0.01$ [a]	3	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	-0.00691	0.00
	Groups 3+4	-0.00594	0.01
RVP_L (RVP-9)	All	-0.01834	0.53
RVP_H	Groups 1+2	0.03135	0.00
	Groups 3+4	same	
RVP_H · T	Groups 1+2	--	--
	Groups 3+4	--	--
OxPct		0.02361	0.00

[a] Expected tests with $p<0.01$ = 1.8

Table 5-10 Model Summary for NOx FTP Bag 1 (N=180, 15 Vehicles)			
		Coefficient	**Prob>|t|**
Full Model			
	Intercept	--	--
	T (T-75)	-0.00696	0.00
	T · OxPct	-0.00060	0.21
	RVP_L (RVP-9)	-0.01051	0.70
	RVP_H (RVP-9)	0.00833	0.58
	RVP_H · T	-0.00061	0.37
	RVP · OxPct	0.00216	0.64
	OxPct	-0.00651	0.74
	OxPct · OxPct	0.00235	0.36
Reduced Model			
	T (T-75)	-0.00974	0.00
	T · OxPct	--	--
	RVP_L (RVP-9)	-0.02198	0.38
	RVP_H (RVP-9)	0.01855	0.03
	RVP_H · T	--	--
	OxPct	0.01670	0.00
	OxPct · OxPct	--	--
Outlier Assessment			
	Tests with p<0.01 [a]	2	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	-0.01046	0.00
	Groups 3+4	-0.00896	0.00
RVP_L (RVP-9)	All	-0.02204	0.38
RVP_H	Groups 1+2	0.01857	0.03
	Groups 3+4	Same	
$RVP_{H\cdot}$ · T	Groups 1+2	--	--
	Groups 3+4	--	--
OxPct		0.01669	0.00

[a] Expected tests with p<0.01 = 1.8

Table 5-11 Model Summary for NOx FTP Bag 2 (N=180, 15 Vehicles)			
		Coefficient	**Prob>|t|**
Full Model			
	Intercept	--	--
	T (T-75)	-0.00514	0.52
	T · OxPct	0.00031	0.84
	RVP_L (RVP-9)	-0.12002	0.18
	RVP_H (RVP-9)	0.16090	0.00
	RVP_H · T	0.00191	0.40
	RVP · OxPct	-0.03218	0.04
	OxPct	0.04019	0.54
	OxPct · OxPct	0.00191	0.82
Reduced Model			
	T (T-75)	--	--
	T · OxPct	--	--
	RVP_L (RVP-9)	-0.08755	0.26
	RVP_H (RVP-9)	0.14026	0.00
	RVP_H · OxPct	-0.03448	0.01
	OxPct	0.05243	0.01
	OxPct · OxPct	--	--
Outlier Assessment			
	Tests with p<0.01 [a]	2	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	--	--
	Groups 3+4	--	--
RVP_L (RVP-9)	All	-0.07059	0.37
RVP_H	Groups 1+2	0.06209	0.03
	Groups 3+4	Same	
RVP_H · T	Groups 1+2	--	--
	Groups 3+4	--	--
OxPct		0.03110	0.01

[a] Expected tests with p<0.01 = 1.8

Table 5-12 Model Summary for NOx FTP Bag 3 (N=180, 15 Vehicles)			
		Coefficient	**Prob>|t|**
Full Model			
	Intercept	--	--
	T (T-75)	0.00669	0.22
	T · OxPct	-0.00202	0.06
	RVP_L (RVP-9)	-0.01100	0.86
	RVP_H (RVP-9)	0.05348	0.12
	RVP_H · T	-0.00011	0.94
	RVP · OxPct	-0.00726	0.50
	OxPct	0.05997	0.18
	OxPct · OxPct	-0.00605	0.30
Reduced Model			
	T (T-75)	--	--
	T · OxPct	--	--
	RVP_L (RVP-9)	-0.03790	0.47
	RVP_H (RVP-9)	0.04520	0.02
	RVP_H · T	--	--
	OxPct	0.03620	0.00
	OxPct · OxPct	--	--
Outlier Assessment			
	Tests with p<0.01 [a]	4	
	Tests Excluded	none	
Technology Model			
T	Groups 1+2	--	--
	Groups 3+4	--	--
RVP_L (RVP-9)	All	-0.03790	0.47
RVP_H	Groups 1+2	0.04520	0.02
	Groups 3+4	same	
RVP_H · T	Groups 1+2	--	--
	Groups 3+4	--	--
OxPct		0.03620	0.00

[a] Expected tests with p<0.01 = 1.5

5.4 Alternative Statistical Analysis

To assess the uncertainty introduced by the confounding of T_{50} variations with the design effects of RVP and oxygenation, an alternative statistical analysis was conducted in which the terms RVP·OxPct and $OxPct^2$ (i.e., the terms that are confounded with the variation in T50) were dropped from consideration and a T_{50} term was introduced. This change in formulation of the statistical model shifts part of the explanation of emission changes away from RVP and OxPct to the T_{50} term.

The mathematical form used in the alternative statistical analysis is given in Eq. 5-3:

$$\begin{aligned} \ln E = \ln E_0 &+ C_T \cdot T + C_{T,O2} \cdot T \cdot OxPct \\ &+ C_{RVP\text{-}L} \cdot RVP_L \\ &+ C_{RVP\text{-}H} \cdot RVP_H + C_{RVP\text{-}H,T} \cdot RVP_H \cdot T + C_{RVP,O2} \cdot RVP \cdot OxPct \\ &+ C_{1,O2} \cdot OxPct + C_{2,O2} \cdot OxPct^2 \end{aligned} \qquad \text{(Eq. 5-3)}$$

where: $T = T - 75°F$
$RVP_L = \min(0, RVP - 9\text{ psi})$
$RVP_H = \max(0, RVP - 9\text{ psi})$
$RVP = RVP - 9\text{ psi}$
OxPct = Oxygen content (as a weight percent, not decimal fraction)
$dT_{50} = T_{50} - 190°F$

The alternative statistical analysis was conducted in a manner similar to that described above, but without repeating the analysis to select statistically significant terms in each case, so that the alternative models are comparable to the primary models except for the changes introduced by the dT_{50} term. As with the primary analysis, a *Full Model* was initially estimated using the alternative formulation given above. Then, a *Reduced Model* was estimated by including a dT_{50} term with the subset of terms in Eq. 5-3 that were included in the models of the primary analysis. The dT_{50} term is retained in the Reduced Model, even though it is not statistically significant at accepted levels, to show the effect on the coefficients estimated for other terms and to demonstrate the weakness of the dT_{50} term itself. A *Technology Model* was estimated in a similar manner, retaining the technology distinctions and terms used in the primary analysis.

Tables 5-13 through 5-24 compile the statistical results of the alternative analysis in comparison to the primary analysis. Inclusion of the dT_{50} term has the effect of reducing the coefficient estimated for the RVP_H effect, while leaving the coefficients of the temperature effect and the RVP · T interaction largely unchanged. The oxygenation effect is now represented by a linear slope for the emissions change between E0 and E20, while the deviation of emissions at E20 from the linear trend is included in the dT_{50} term. The statistical weakness of the dT_{50} term suggests that the design effects of RVP and temperature are preferred representations for emission changes, even if their coefficient values are influenced by T_{50} changes.

Table 5-13
Alternative Model for CO FTP Composite
(N=180, 15 Vehicles)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	-0.01857	0.00	-0.01889	0.00
	T · OxPct	0.00006	0.98	0.00006	0.93
	RVP_L (RVP-9)	0.00013		-0.00659	0.88
	RVP_H (RVP-9)	0.07946	0.00	0.05543	0.01
	RVP_H · T	0.00370	0.00	0.00378	0.00
	RVP · OxPct	-0.00360	0.92	n/a	n/a
	OxPct	-0.09466	0.00	-0.07007	0.00
	OxPct · OxPct	0.00640	0.08	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	-0.00348	0.35
Reduced Model					
	T (T-75)	-0.01879	0.00	-0.01909	0.00
	RVP_L (RVP-9)	0.00001	1.00	-0.00752	0.85
	RVP_H (RVP-9)	0.07271	0.00	0.05565	0.01
	RVP_H · T	0.00373	0.00	0.00380	0.00
	OxPct	-0.10337	0.00	-0.06965	0.00
	OxPct · OxPct	0.00746	0.02	n/a	n/a
	dT_{50} (T_{50}–190F)	-0.01879	0.00	-0.00352	0.33
Technology Model					
T	Groups 1+2	-0.01315	0.00	-0.01344	0.00
	Groups 3+4	-0.02519	0.00	-0.02550	0.00
RVP_L (RVP-9)	All	-0.00025	0.99	-0.00749	0.84
RVP_H	Groups 1+2	0.10843	0.00	0.09161	0.00
	Groups 3+4	0.03396	0.12	0.01725	0.48
RVP · T	Groups 1+2	0.00474	0.00	0.00480	0.00
	Groups 3+4	0.00276	0.03	0.00284	0.03
OxPct		-0.10312	0.00	-0.06918	0.00
dT_{50} (T_{50}–190F)		0.00743	0.01	-0.00343	0.32

Table 5-14
Alternative Model for CO FTP Bag 1
(N=180, 15 Vehicles)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	-0.02751	0.00	-0.02795	0.00
	T · OxPct	0.00035	0.57	0.00036	0.58
	RVP_L (RVP-9)	-0.03644	0.31	-0.04108	0.29
	RVP_H (RVP-9)	0.05231	0.01	0.01944	0.31
	RVP_H · T	0.00315	0.00	0.00325	0.00
	RVP · OxPct	-0.00717	0.25	n/a	n/a
	OxPct	-0.09410	0.00	-0.06403	0.00
	OxPct · OxPct	0.00754	0.03	n/a	n/a
	dT_{50} (T_{50}–190F)	--	--	-0.00348	0.30
Reduced Model					
	T (T-75)	-0.02623	0.00	-0.02665	0.00
	RVP_L (RVP-9)	-0.02974	0.39	-0.03508	0.34
	RVP_H (RVP-9)	0.03591	0.02	0.01803	0.34
	RVP_H · T	0.00299	0.00	0.00309	0.00
	OxPct	-0.11536	0.00	-0.06670	0.00
	OxPct · OxPct	0.00950	0.00	n/a	n/a
	dT_{50} (T_{50}–190F)	-0.02623	0.00	-0.00324	0.33
Technology Model					
T	Groups 1+2	-0.02377	0.00	-0.02665	0.00
	Groups 3+4	-0.02896	0.00	Same	
RVP_L (RVP-9)	All	-0.02967	0.38	-0.03508	0.34
RVP_H	Groups 1+2	0.03599	0.02	0.01803	0.34
	Groups 3+4	Same		Same	
RVP_H · T	Groups 1+2	0.00300	0.00	0.00309	0.00
	Groups 3+4	Same		Same	
OxPct		-0.11523	0.00	-0.06670	0.00
dT_{50} (T_{50}–190F)		n/a	n/a	-0.00324	0.33

Table 5-15
Alternative Model for CO FTP Bag 2
(N=180, 15 Vehicles)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	0.01718	0.20	0.01736	0.19
	T · OxPct	-0.00473	0.07	-0.00474	0.07
	RVP_L (RVP-9)	0.33022	0.03	0.33987	0.03
	RVP_H (RVP-9)	0.13600	0.11	0.15060	0.06
	RVP_H · T	-0.00486	0.20	0.00482	0.21
	RVP · OxPct	0.00041	0.99	n/a	n/a
	OxPct	-0.10208	0.35	-0.11998	0.10
	OxPct · OxPct	-0.00514	0.72	n/a	n/a
	dT_{50} (T_{50}–190F)	--	--	0.00366	0.79
Reduced Model					
	T (T-75)	--	--	--	--
	RVP_L (RVP-9)	0.03584	0.74	0.03779	0.75
	dVeh07 · RVP_L	3.32832	0.00	3.32832	0.00
	RVP_H (RVP-9)	0.16848	0.00	0.17009	0.00
	RVP_H · T	0.00705	0.00	0.00705	0.00
	OxPct	-0.08735	0.00	-0.08487	0.14
	OxPct · OxPct	--	--	n/a	n/a
	dT_{50} (T_{50}–190F)	--	--	0.00054	0.96
Technology Model					
T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
RVP_L (RVP-9)	All	0.03584	0.74	0.03779	0.75
dVeh07 · RVP_L		3.32832	0.00	3.32832	0.00
RVP_H	Groups 1+2	0.16848	0.00	0.17009	0.04
	Groups 3+4	Same		same	
RVP_H · T	Groups 1+2	0.00705	0.00	0.00705	0.00
	Groups 3+4	Same		same	
OxPct		-0.08735	0.00	-0.08487	0.14
dT_{50} (T_{50}–190F)		n/a	n/a	0.00054	0.96

Table 5-16
Alternative Model for CO FTP Bag 3
(N = 156, excluding Tests with CO_{Bag3} = 0.000)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	0.00307	0.66	0.00252	0.72
	T · OxPct	0.00022	0.87	0.00024	0.86
	RVP_L (RVP-9)	0.02292	0.76	0.02144	0.79
	RVP_H (RVP-9)	0.10408	0.02	0.06034	0.14
	RVP_H · T	0.00138	0.49	0.00156	0.44
	RVP · OxPct	-0.01126	0.40	n/a	n/a
	OxPct	-0.10838	0.05	-0.07098	0.06
	OxPct · OxPct	0.00905	0.22	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	-0.00358	0.61
Reduced Model					
	T (T-75)	--	--	--	--
	RVP_L (RVP-9)	0.00248	0.97	0.00328	0.96
	RVP_H (RVP-9)	0.06640	0.01	0.07101	0.05
	RVP_H · T	--	--	0.00230	0.12
	OxPct	-0.13783	0.00	-0.07256	0.04
	OxPct · OxPct	0.01191	0.06	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	-0.00319	0.65
Technology Model					
T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
RVP_L (RVP-9)		0.02253	0.71	0.00623	0.93
RVP_H	Groups 1+2	0.14635	0.00	0.12626	0.00
	Groups 3+4	None		None	
RVP_H · T	Groups 1+2	0.00527	0.00	0.00526	0.00
	Groups 3+4	None		None	
OxPct		-0.13279	0.00	-0.07535	0.01
dT_{50} (T_{50}–190F)		n/a	n/a	-0.00383	0.52

Table 5-17
Alternative Model for HC FTP Composite
(N = 168, excluding Vehicle 11)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	-0.01164	0.00	-0.01166	0.00
	T · OxPct	-0.00058	0.11	-0.00058	0.11
	RVP_L (RVP-9)	0.00022	0.99	0.00099	0.96
	RVP_H (RVP-9)	0.01679	0.15	0.01548	0.15
	$RVP_H \cdot T$	0.00059	0.26	0.00059	0.26
	RVP · OxPct	-0.00075	0.83	n/a	n/a
	OxPct	-0.02045	0.18	-0.01994	0.05
	OxPct · OxPct	0.00006	0.98	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00013	0.95
Reduced Model					
	T (T-75)	-0.01026	0.00	-0.01034	0.00
	T · OxPct	-0.00071	0.04	-0.00069	0.05
	RVP_L (RVP-9)	0.01840	0.29	0.01069	0.60
	RVP_H (RVP-9)	--	--	--	--
	$RVP_H \cdot T$	--	--	--	--
	OxPct	-0.02281	0.00	-0.02672	0.00
	OxPct · OxPct	--	--	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	-0.00101	0.48
Technology Model					
T	Groups 1+2	-0.00812	0.00	-0.00820	0.00
	Groups 3+4	-0.01301	0.00	-0.01308	0.00
T · OxPct		-0.00072	0.03	-0.00069	0.04
RVP_L (RVP-9)	All	0.01850	0.27	0.01100	0.58
RVP_H	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
$RVP_H \cdot T$	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		-0.02279	0.00	-0.02660	0.00
dT_{50} (T_{50}–190F)		n/a	n/a	-0.00098	0.48

Table 5-18
Alternative Model for HC FTP Bag 1
(N = 140, excluding Vehicle 11)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	-0.01760	0.00	-0.01765	0.00
	T · OxPct	-0.00074	0.08	-0.00073	0.08
	RVP_L (RVP-9)	-0.00613	0.80	-0.00631	0.80
	RVP_H (RVP-9)	0.01549	0.25	0.01214	0.33
	$RVP_H \cdot T$	0.00080	0.19	0.00081	0.18
	RVP · OxPct	-0.00087	0.83	n/a	n/a
	OxPct	-0.02842	0.11	-0.02559	0.03
	OxPct · OxPct	0.00069	0.76	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	-0.00027	0.90
Reduced Model					
	T (T-75)	-0.01579	0.00	-0.01583	0.00
	T · OxPct	-0.00092	0.02	-0.00090	0.02
	RVP_L (RVP-9)	0.00909	0.65	0.00486	0.84
	RVP_H (RVP-9)	--	--	--	--
	$RVP_H \cdot T$	--	--	--	--
	OxPct	-0.02634	0.00	-0.02848	0.00
	OxPct · OxPct	--	--	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	-0.00055	0.74
Technology Model					
T	Groups 1+2	-0.01379	0.00	-0.01383	0.00
	Groups 3+4	-0.01835	0.00	-0.01838	0.00
T · OxPct		-0.00092	0.02	-0.00091	0.02
RVP_L (RVP-9)	All	0.00919	0.64	0.00515	0.83
RVP_H	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
$RVP_H \cdot T$	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		-0.02633	0.00	-0.02837	0.00
dT_{50} (T_{50}–190F)		n/a	n/a	-0.00053	0.75

Table 5-19 Alternative Model for HC FTP Bag 2 (N = 180, 15 Vehicles)					
		Base Models		Including T50 Effect	
		Coefficient	Prob>|t|	Coefficient	Prob>|t|
Full Model					
	Intercept	--	--	--	--
	T (T-75)	0.00410	0.23	0.00433	0.20
	T · OxPct	-0.00079	0.24	-0.00079	0.24
	RVP_L (RVP-9)	0.02665	0.49	0.03335	0.41
	RVP_H (RVP-9)	0.00926	0.97	0.01659	0.41
	RVP_H · T	-0.00086	0.38	-0.00091	0.35
	RVP · OxPct	0.00177	0.79	n/a	n/a
	OxPct	0.02271	0.42	0.00368	0.84
	OxPct · OxPct	-0.00510	0.16	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00304	0.39
Reduced Model					
	T (T-75)	--	--	--	--
	T · OxPct	--	--	--	--
	RVP_L (RVP-9)	0.02654	0.37	0.01669	0.6386
	RVP_H (RVP-9)	--	--	--	--
	RVP_H · T	--	--	--	--
	OxPct			-0.01021	0.44
	OxPct · OxPct			n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	-0.00115	0.67
Technology Model					
T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
T · OxPct		--	--	--	--
RVP_L (RVP-9)	All	-0.00258	0.93	0.01063	0.76
RVP_H	Groups 1+2	0.06932	0.00	0.04831	0.01
	Groups 3+4	0.00230	0.02	0.00237	0.90
RVP_H · T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		--	--	0.00957	0.58
dT_{50} (T_{50}–190F)		n/a	n/a	0.00262	0.44

Table 5-20
Alternative Model for HC FTP Bag 3
(N = 180, 15 Vehicles)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	0.00613	0.02	0.00608	0.02
	T · OxPct	-0.00072	0.17	-0.00072	0.17
	RVP_L (RVP-9)	0.00241	0.93	0.00987	0.75
	RVP_H (RVP-9)	0.02259	0.18	0.01966	0.20
	RVP_H · T	-0.00020	0.79	-0.00019	0.80
	RVP · OxPct	-0.00448	0.38	n/a	n/a
	OxPct	-0.00362	0.87	-0.00665	0.61
	OxPct · OxPct	-0.00135	0.63	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00191	0.48
Reduced Model					
	T (T-75)	0.00387	0.01	0.00370	0.01
	T · OxPct	--	--	--	--
	RVP_L (RVP-9)	-0.00662	0.81	0.00015	1.00
	RVP_H (RVP-9)	0.01942	0.03	0.02146	0.02
	RVP_H · T	--	--	--	--
	OxPct	--	--	--	--
	OxPct · OxPct	--	--	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00164	0.16
Technology Model					
T	Groups 1+2	0.00039	0.01	0.00370	0.01
	Groups 3+4	same		--	--
RVP_L (RVP-9)	All	-0.00662	0.81	-0.00015	1.00
RVP_H	Groups 1+2	0.01942	0.03	0.02146	0.02
	Groups 3+4	same		--	--
RVP_H · T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		--	--	--	--
dT_{50} (T_{50}–190F)		n/a	n/a	0.00164	0.16

Table 5-21
Alternative Model for NOx FTP Composite
(N=180, 15 Vehicles)

		Base Models		**Including T50 Effect**	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	-0.00397	0.16	-0.00410	0.16
	T · OxPct	-0.00069	0.22	-0.00068	0.23
	RVP_L (RVP-9)	-0.01120	0.73	-0.00753	0.83
	RVP_H (RVP-9)	0.03777	0.04	0.02988	0.08
	RVP_H · T	-0.00026	0.75	-0.00023	0.78
	RVP · OxPct	-0.00411	0.46	n/a	n/a
	OxPct	0.01520	0.52	0.01887	0.23
	OxPct · OxPct	0.00056	0.85	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00052	0.86
Reduced Model					
	T (T-75)	-0.00644	0.00	-0.00645	0.00
	RVP_L (RVP-9)	--	--	-0.01809	0.56
	RVP_H (RVP-9)	-0.01831	0.53	0.03153	0.02
	RVP_H · T	0.03134	0.00	--	--
	OxPct	--	--	0.002391	0.11
	OxPct · OxPct	0.02362	0.00	n/a	n/a
	dedT_{50} (T_{50}–190F)	n/a	n/a	0.000063	0.98
Technology Model					
T	Groups 1+2	-0.00691	0.00	-0.00691	0.00
	Groups 3+4	-0.00594	0.01	-0.00594	0.01
RVP_L (RVP-9)	All	-0.01834	0.53	-0.01815	0.56
RVP_H	Groups 1+2	0.03135	0.00	0.03152	0.02
	Groups 3+4	same		same	
RVP_H · T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		0.02361	0.00	0.02388	0.11
dT_{50} (T_{50}–190F)		n/a	n/a	0.00006	0.98

Table 5-22
Alternative Model for NOx FTP Bag 1
(N=180, 15 Vehicles)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	-0.00696	0.00	-0.00700	0.00
	T · OxPct	-0.00060	0.21	-0.00060	0.21
	RVP_L (RVP-9)	-0.01051	0.70	-0.01704	0.55
	RVP_H (RVP-9)	0.00833	0.58	0.00479	0.73
	RVP_H · T	-0.00061	0.37	-0.00060	0.38
	RVP · OxPct	0.00216	0.64	n/a	n/a
	OxPct	-0.00651	0.74	0.00106	0.93
	OxPct · OxPct	0.00235	0.36	n/a	n/a
	dT_{50} (T_{50}–190F)	--	--	-0.00207	0.40
Reduced Model					
	T (T-75)	-0.00974	0.00	-0.00970	0.00
	RVP_L (RVP-9)	--	--	-0.03050	0.25
	RVP_H (RVP-9)	-0.02198	0.38	0.01127	0.32
	RVP_H · T	0.01855	0.03	--	--
	OxPct	--	--	0.00550	0.66
	OxPct · OxPct	0.01670	0.00	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	-0.00243	0.32
Technology Model					
T	Groups 1+2	-0.01046	0.00	-0.01042	0.00
	Groups 3+4	-0.00896	0.00	-0.00894	0.00
RVP_L (RVP-9)	All	-0.02204	0.38	-0.03058	0.25
RVP_H	Groups 1+2	0.01857	0.03	0.01126	0.32
	Groups 3+4	Same		same	
RVP_H · T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		0.01669	0.00	0.00544	0.66
dT_{50} (T_{50}–190F)		n/a	n/a	-0.00244	0.32

Table 5-23
Alternative Model for NOx FTP Bag 2
(N=150, 15 Vehicles)

		Base Models		Including T50 Effect	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	-0.00514	0.52	-0.00594	0.46
	T · OxPct	0.00031	0.84	0.00032	0.84
	RVP_L (RVP-9)	-0.12002	0.18	-0.08635	0.37
	RVP_H (RVP-9)	0.16090	0.00	0.10606	0.03
	$RVP_H \cdot T$	0.00191	0.40	0.00211	0.36
	RVP · OxPct	-0.03218	0.04	n/a	n/a
	OxPct	0.04019	0.54	0.06005	0.17
	OxPct · OxPct	0.00191	0.82	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00587	0.48
Reduced Model					
	T (T-75)	--	--	--	--
	RVP_L (RVP-9)	--	--	-0.04970	0.55
	RVP_H (RVP-9)	-0.08755	0.26	--	--
	$RVP_H \cdot T$	0.14026	0.00	0.07927	0.04
	OxPct	-0.03448	0.01	0.05762	0.17
	OxPct · OxPct	0.05243	0.01	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00575	0.48
Technology Model					
T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
RVP_L (RVP-9)	All	-0.07059	0.37	-0.04970	0.55
RVP_H	Groups 1+2	0.06209	0.03	0.07927	0.04
	Groups 3+4	Same		same	
$RVP_H \cdot T$	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		0.03110	0.01	0.05762	0.17
dT_{50} (T_{50}–190F)		n/a	n/a	0.00575	0.48

Table 5-24 **Alternative Model for NOx FTP Bag 3** **(N=150, 15 Vehicles)**					
		Base Models		**Including T50 Effect**	
		Coefficient	**Prob>|t|**	**Coefficient**	**Prob>|t|**
Full Model					
	Intercept	--	--	--	--
	T (T-75)	0.00669	0.22	0.00675	0.21
	T · OxPct	-0.00202	0.06	-0.00202	0.06
	RVP_L (RVP-9)	-0.01100	0.86	0.00761	0.91
	RVP_H (RVP-9)	0.05348	0.12	0.05987	0.06
	RVP_H · T	-0.00011	0.94	-0.00012	0.94
	RVP · OxPct	-0.00726	0.50	n/a	n/a
	OxPct	0.05997	0.18	0.04104	0.16
	OxPct · OxPct	-0.00605	0.30	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00567	0.31
Reduced Model					
	T (T-75)	--	--	--	--
	RVP_L (RVP-9)	--	--	-0.02230	0.69
	RVP_H (RVP-9)	-0.03790	0.47	--	--
	RVP_H · T	0.04520	0.02	0.05803	0.02
	OxPct	--	--	0.05600	0.05
	OxPct · OxPct	0.03620	0.00	n/a	n/a
	dT_{50} (T_{50}–190F)	n/a	n/a	0.00429	0.44
Technology Model					
T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
RVP_L (RVP-9)	All	-0.03790	0.47	-0.02230	0.69
RVP_H	Groups 1+2	0.04520	0.02	0.05803	0.02
	Groups 3+4	same		same	
RVP_H · T	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		0.03620	0.00	0.05600	0.05
dT_{50} (T_{50}–190F)		n/a	n/a	0.00429	0.44

5.5 Summary of Correction Factors Based on Primary Analysis

This subsection summarizes the coefficient values for the correction factor equations developed from the primary analysis. In addition, the combined effects of temperature, RVP, and oxygenate effects are separated into their individual contributions. Tables 5-25 and 5-26 summarize the correction factor results for CO emissions.

Table 5-25
Correction Factor Coefficients for FTP CO Emissions

		Composite	Bag 1	Bag 2	Bag 3
T	Groups 1+2	-0.01315	-0.02327	--	--
	Groups 3+4	-0.02519	-0.02846	--	--
RVP_H	Groups 1+2	0.10843	0.03599	0.16848	0.14635
	Groups 3+4	0.03396			none
$RVP_H \cdot T$	Groups 1+2	0.00474	0.00300	0.00705	0.00527
	Groups 3+4	0.00276			none
OxPct		-0.10312	-0.11523	-0.08735	-0.13279
OxPct · OxPct		0.00743	0.00949	--	0.01105

Table 5-26
Estimated Effects of Design Variables on FTP CO Emissions
(Compared to Design Variable Conditions Stated, Percent)

	Design Variable Conditions	Composite	Bag 1	Bag 2	Bag 3
T = 50°F					
Groups 1+2	T 75F->50F, RVP=9, E0	39%	81%	--	--
Groups 3+4		88%	106%	--	--
RVP = 13 psi at 75°F					
Groups 1+2	RVP 9->13, T=75°F, E0	54%	15%	96%	80%
Groups 3+4		15%			none
RVP = 13 psi at 50°F					
Groups 1+2	RVP 9->13, T=50°F, E0	- 4%	-14%	-3%	6%
Groups 3+4		-13%			none
Oxygenation at 75°F and 50°F					
E10	E0->E10-E20, RVP = Any, T = Any	-24%	-26%	-28%	-29%
E15		-29%	-30%	-38%	-33%
E20		-30%	-30%	-48%	-33%

For CO, the effect of non-FTP conditions is largely driven by low ambient temperature. At 50°F, CO has increased substantially due to temperature alone (at constant RVP). Increasing gasoline RVP to 13 psi offsets a small part of the cold-temperature emissions increase in Bag 1 and has a small benefit in Bag 2 and a small adverse effect in Bag 3. The Bag 1 RVP effect switches from adverse to beneficial at temperatures below 63°F. At 75°F and higher, increased RVP has a consistently adverse effect on CO. Fuel oxygenation at the E10 level decreases CO emissions by 24–29 percent in all Bags and independently of temperature and RVP, but during vehicle start (Bags 1 and 3) little additional benefit is seen from oxygen content in excess of E10.

To illustrate these trends, Figures 5-1 through 5-6 show estimated CO emissions as a function of temperature and RVP. Emissions for RVP 7 psi fuels are the same as shown for 9 psi because no statistically significant emissions change could be detected for RVP between 7 and 9 psi. Only Group 1 (Tier 1) and Group 4 (Tier 2 Enhanced) vehicles are shown because the trends do not differ for the other groups. As the graphs make clear, the primary effect on Bag 1 CO emissions is cold ambient temperatures, with a relative minor beneficial effect for high RVP gasoline at temperatures below about 55°F. RVP has a much larger and consistently adverse effect in Bags 2 and 3.

Figure 5-1
Group 1, Bag 1 CO Trends

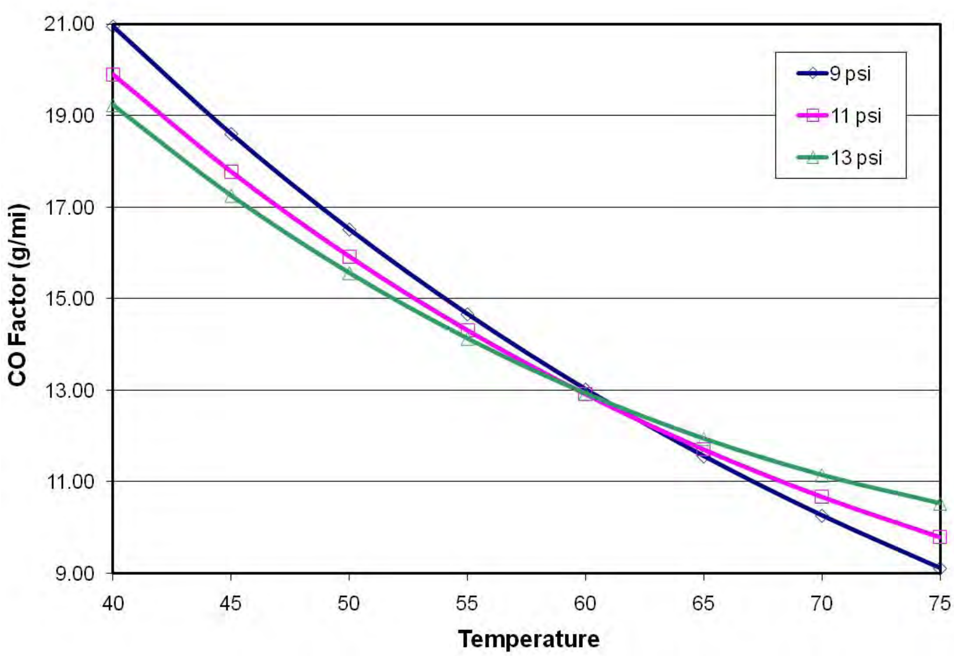


Figure 5-2
Group 1, Bag 2 CO Trends

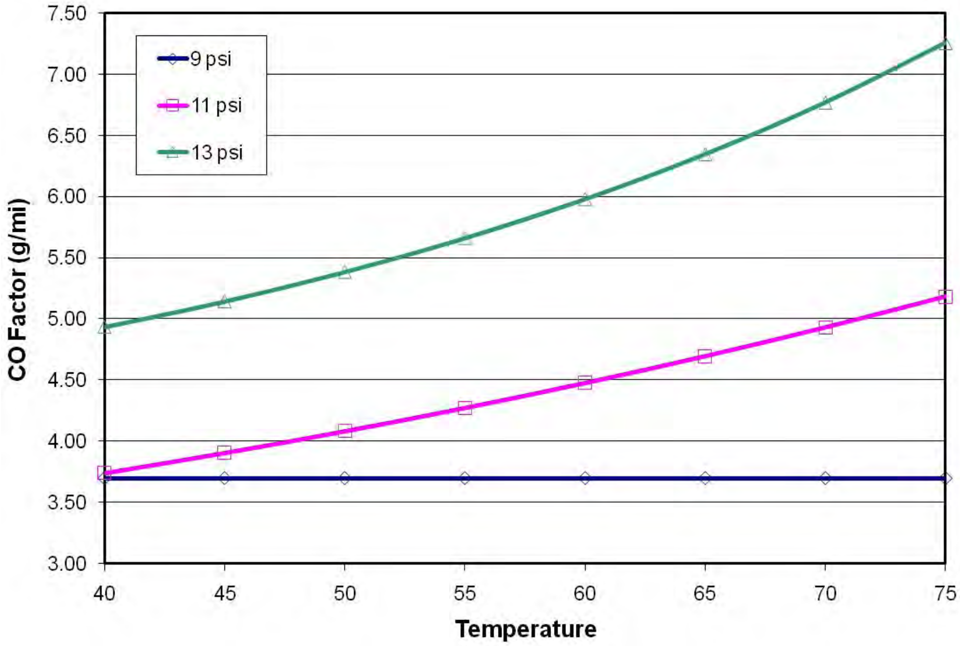


Figure 5-3
Group 1, Bag 3 CO Trends

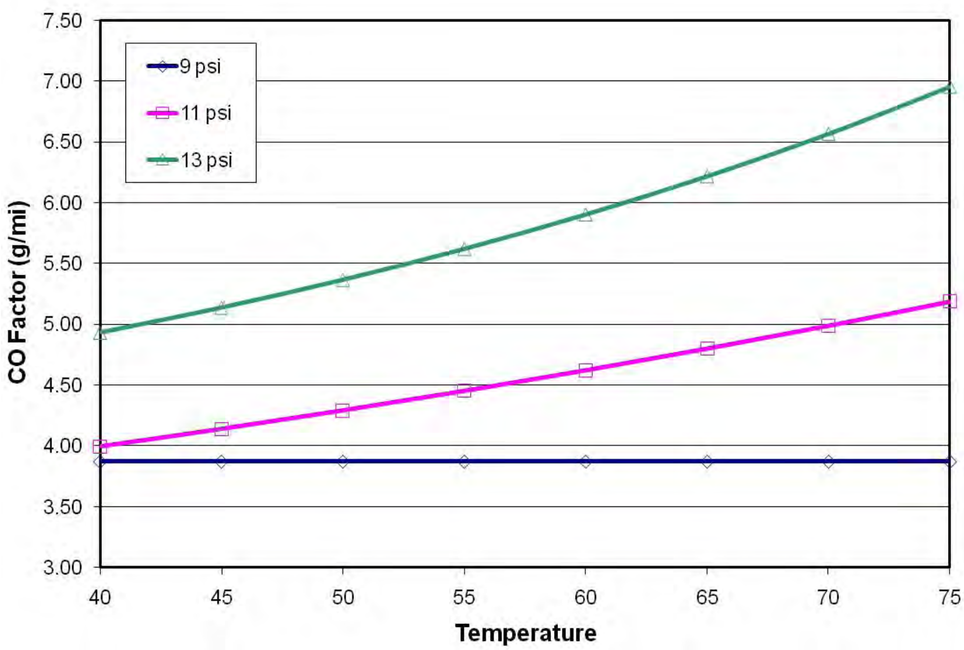


Figure 5-4
Group 4, Bag 1 CO Trends

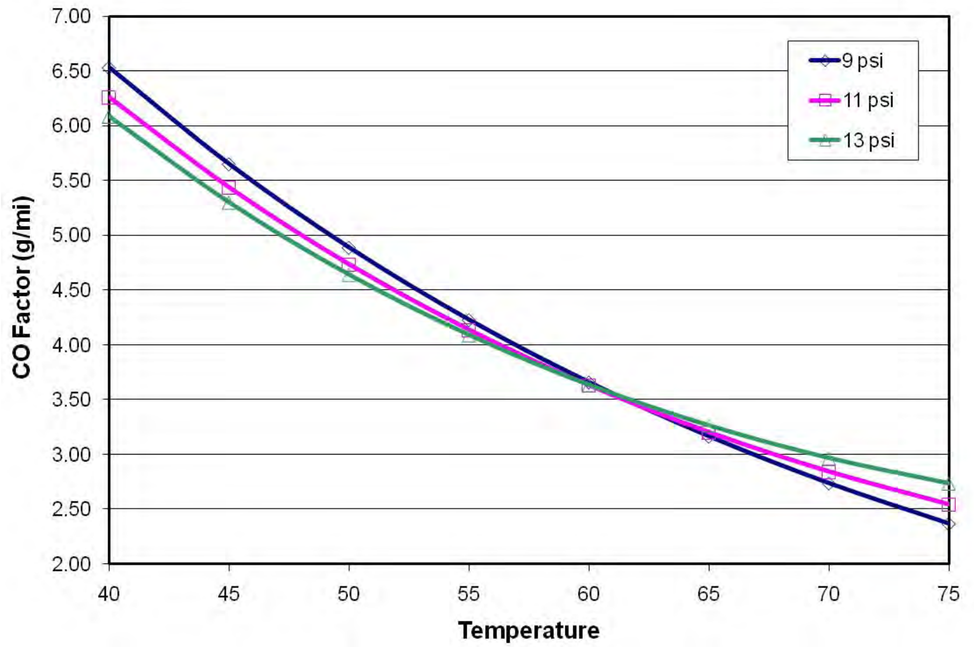


Figure 5-5
Group 4, Bag 2 CO Trends

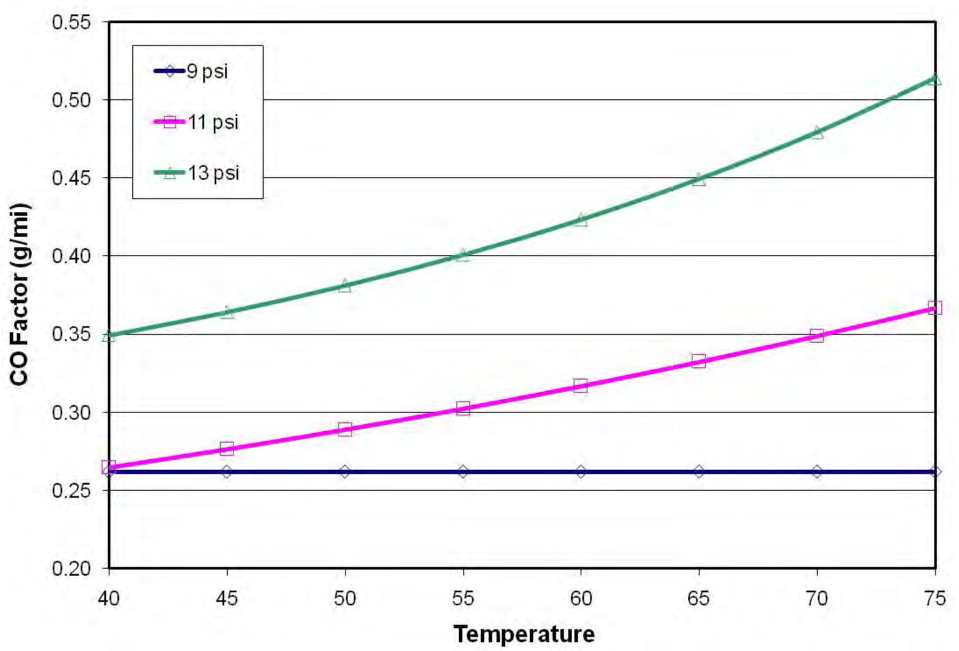
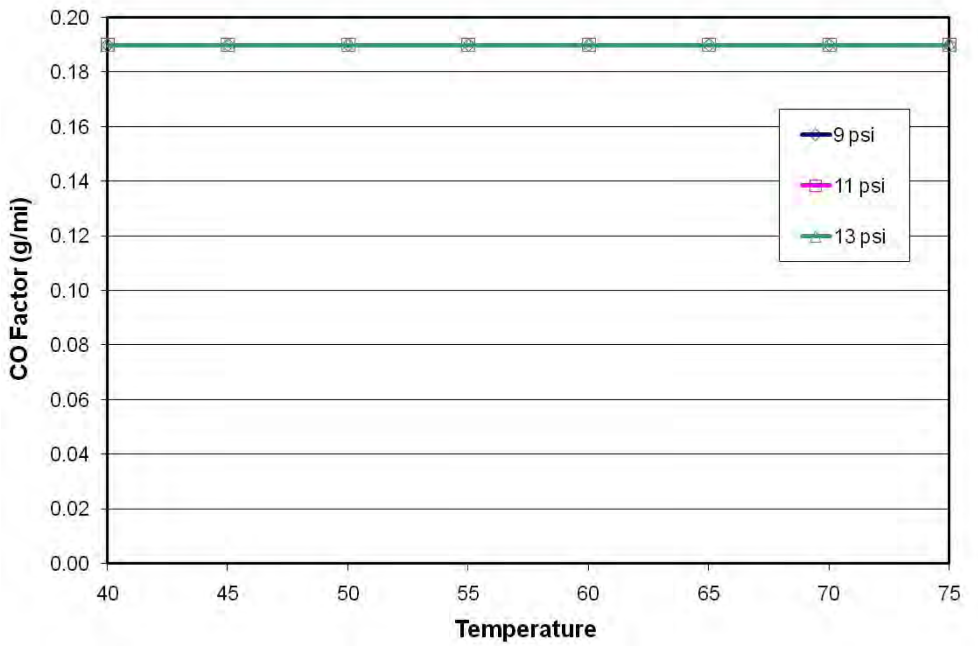


Figure 5-6
Group 4, Bag 3 CO Trends



Tables 5-27 and 5-28 summarize the correction factor results for THC emissions. As for CO, cold ambient temperatures significantly increase Bag 1 THC emissions. Unlike CO, however, no RVP effect can be detected for Bag 1 THC. For Bags 2 and 3, the RVP effect is found to be the same at both 50°F and 75°F. For Bag 2, gasoline RVP of 13 psi has a substantial effect on THC emissions for Group 1 and 2 vehicles, but only a negligibly small effect is seen for Groups 3 and 4 vehicles. A small but adverse Bag 3 effect is seen for all vehicles. Fuel oxygenation has a small beneficial effect for

Table 5-27
Correction Factor Coefficients for FTP THC Emissions

		Composite	Bag 1	Bag 2	Bag 3
T	Groups 1+2	-0.00812	-0.01379	--	0.00039
	Groups 3+4	-0.01301	-0.01835	--	
T · OxPct		-0.00072	-0.00092	--	--
RVP_H	Groups 1+2	--	--	0.06932	0.01942
	Groups 3+4	--	--	0.00230	
$RVP_H \cdot T$	Groups 1+2	--	--	--	--
	Groups 3+4	--	--	--	--
OxPct		-0.02279	-0.02633	--	--
OxPct · OxPct		--	--	--	--

<table>
<tr><th colspan="6">Table 5-28
Estimated Effects of Design Variables on FTP THC Emissions
(Compared to Design Variable Conditions Stated, Percent)</th></tr>
<tr><th></th><th>Design Variable Conditions</th><th>Composite</th><th>Bag 1</th><th>Bag 2</th><th>Bag 3</th></tr>
<tr><td colspan="6">T = 50°F</td></tr>
<tr><td>Groups 1+2</td><td rowspan="2">T 75F->50F, RVP=9, E0</td><td>23%</td><td>41%</td><td>--</td><td rowspan="2">negligible</td></tr>
<tr><td>Groups 3+4</td><td>38%</td><td>58%</td><td>--</td></tr>
<tr><td colspan="6">RVP = 13 psi at 75°F</td></tr>
<tr><td>Groups 1+2</td><td rowspan="2">RVP 9->13, T=75°F, E0</td><td rowspan="2">--</td><td rowspan="2">--</td><td>32%</td><td rowspan="2">8%</td></tr>
<tr><td>Groups 3+4</td><td>1%</td></tr>
<tr><td colspan="6">RVP = 13 psi at 50°F</td></tr>
<tr><td>Groups 1+2</td><td rowspan="2">RVP 9->13, T=50°F, E0</td><td rowspan="2">--</td><td rowspan="2">--</td><td>32%</td><td rowspan="2">8%</td></tr>
<tr><td>Groups 3+4</td><td>1%</td></tr>
<tr><td colspan="6">Oxygenation at 75°F</td></tr>
<tr><td>E10</td><td rowspan="3">E0->E10-E20, RVP = Any, T = 75°F</td><td>-8%</td><td>- 9%</td><td>--</td><td>--</td></tr>
<tr><td>E15</td><td>-12%</td><td>-14%</td><td>--</td><td>--</td></tr>
<tr><td>E20</td><td>-16%</td><td>-18%</td><td>--</td><td>--</td></tr>
<tr><td>Oxygenation at 50°F</td><td>E0->E10-E20, RVP = Any, T = 50°F</td><td>negligible</td><td>negligible</td><td>--</td><td>--</td></tr>
</table>

Composite Bag 1 THC emissions only and only at an ambient temperature of 75°F. The oxygenation benefit decreases with temperature and is negligible at an ambient temperature of 50°F.

Tables 5-29 and 5-30 summarize the correction factor results for NOx emissions. Because the Bag 1 RVP effects were found to differ between PCs and LDTs, separate estimates are given in the tables; however, no such differences could be detected for the FTP Composite or Bags 2 and 3 phases. Cold ambient temperatures increase Bag 1 NOx emissions by 25 to 30 percent depending on the vehicle group. High RVP gasoline has no direct effect on Bag 1 NOx emissions of PCs, but is found to increase LDT emissions by 18 percent at an RVP of 13 psi at all temperatures. High RVP gasoline has adverse effects on Bag 2 and Bag 3 NOx emissions for all vehicles at all temperatures. Fuel oxygenation at the E10 level increases NOx emissions by approximately 10 percent in all FTP Bags and by larger amounts at higher oxygen contents.

Table 5-29
Correction Factor Coefficients for FTP NOx Emissions

		Composite	Bag 1		Bag 2	Bag 3
		All	**PCs**	**LDTs**	**All**	**All**
T	Groups 1+2	-0.00691	-0.01046	-0.01046	--	--
	Groups 3+4	-0.00594	-0.00896	-0.00896		
RVP	Groups 1+2	0.03135	--	0.04152	0.06290	0.04520
	Groups 3+4		--			
RVP · T	Groups 1+2	--	--	--	--	--
	Groups 3+4		--	--	--	--
OxPct		0.02361	0.01640	0.01640	0.03110	0.03620
OxPct · OxPct		--	--	--	--	--

Table 5-30
Estimated Effects of Design Variables on FTP NOx Emissions
(Compared to Design Variable Values as Stated, Percent)

	Design Variable Conditions	Composite	Bag 1		Bag 2	Bag 3
		All	**PC**	**LDT**	**All**	**All**
T = 50°F						
Groups 1+2	T 75F->50F, RVP = 9, E0	19%	30%		--	--
Groups 3+4		16%	25%		--	--
RVP = 13 psi at 75°F						
Groups 1+2	RVP 9->13, T=75°F, E0	13%	none	18%	28%	20%
Groups 3+4		13%				
RVP = 13 psi at 50°F						
Groups 1+2	RVP 9->13, T=50°F, E0	13%	none	18%	28%	20%
Groups 3+4		13%				
Oxygenation at 75°F and 50°F						
E10	E0->E10-E20, RVP = Any, T = Any	9%	6%		12%	14%
E15		14%	10%		19%	22%
E20		19%	13%		26%	31%

5.6 Comparison of Adjustment Factors to Those in MOBILE6.2

Table 5-31 compares the CO adjustment factors estimated for this study to those currently incorporated in the MOBILE6.2 model. One major finding is the continued presence of an oxygenate effect in Tier 1 and later vehicles that reduces CO emissions on

Table 5-31 Comparison of CO Adjustment Factors to MOBILE6.2 Factors			
	MOBILE6.2 Factors	**CRC E74b Factors**	
Oxygenate Effect (Tier 1 and Later Vehicles)			
Normal Emitters	no effect	Bag 1	-8.4% per %O_2 [a]
		Bag 2	-8.7% per %O_2 [a]
		Bag 3	-9.5% per %O_2
High Emitters	-5.3% per %Oxygen	not tested	
RVP Effect (RVP 9-13) at 75°F Group 1/2 Vehicles			
Bag 1	4.2% per psi	Bag 1	3.7% per psi
Bag 2	30% per psi	Bag 2	18.4% per psi
Bag 3	26% per psi	Bag 3	15.8% per psi
Group 3/4 Vehicles			
Bag 1	4.2% per psi	Bag 1	3.7% per psi
Bag 2	30% per psi	Bag 2	18.4% per psi
Bag 3	26% per psi	Bag 3	not detected
RVP Effect (RVP 9-13) at 50°F Group 1/2 Vehicles			
Bag 1	0.7% per psi	Bag 1	-3.8% per psi
Bag 2	5.0% per psi	Bag 2	0.7% per psi
Bag 3	4.4% per psi	Bag 3	2.5% per psi
Group 3/4 Vehicles			
Bag 1	0.7% per psi	Bag 1	-3.8% per psi
Bag 2	5.0% per psi	Bag 2	0.7% per psi
Bag 3	4.4% per psi	Bag 3	not detected

[a] Oxygenate effect depends on oxygen content. Value shown is for E10.

the order of 8% per percent oxygen content of the fuel. MOBILE6.2 assumes no benefit from oxygenated fuels in normal emitting Tier 1 and later vehicles. The approximately 7-9% per percent effect found here is even larger than the ~5% per percent effect assumed for high emitters in MOBILE6.2. As previously noted, none of the vehicles tested in this program were high emitters and therefore no inferences can be drawn from the data, although for inventory purposes it would be reasonable to assume that high emitters experience at least the same effect as normal emitters.

For Tier 1 and later vehicles (Groups 1 and 2), the CO emissions effects due to gasoline RVP in the range 9 to 13 psi are generally comparable to (Bag 1) or much smaller than (Bags 2 and 3) the responses assumed in MOBILE6.2. For Tier 2 vehicles (Groups 3 and 4), this study estimates a comparable effect in Bag 1, a much smaller effect in Bag 2, and cannot detect an effect in Bag 3. The overall consequence of the revised CO RVP adjustment factors for a fleet of in-use vehicles will depend on the mix of vehicles in the fleet and the relative contributions of cold-start, hot-start, and running emissions.

As demonstrated in Section 4.6, this study confirms the assumption made in MOBILE6.2 that gasoline RVP reductions below 9 psi have little or no effect on CO emissions.

Correction factors developed in this study for exhaust NOx and THC emissions are compared in the following tables. As Table 5-32 shows, the correction factors for

Table 5-32
Comparison of THC Adjustment Factors to MOBILE6.2 Factors

	MOBILE6.2 Factors	CRC E74b Factors	
Oxygenate Effect [a] (Tier 1 and Later Vehicles)			
Normal Emitters	Variable but negative [a]	Bag 1	-2.6% per %oxygen [b]
		Bag 2	no effect
		Bag 3	no effect
High Emitters	Variable but negative [a]	not tested	
RVP Effect (RVP 9-13) at 75°F Group 1/2 Vehicles			
Bag 1	2.3% per psi	Bag 1	no effect
Bag 2	17% per psi	Bag 2	7.2% per psi
Bag 3	14% per psi	Bag 3	2.0% per psi
Group 3/4 Vehicles			
Bag 1	2.3% per psi	Bag 1	no effect
Bag 2	17% per psi	Bag 2	0.2% per psi
Bag 3	14% per psi	Bag 3	2.0% per psi
RVP Effect (RVP 9-13) at 50°F Group 1/2 Vehicles			
Bag 1	0.4% per psi	Bag 1	no effect
Bag 2	2.8% per psi	Bag 2	7.2% per psi
Bag 3	2.4% per psi	Bag 3	2.0% per psi
Group 3/4 Vehicles			
Bag 1	0.4% per psi	Bag 1	no effect
Bag 2	2.8% per psi	Bag 2	0.2% per psi
Bag 3	2.4% per psi	Bag 3	2.0% per psi

[a] Oxygenate effect in MOBILE6.2 depends on the absolute level of the basic emission rate at standard conditions computed using a methodology carried over from MOBILE4.1.
[b] Oxygenate effects tabulated for this study are at 75°. Oxygenate is estimated to have negligible effect at 50°.

oxygenate effects on THC emissions cannot be effectively compared owing to the dependence of the MOBILE6.2 factors on the base THC emission rate of the vehicle technology group in question. For Bag 1, both MOBILE6.2 and the current study indicate declining THC emissions with increasing oxygen content, but this study does not detect an oxygenate effect on THC emissions in Bags 2 and 3. Adjustments for RVP effects on exhaust THC emissions based on the current study are again similar to those in MOBILE6.2, with increasing RVP leading to higher THC emissions, although the Bag 2 effect seen here is larger. However, this study finds no difference in the magnitude of the effect (on a percentage basis) at 50°F compared to that at 75°F.

Table 5-33 shows that, as expected, increasing oxygen content leads to increased NOx emissions, despite the fact that MOBILE6.2 ignores this effect. Directionally, the adjustment factors for RVP effects on NOx are consistent with those in MOBILE6.2, although somewhat larger in size, with NOx emissions increasing with increasing RVP.

Table 5-33
Comparison of NOx Adjustment Factors to MOBILE6.2 Factors

	MOBILE6.2 Factors	**CRC E74b Factors**	
Oxygenate Effect (Tier 1 and Later Vehicles)			
Normal Emitters	No effect	Bag 1	1.6% per %oxygen
		Bag 2	3.1% per %oxygen
		Bag 3	3.6% per %oxygen
High Emitters	No effect	not tested	
RVP Effect (RVP 9-13) at 75°F All Vehicles			
Bag 1	1.4% per psi	Bag 1	4.2% per psi
Bag 2	2.8% per psi	Bag 2	6.4% per psi
Bag 3	No effect	Bag 3	4.6% per psi
RVP Effect (RVP 9-13) at 50°F All Vehicles			
Bag 1	0.2% per psi	Bag 1	4.2% per psi
Bag 2	0.5% per psi	Bag 2	6.4% per psi
Bag 3	No effect	Bag 3	4.6% per psi

However, this study finds no difference in the magnitude of the RVP effect (on a percentage basis) at 50°F compared to that at 75°F. The current study does, however, show Bag 3 impacts, whereas MOBILE6.2 assumes no effect.

5.7 Comparison of RVP and Oxygenate Effects to Those of Previous Sierra Study

As noted previously, in 2003 Sierra examined available CO exhaust test data at temperatures below 75°F and developed RVP and temperature adjustments using the same form used in this study.[*] That study compiled data from seven test programs and extracted data from 1988-and-newer model year, fuel-injected vehicles tested at temperatures between 35° and 75°F for use in adjustment factor analysis. It was observed in that analysis that the RVP and RVP · T coefficients were significantly more uncertain than the temperature coefficient. Because the overall goal was to develop a new RVP adjustment approach, the RVP-related coefficients were defined even if not statistically significant.[†]

Table 5-34 presents the RVP and temperature correction coefficients for CO exhaust from both studies for comparative purposes. The temperature coefficient from the E-74b test program is about half that of the previous Sierra analysis, which may be a reflection of the effects of cold temperature CO standards. The RVP coefficient of the E-74b test program is greater and the coefficient that defines how the RVP effect changes with temperature is also greater.

Table 5-35 presents the percent change in emissions due to reducing RVP from 11.7 psi to 9.0 psi using the equation coefficients of the two studies. Additionally, the percent change in emissions as estimated by MOBILE6.2 is presented. The RVP of 11.7 was chosen as this is the MOBILE6.2 upper limit for RVP adjustment.[‡] Overall, the relative RVP effects observed in the E-74b data are distinctly different from those of the previous Sierra analysis. However, it should be recalled that the absolute (e.g., g/mi) CO emissions of the vehicles previously analyzed by Sierra were much higher than those of the E-74b program vehicles. In addition, at lower temperatures, the E-74b data show a reduction in CO emissions at higher RVP. Finally, both the E-74b data and previous Sierra analysis show a smaller relative impact of RVP on CO emissions than is predicted by MOBILE6.2.[§]

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[*]"Review of Current and Future CO Emissions From On-Road Vehicles in Selected Western Areas," Report No. SR03-01-01, prepared for Western States Petroleum Association by Sierra Research, January 2003.

[†]There is a greater degree of variability inherent in the previous Sierra analysis due to the wider variability of vehicles and test conditions reflected in the data. Only FTP-composite and matched vehicle test data were included in the analysis.

[‡]The modeling limit is discussed further in Section 6 of this report.

[§]As discussed in the 2003 Sierra report, the MOBILE6.2 RVP corrections are based on 75°F test data only, and the RVP effect is assumed to decline linearly to no effect at 45°F.

Table 5-34 Comparison of RVP and Temperature Adjustment Equation Coefficients for FTP Composite Exhaust CO Emissions		
Modeling Coefficient	**CRC E-74b**	**Previous Sierra (All Data)**
T	-0.01857	-0.0355
RVP	0.07946	0.0116
RVP · T	0.00370	0.000144

Table 5-35 Estimated Impact of Reducing RVP from 11.7 to 9.0 psi on FTP Composite CO Emissions			
Temperature (°F)	**CRC E-74b**	**Previous Sierra (All Data)**	**MOBILE6.2***
75	-19.3%	-3.1%	-46.1%
65	-10.8%	-2.7%	-35.6%
55	-1.5%	-2.3%	-20.4%
45	8.9%	-1.9%	0.0%

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*MOBILE6.2 was operated for calendar year 2007 using a national default fleet mix. Trip length, vehicle soak periods, start emissions, and driving cycle adjustments were defined to simulate those characteristics of the FTP composite test cycle.

6. COMPARISON OF MOBILE6.2 AND UPDATED CO ADJUSTMENT FACTORS

This section first describes the methodology to incorporate the emission adjustment factors presented in the previous section into MOBILE6.2; it then compares the estimated wintertime CO emissions inventory for Clark County (Las Vegas), Nevada obtained using the updated adjustment factors to that derived with the original factors in MOBILE6.2. The Las Vegas area was selected for this comparison for several reasons. It—along with the Phoenix, Arizona area—represents one of the two major urban areas where regulations requiring winter gasoline to contain 3.5 percent oxygen by weight and limiting RVP to 9 psi were implemented in order to reduce CO emissions from on-road vehicles. Because limited project resources precluded comparisons in both areas, it was selected over Phoenix due to the availability of the emission inventory data required to perform the comparison.

6.1 Methodology

MOBILE6.2 – For the Las Vegas CO inventory analysis, selected winter gasoline RVP and oxygenate scenarios were analyzed under typical winter conditions for the CO SIP evaluation years of 2006, 2010, and 2015. Emission factors were estimated by the U.S. EPA's MOBILE6.2 model[*] and combined with data on vehicle miles traveled (VMT) to yield on-road CO inventories for the study area.

The MOBILE6.2 emission factor modeling relied on input data specific to Clark County, which reflect local winter temperatures, fuel parameters, registration distributions, VMT distributions by vehicle class, VMT distributions by hour of day, distribution of vehicle starts by hour of day, and inspection and maintenance (I/M) parameters. These modeling data, specific to the evaluation calendar years, were those from the recent 2005 SIP revision.[†] Hourly winter temperatures, a key assumption for the analysis, fell within the range of 42ºF (minimum) and 66ºF (maximum). The diurnal profiles for temperature and VMT are shown in Figure 6-1. Combining the hourly temperature profile with the hourly VMT profile showed that 70% of the VMT on the average winter day fell within the 50ºF to 75ºF range, making the Clark County area ideally suited for an evaluation of fuel adjustment factors at these temperatures.

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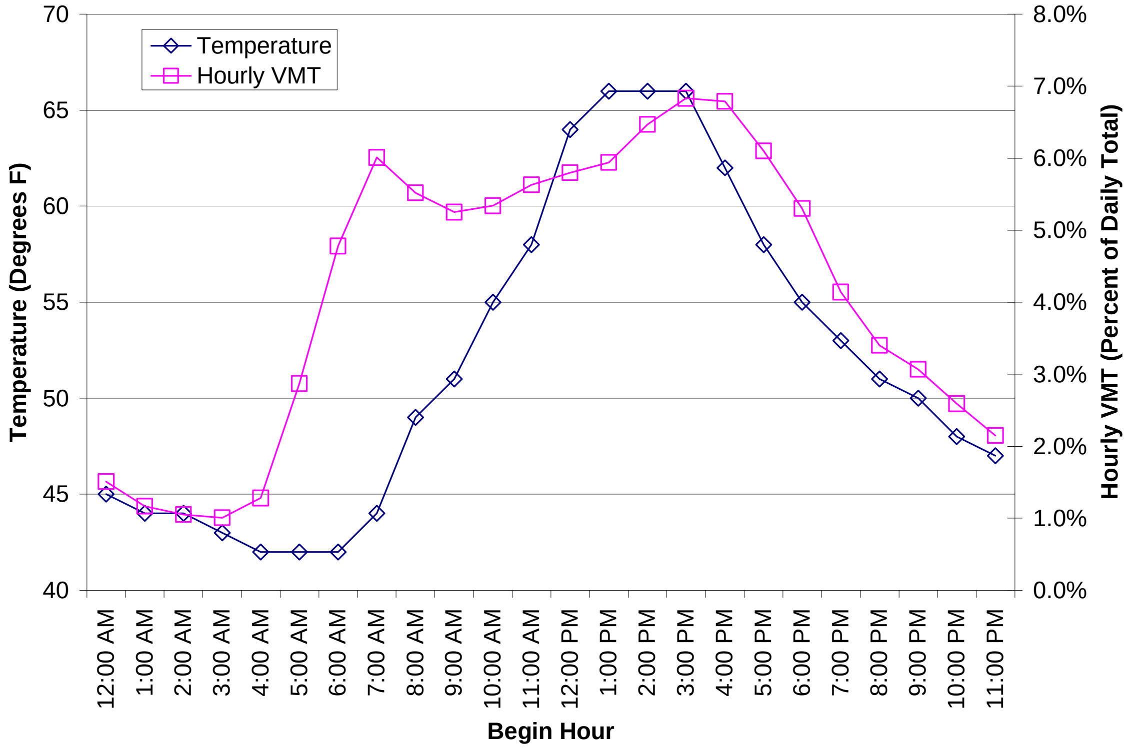
[*] Version 6.2.03 dated September 2003.

[†] "Carbon Monoxide State Implementation Plan Revision Las Vegas Valley Nonattainment Area Clark County, Nevada," Clark County Department of Air Quality and Environmental Management and Clark County Board of Commissioners, October 2005.

Figure 6-1
Las Vegas Typical Winter Day Diurnal Profiles



Las Vegas VMT data were taken from a 2007 analysis of summer gasoline volatility control options as these represented more recent travel demand modeling since the 2005 SIP revision.* Interpolation between calendar years was completed, as needed, to match the inventory years of this analysis. The VMT data used represent the urban portion of Clark County, which is also the region subject to the local I/M program requirements. Average daily VMT estimates used in this evaluation were 40,050,285 for 2006; 50,608,417 for 2010; and 59,804,322 miles for 2015.

As noted above, winter gasoline sold in Clark County is currently subject to RVP limits as well as specifications for oxygenate content. In addition, sulfur and aromatic content restrictions apply. The current wintertime gasoline fuel requirements in Clark County are summarized in Table 6-1; the 2006 winter Clark County gasoline properties are summarized in Table 6-2. These data were taken from the Winter 2006 Alliance of Automobile Manufacturers (AAM) Fuel Survey Data.†

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*"Demonstration of the Necessity of Regulations Requiring 7.0 PSI RVP Gasoline in Clark County, Nevada as an Ozone Control Strategy," Sierra Research, November 2007.
†"Alliance of Automobile Manufacturers North American Fuel Survey Motor Gasoline Winter 2006," Alliance of Automobile Manufacturers, 2006.

Table 6-1 Wintertime Gasoline Fuel Requirements for Clark County	
Fuel Property	**Standard**
Reid Vapor Pressure (RVP)	Max 9.0 psi (10.0 psi for fuel with 9+ vol % EtOH)
Sulfur Content	Max 80 ppmw; Flat limit of 40 ppmw
Aromatic Content	Max 30 vol %; Flat limit of 25 vol %
Oxygen Content	Min 3.5 wt %

Table 6-2 Winter 2006 Gasoline Parameters	
Fuel Property	**Clark County Gasoline**
Methyl Tertiary Butyl Ether (MTBE) (wt% oxygen)	0
Ethyl Tertiary Butyl Ether (ETBE) (wt% oxygen)	0
Ethanol (wt% oxygen)	3.47
Tertiary Amyl Methyl Ether (TAME) (wt% oxygen)	0
Sulfur (ppm)	31
RVP (psi)	8.8
E200 (%)	46.4
E300 (%)	78.7
Aromatics (vol%)	20.2
Olefins (vol%)	6.7
Benzene (vol%)	0.60

For the fuel scenarios, both RVP and oxygenate levels were varied. A total of nine fuel scenarios were modeled (the unique combinations of three RVP and three oxygenate levels) by including the following parameters:

- RVP of 9, 11.7, and 13.3 psi; and
- Oxygen content of 0, 2.7, and 3.5 weight percent.

The RVP levels selected reflect the current 9 psi limit, the maximum RVP adjustment currently allowed in MOBILE6.2 (11.7 psi), and the maximum RVP of the fuels in this test program (13.3 psi).[*] The oxygenate levels were chosen on the basis of the minimum content required for serious CO nonattainment areas (2.7 weight percent), the maximum

[*] 11.7 psi is the upper bound for gasoline volatility effects in the U.S. EPA MOBILE6.2 model. This level represents the highest RVP of the test fuels from which the model's gasoline volatility algorithms are based. As such, the standard version of the model treats any gasoline with volatility over 11.7 psi as 11.7 psi fuel.

level currently allowed (3.5 weight percent), and the elimination of an oxygenate requirement (0 weight percent).*

Code Modifications to Incorporate Adjustment Factors and Provide for Comparisons – Two versions of MOBILE6.2 were used in the inventory analysis of the nine fuel scenarios. One was the standard U.S. EPA model with the 11.7 psi RVP upper limit raised to 13.3 psi, and the second was developed by modifying the source code to update the treatment of temperature, volatility, and oxygenate effects as measured in the CRC E-74b test data. A summary of these models is outlined below.

- U.S. EPA MOBILE6.2 – This is the standard regulatory model currently available from the U.S. EPA. The maximum volatility effect of 11.7 psi was modified for this project by raising it to 13.3 psi. This means that the model's existing RVP correction algorithms were extrapolated to 13.3 psi, and the correction equation coefficients were unchanged.

- Updated Adjustment Factor Version of MOBILE6.2 – The U.S. EPA model was modified with updated Tier 1 and later vehicle adjustment factors for varying temperature, gasoline volatility, and oxygenate levels based on the CRC E-74b test program. The maximum volatility effect of 11.7 psi was raised to the test program maximum of 13.3 psi. Note that although none of the vehicles in the test program were "high emitters," the oxygenate adjustment factors developed here were also applied to vehicles in that emissions regime.†

For modeling volatility effects below 75ºF, the U.S. EPA version of MOBILE6.2 applies a multiplicative adjustment factor to correct for gasoline volatility in excess of 9.0 psi (where the adjustment factor equals unity at 9.0 psi). The exponential equation used to define the multiplicative adjustment factor below 75ºF is as follows:

$$RVP_{ADJ} = EXP\left(RVP_{COEFF} \bullet (RVP - 9)\right) \bullet \left(\frac{T - 45}{30}\right)$$

Where

RVP_{ADJ} =	RVP adjustment (unitless multiplier),
RVP_{COEFF} =	RVP equation coefficient (psi^{-1}),
RVP =	RVP (psi), and
T =	Temperature (°F).

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*Because Clark County is still designated as a "serious" nonattainment area with respect to attainment of the eight-hour CO NAAQS, winter gasoline is still required by the Clean Air Act to contain at least 2.7% oxygen by weight.

†The revised Tier 1 and later vehicle oxygenate corrections (for normal emitters) were found to be greater than the existing model assumption for high emitters (a value carried over from Tier 0 vehicles). Engineering judgment was applied in which the oxygenate effect for high emitters of a given vehicle technology would not be less than those estimated for normal emitters. Therefore, the Tier 1 and later vehicle high emitter oxygenate corrections were modified to equal those estimated for normal emitters.

However, an alternate form of the RVP adjustment equation (that used by the model for temperatures over 75ºF) was used as the basis for the updated adjustment factor version of MOBILE6.2. This equation, which combines both temperature and RVP adjustments, is shown below. The equation also includes a combined temperature and RVP term allowing for a varying RVP effect as temperature changes.*

$$\mathrm{T\ \&\ RVP_{ADJ}} = \mathrm{EXP}\left(\mathrm{RVP_{COEFF}}\left(\mathrm{RVP}-9\right)\right) + \mathrm{T_{COEFF}}\left(\mathrm{T}-75\right) + \mathrm{RT_{COEFF}}\left(\mathrm{RVP}-9\right)\left(\mathrm{T}-75\right)$$

Where

$\mathrm{T\ \&\ RVP_{ADJ}}$ =	Combined temperature and RVP adjustment (unitless multiplier),
$\mathrm{RVP_{COEFF}}$ =	RVP term coefficient (psi^{-1}),
$\mathrm{T_{COEFF}}$ =	Temperature term coefficient ($^{o}\mathrm{F}^{-1}$),
$\mathrm{RT_{COEFF}}$ =	Combined RVP and temperature term coefficient ($^{o}\mathrm{F}^{-1}\mathrm{psi}^{-1}$),
RVP =	RVP (psi), and
T =	Temperature (^{o}F).

The updated equation coefficients ($\mathrm{RVP_{COEFF}}$, $\mathrm{T_{COEFF}}$, and $\mathrm{RT_{COEFF}}$) were programmed directly into the source code, including conditional statements needed to make proper vehicle technology distinctions (i.e., keep the Tier 0 code unchanged and continuing to use the existing U.S. EPA modeling approach). Additional minor code modifications were made so that additional vehicle characteristics were available (for model year and vehicle class) such that vehicle technologies could be correctly identified. Lastly, the model's existing temperature corrections for Tier 1 and later vehicles were deactivated to avoid double counting the temperature correction, given that the new equation and coefficients in the updated model encompass both temperature and volatility corrections.

For modeling oxygenate effects, MOBILE6.2 applies a multiplicative adjustment factor to correct for oxygen levels between zero and 3.5 weight percent (where the adjustment factor equals unity at zero oxygen content). The equation used to define the multiplicative adjustment is as follows:

$$\mathrm{OXY_{ADJ}} = 1 + \left(\frac{\mathrm{OXY} \bullet \mathrm{OXY_{COEFF}}}{100}\right)$$

Where

$\mathrm{OXY_{ADJ}}$ =	OXY adjustment (unitless multiplier),
$\mathrm{OXY_{COEFF}}$ =	OXY equation coefficient (% exhaust impact/wt. % oxygen), and
OXY =	Weight percent oxygen (in gasoline-oxygenate blend).

*This equation is improved over the default MOBILE6.2 equation because it allows for the evaluation of all coefficients (temperature and RVP) based on the actual test data and because it does not simply assume a linear decay in the 75ºF RVP effect between 75º and 45º as computed by the U.S. EPA model.

The updated oxygenate effect coefficients (OXY_{COEFF}) were programmed directly into the source code, including conditional statements needed to make proper vehicle technology distinctions. Additional code modifications were made so that FTP phase-specific coefficients could be applied. This differs from the regulatory version of the model in which the coefficients are uniform for all FTP phases (i.e., based on FTP composite test results). Combining the FTP phase-specific corrections into start and running exhaust corrections was modeled on the similar approach developed for temperature and volatility by the U.S. EPA.[*†]

It should be noted that because the fuel scenarios include the case of 9.0 psi and zero oxygen content (instances where the adjustment factors for these two effects become unity), the only difference in predicted emission rates between model versions for this specific case becomes the temperature correction adjustments. This allows for a quantification of the temperature adjustment differences alone, independent of the other fuel adjustments.

6.2 Results

The winter on-road CO emission inventories for Las Vegas obtained using MOBILE6.2 and the updated adjustment factors are presented in Table 6-3 for each of the nine combinations of RVP and oxygen content, for each of the three analysis years. The results are also presented graphically in Figures 6-2 through 6-4.

As can be seen from the data in Table 6-3 and more easily in Figure 6-2, use of the updated adjustment factors for oxygenate content has a profound impact on the Las Vegas CO inventory. Figure 6-2 shows only the oxygenate effect at the three oxygenate levels analyzed for gasoline at 9.0 psi RVP for the three analysis years. The first point is that the predicted reduction in CO emissions associated with moving from zero to 3.5% oxygen by weight is more than 3 times greater using the updated adjustments than is

[*]In MOBILE6.2, exhaust emissions are estimated for two components: the running LA4 plus the incremental start offset; however, correction factors within MOBILE6.2 continue to be applied on an FTP phase-specific basis, as they were originally derived in MOBILE5 and earlier versions. The MOBILE6.2 model applies both Phase 1 and Phase 3 corrections to the incremental start exhaust (depending on the length of the vehicle soak period); the model applies a weighted Bag 2 and Bag 3 correction to the running LA4 exhaust. See the MOBILE6.2 technical documentation "Exhaust Emission Temperature Correction Factors for MOBILE6: Adjustments for Engine Start and Running LA4 Emissions for Gasoline Vehicles (M6.STE.004)" for an elaboration and justification of this approach as well as a discussion of its shortfalls.
[†]Consideration was given to whether phase-specific corrections should be retained or alternatively whether corrections should be converted into "start increments" and "running exhaust" using the regression analysis of the U.S. EPA for the development of exhaust basic emission rates. The concerns with the alternative approach were (1) that the U.S. EPA analysis was based on predominately high-emitting Tier 0 vehicles and was not representative of the CRC test fleet, and (2) that the regression coefficients should not remain constant across conditions that include varying temperature and fuel parameters. For these reasons, and for maintaining consistency with MOBILE6.2, the phase-specific correction method was retained.

Table 6-3 Comparison of Las Vegas Winter On-Road CO Inventory Based on MOBILE6.2 and Updated Adjustment Factors (tons per day)						
RVP	MOBILE6.2			Updated Adjustment Factors		
	0 % Oxygen	2.7% Oxygen	3.5% Oxygen	0 % Oxygen	2.7% Oxygen	3.5% Oxygen
2006						
9	473	443	434	392	319	301
11.7	559	523	513	440	359	339
13.3	643	602	590	449	366	345
2010						
9	480	459	453	368	294	277
11.7	566	540	532	402	322	303
13.3	650	620	611	411	329	310
2015						
9	475	459	455	341	268	252
11.7	556	537	531	360	284	267
13.3	635	613	607	367	290	272

Figure 6-2
Winter On-Road CO Emission Inventory for Clark County, Nevada
9 RVP Gasoline

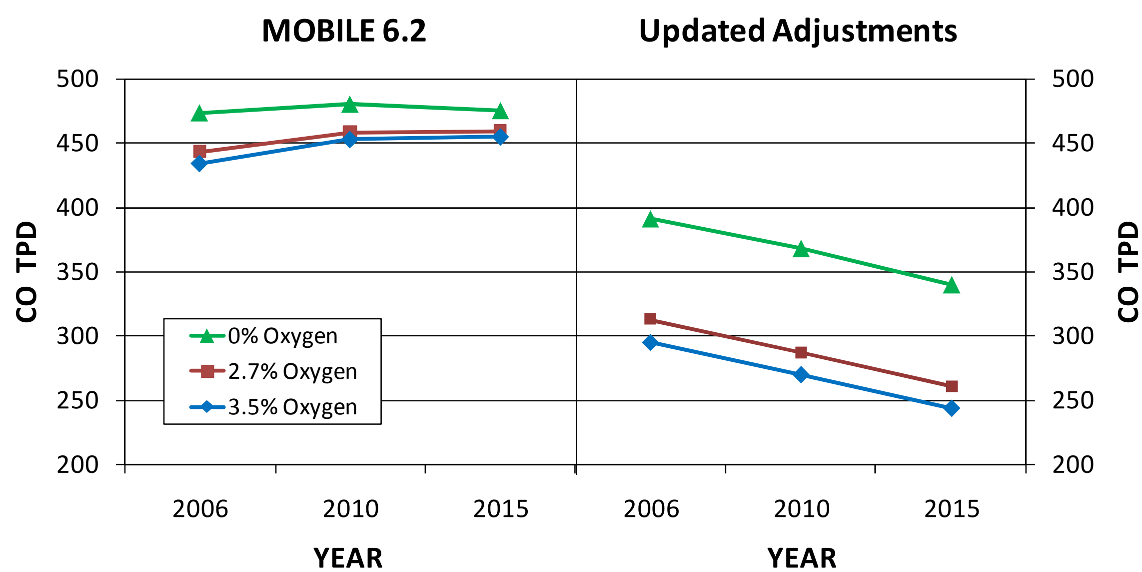


Figure 6-3
2010 Winter On-Road CO Emission Inventory for Clark County, Nevada as a Function of RVP

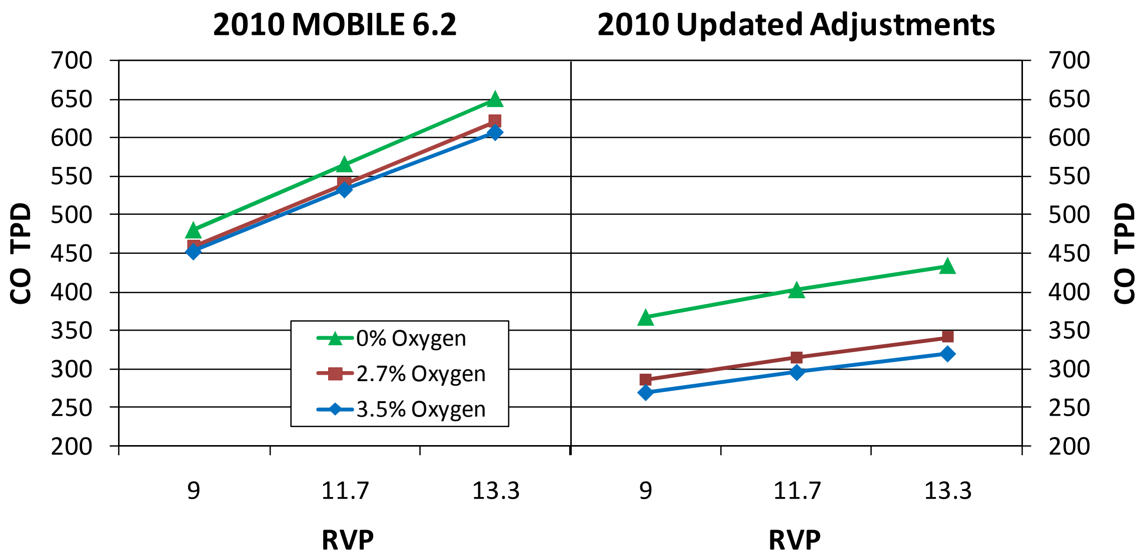
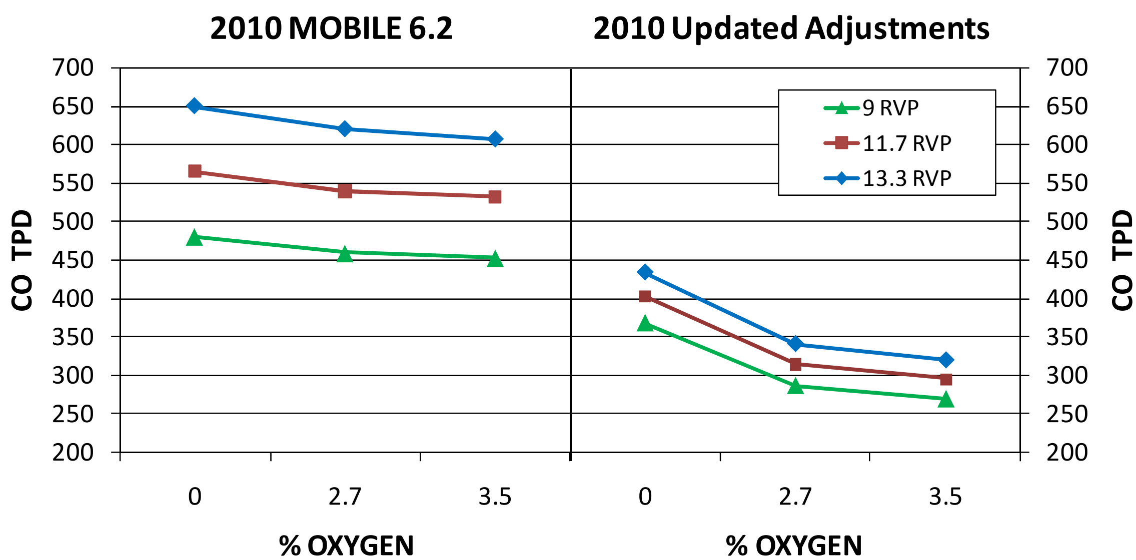


Figure 6-4
2010 Winter On-Road CO Emission Inventory for Clark County, Nevada as a Function of Oxygenate Level



predicted by MOBILE6.2. The second point is that because the updated adjustments show oxygen impacts in advanced technology vehicles, the trend in CO emissions over time at a given oxygen content decreases, rather than increases as predicted by MOBILE6.2.

Figures 6-2 and 6-3 compare the 2010 inventories generated using MOBILE6.2 and the updated adjustment factors as a function of RVP for constant oxygenate levels and as a function of oxygenate content for constant RVP, respectively. As shown in Figure 6-2, the updated adjustment factors show significantly smaller RVP impacts, as evidenced by the smaller slopes of the lines. Indeed, the updated adjustment model results in a 45 percent reduction in the RVP effect in 2010 for this modeling scenario. Figure 6-3 again highlights the large differences between the MOBILE6.2 and updated oxygenate adjustments.

Moreover, the two model results for 0% oxygen at 9.0 psi can be compared to illustrate the differences in temperature corrections (as reported in Table 6-3). In 2010, the updated adjustment model inventory of 368 tons per day is 23 percent less than the 480 tons per day inventory using the standard MOBILE6.2. Both MOBILE6.2 models estimate an increase in CO for temperatures below 75ºF; however, the increase in CO at lower temperatures is significantly less in the updated adjustments model.

Finally, one additional comparison of the E-74b data to MOBILE6.2 was performed. In this comparison, FTP composite CO emission rates at standard conditions from the E-74b program were compared against the MOBILE6.2 output emission rates at similar conditions. In order to perform this comparison, MOBILE6.2 was run at 75°F, 9.0 psi, and 0 wt% oxygen for calendar year 2006.[*] The individual test vehicles were matched to MOBILE6.2 emission factor predictions based on vehicle weight class and model year, and the results were averaged over the four technology groups examined for this study. The four results are shown in Table 6-4. Notably, the Tier 1 technology group and the model prediction are the most similar (a 16 percent difference). However, the improvement in CO exhaust with successive technology groups is much greater in the test fleet (relative to that predicted by the model). This sample population suggests that CO emission rates are declining more quickly than what is assumed in MOBILE6.2.

[*] Trip length, vehicle soak periods, start emissions and driving cycle adjustments were defined to simulate those characteristics of the FTP composite test cycle. Moreover, the high emitter fraction of the fleet was forced to zero (i.e., 100 percent of the fleet was normal emitters).

Table 6-4
Comparison of E-74b and MOBILE6.2 Emission Rates FTP Composite CO Exhaust Emissions at Standard Conditions (grams per mile)

Technology Group	MOBILE6.2	CRC E-74b	Percent Difference
Tier 1	5.8	4.9	-16%
NLEV	2.2	1.3	-41%
Tier 2, Enhanced Evaporative	1.3	0.7	-50%
Tier 2, Near Zero Evaporative	1.2	0.2	-81%

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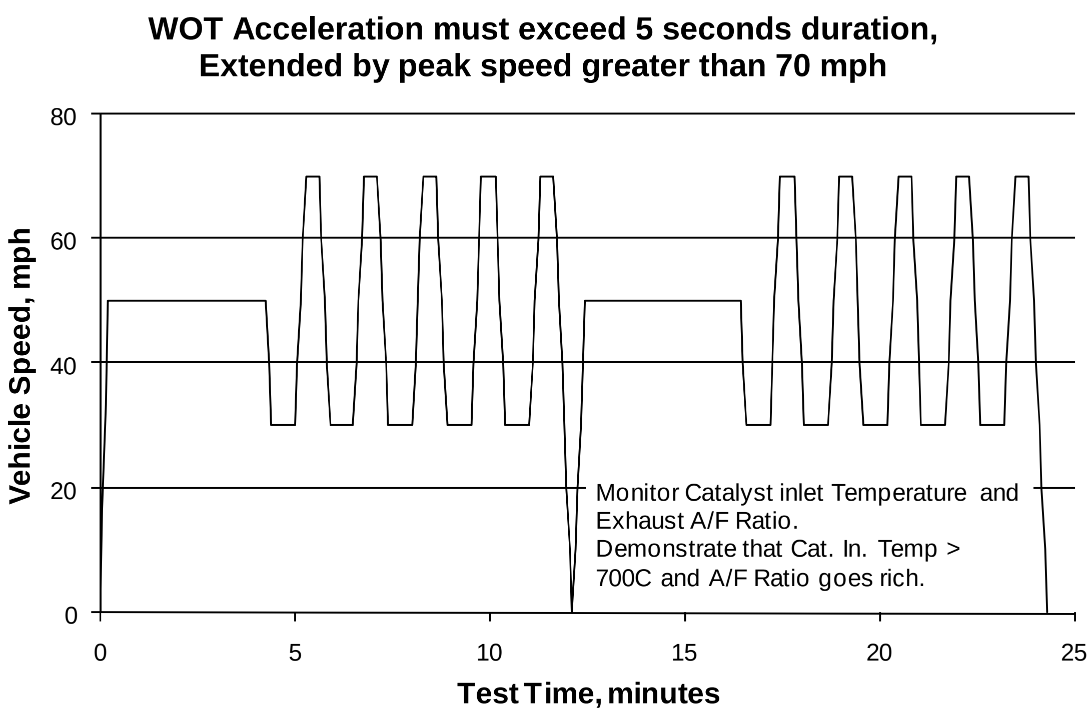
APPENDIX A

Sulfur Removal Protocol Used in Testing

Sulfur Removal Protocol Used in Testing

This procedure is designed to cause the vehicle to transiently run rich at high catalyst temperature, so as to remove accumulated sulfur from the catalyst via hydrogen sulfide formation. The drive trace is shown below the descriptive protocol. The catalyst inlet temperature and the exhaust air/fuel (A/F) ratio must be monitored during this procedure. It is required to demonstrate that the catalyst inlet temperature exceeds 700°C during the wide-open throttle (WOT) accelerations and that rich air/fuel mixtures are achieved during WOT. If these parameters are not achieved, increased loading on the dynamometer should be added for this protocol (but not during the emissions test).

1. Drive the vehicle from idle to 55 mph and hold speed for 5 minutes (to bring catalyst to full working temperature).
2. Reduce vehicle speed to 30 mph and hold speed for one minute.
3. Accelerate at WOT for a minimum of 5 seconds, to achieve a speed in excess of 70 mph. Continue WOT above 70 mph, if necessary to achieve 5-second acceleration duration. Hold the peak speed for 15 seconds and then decelerate to 30 mph.
4. Maintain 30 mph for one minute.
5. Repeat steps 3 and 4 to achieve 5 WOT excursions.
6. One sulfur removal cycle has been completed.
7. Repeat steps 1 to 5 for the second sulfur removal cycle.
8. The protocol is complete if the necessary parameters have been achieved.



APPENDIX B

Additional Vehicle and Test Information and Emissions Data

Test Vehicle VIN and Engine/Evap Family					
Veh No	Model Year	Make	VIN	Engine Family	Evaporative Family
001	1994	Chevrolet	2G1WL54T0R1115291	R1G3.1V7GAEA	R1G1058AYM0A
002	1996	Ford	1FALP52U6TG137967	TFM3.0V8GKEK	TFM1115AYMEB
003	1995	Jeep	1J4FJ67S6SL657625	SCR4.078GAEA	SCR1058AYP0N
004	1999	Honda	AHGCG5651XA016867	XHNXV02.3PA3	XHNXR0130AAA
005	2001	Toyota	1NXBR12E81Z533653	1TYXV01.8FFA	1TYXR0115AK1
006	2002	Nissan	1N4AL11D42C224558	2NSXV02.5D5A	2NSXR0120RCB
007	2001	Dodge	2B4GP44361R210600	1CRXT03.32DP	1CRXR0165XAA
008	2002	Chevrolet	1GNDS13S422364628	2GMXT04.2185	2GMXR0175922
009	2004	Dodge	1B3EL36X54N278471	4CRXV02.4VE0	4CRXR0130GBA
010	2004	Chevrolet	2G1WF52E049104510	4GMXV03.8042	4GMXR0124919
011	2004	Toyota	4T1BF30K94U575699	4TYXV03.0WMA	4TYXR0130A11
012	2006	Ford	1FAFP53U16A148832	6FMXV03.0VEY	6FMXR0185GAK
013	2004	Dodge	1D7HA16N94J136979	4CRXT04.75J0	4CRXR0218GDH
014	2004	Ford	1FMYU02174KA86202	4FMXT03.01FE	4FMXR0110BBE
015	2004	Toyota	JTEDPZ1AZ40035821	4TYXT03.3PEM	4TYXR0165P21

Test Results - Vehicle 001														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4831	AsRcvd	75	0.786	0.841	10.35	1.523	423.9	20.1	0.073	0.117	3.53	0.537	426.4	20.6
5060	1	50	0.935	1.050	10.67	1.993	469.2	17.4	0.073	0.110	2.22	0.755	451.3	18.7
5034	2	50	0.857	0.965	11.01	1.817	452.0	18.0	0.058	0.103	2.49	0.841	455.9	18.5
5082	3	50	0.945	1.078	14.74	1.830	474.4	17.3	0.063	0.117	2.37	0.757	465.0	18.5
5165	4	50	1.132	1.274	16.92	2.552	476.7	16.2	0.055	0.095	1.64	0.868	455.1	17.9
5072	5	50	0.925	1.057	14.35	1.871	459.9	17.7	0.096	0.146	4.05	0.808	458.4	18.5
5138	1	75	0.742	0.838	7.41	1.784	443.9	18.6	0.058	0.098	2.42	0.749	451.4	18.7
5010	2	75	0.801	0.911	10.34	1.487	463.4	17.6	0.102	0.175	6.39	0.608	464.0	17.9
5154	3	75	0.829	0.944	10.90	1.648	435.1	19.0	0.115	0.173	5.48	0.597	440.9	19.3
5131	4	75	0.716	0.807	8.19	1.892	448.7	17.7	0.051	0.097	2.73	0.791	449.5	18.0
5148	5	75	0.866	0.986	14.07	1.728	438.4	18.6	0.128	0.197	7.46	0.782	447.6	18.7
5089	6	75	0.900	1.027	12.63	1.713	441.6	18.9	0.058	0.109	2.29	0.801	454.0	19.2
5097	6	75	0.903	1.023	10.74	1.755	452.1	18.6	0.061	0.108	2.25	0.818	466.5	18.7
5112	7	75	0.873	0.987	10.07	1.701	452.6	18.2	0.071	0.118	2.37	0.667	462.8	18.3
5119	7	75	0.814	0.924	9.37	1.742	453.9	18.2	0.059	0.106	2.66	0.677	459.4	18.5
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4831	AsRcvd	75	0.158	0.193	3.82	1.042	350.9	24.9	0.244	0.288	5.03	0.880	405.2	21.5
5060	1	50	0.160	0.208	3.29	1.042	386.7	21.7	0.276	0.332	4.27	1.091	437.2	19.2
5034	2	50	0.124	0.163	3.31	0.970	379.3	22.1	0.242	0.298	4.48	1.079	434.1	19.3
5082	3	50	0.186	0.239	3.90	1.102	387.6	22.0	0.280	0.350	5.36	1.075	445.7	19.0
5165	4	50	0.186	0.236	4.73	1.345	378.1	21.2	0.314	0.378	5.66	1.348	438.4	18.3
5072	5	50	0.205	0.274	6.25	1.200	389.4	21.5	0.298	0.371	6.79	1.137	439.8	19.1
5138	1	75	0.125	0.165	5.22	1.076	386.6	21.6	0.218	0.270	4.23	1.054	432.1	19.4
5010	2	75	0.237	0.308	11.65	0.716	378.2	21.4	0.285	0.365	8.66	0.820	440.3	18.7
5154	3	75	0.147	0.195	4.40	0.955	377.3	22.5	0.272	0.339	6.31	0.913	422.2	20.0
5131	4	75	0.179	0.236	5.35	1.237	384.3	20.8	0.224	0.282	4.58	1.142	431.4	18.6
5148	5	75	0.329	0.414	14.43	0.870	365.6	22.1	0.336	0.420	10.75	1.002	423.2	19.5
5089	6	75	0.167	0.215	3.58	1.034	387.2	22.4	0.263	0.329	4.79	1.054	433.1	19.9
5097	6	75	0.153	0.209	6.05	1.200	391.8	21.9	0.261	0.326	5.05	1.117	443.0	19.5
5112	7	75	0.178	0.230	5.68	1.121	379.1	22.0	0.267	0.329	4.87	1.006	437.7	19.2
5119	7	75	0.177	0.234	5.61	0.959	388.1	21.5	0.248	0.311	4.86	0.976	438.7	19.1

Test Results - Vehicle 002															
			Bag 1						Bag 2						
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4784	AsRcvd	75	0.418	0.469	4.96	0.768	398.0	21.9	0.025	0.057	1.22	0.318	417.8	21.2
4903	1	50	0.555	0.664	10.37	0.862	431.2	19.0	0.030	0.068	1.14	0.362	436.0	19.5
4816	2	50	0.544	0.650	11.47	0.845	426.1	19.1	0.013	0.056	1.16	0.334	416.7	20.3
4827	3	50	0.562	0.680	14.55	0.732	409.8	19.9	0.002	0.039	1.05	0.301	420.7	20.5
4836	4	50	0.673	0.803	18.73	1.116	411.5	18.5	0.029	0.057	0.51	0.349	422.6	19.3
4926	5	50	0.532	0.645	12.38	0.824	413.9	19.8	0.008	0.036	1.26	0.346	431.1	19.9
4938	1	75	0.431	0.515	3.96	0.751	394.9	21.2	0.029	0.066	0.83	0.385	423.1	20.1
4880	2	75	0.410	0.486	5.23	0.698	390.3	21.3	0.031	0.055	0.84	0.304	418.1	20.3
4957	3	75	0.428	0.520	6.15	0.743	400.2	21.1	0.010	0.050	1.07	0.349	424.1	20.3
4949	4	75	0.359	0.439	4.32	0.780	396.5	20.3	0.012	0.048	0.63	0.406	418.4	19.5
4890	5	75	0.434	0.518	7.26	0.733	392.3	21.3	0.021	0.053	1.07	0.303	405.5	21.2
4982	6	75	0.430	0.516	5.42	0.798	398.9	21.5	0.020	0.055	0.65	0.313	418.0	21.0
4990	6	75	0.497	0.596	6.84	0.818	402.3	21.2	0.017	0.053	1.09	0.340	419.7	20.9
4964	7	75	0.406	0.496	5.10	0.782	398.3	21.0	0.030	0.070	0.81	0.387	419.7	20.3
4972	7	75	0.400	0.487	5.31	0.768	400.8	20.8	0.030	0.069	0.90	0.352	424.1	20.1
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4784	AsRcvd	75	0.123	0.162	1.71	0.469	331.2	26.6	0.133	0.171	2.13	0.453	389.9	22.6
4903	1	50	0.080	0.129	1.58	0.521	337.5	25.1	0.153	0.208	3.17	0.509	408.0	20.6
4816	2	50	0.075	0.121	1.40	0.522	332.4	25.4	0.140	0.197	3.36	0.491	395.5	21.2
4827	3	50	0.097	0.148	1.71	0.468	329.1	26.1	0.144	0.202	4.03	0.436	393.3	21.6
4836	4	50	0.078	0.123	1.39	0.506	328.0	24.8	0.176	0.230	4.53	0.551	394.4	20.4
4926	5	50	0.090	0.134	1.56	0.570	338.6	25.2	0.139	0.189	3.65	0.507	402.1	21.1
4938	1	75	0.074	0.120	1.50	0.502	335.0	25.3	0.125	0.174	1.67	0.493	393.1	21.5
4880	2	75	0.066	0.112	1.48	0.484	324.0	26.1	0.119	0.160	1.92	0.435	386.5	21.8
4957	3	75	0.079	0.125	1.49	0.446	335.8	25.6	0.116	0.168	2.24	0.457	394.9	21.7
4949	4	75	0.069	0.116	1.41	0.501	334.0	24.3	0.100	0.148	1.61	0.510	390.7	20.8
4890	5	75	0.101	0.133	1.76	0.424	320.4	26.6	0.128	0.172	2.54	0.426	379.4	22.5
4982	6	75	0.159	0.208	1.59	0.571	330.1	26.4	0.143	0.192	1.90	0.484	390.0	22.4
4990	6	75	0.094	0.143	1.58	0.504	346.3	25.2	0.138	0.190	2.42	0.484	395.9	22.0
4964	7	75	0.086	0.135	1.50	0.483	337.1	25.2	0.124	0.176	1.89	0.495	392.6	21.6
4972	7	75	0.081	0.127	1.52	0.527	335.5	25.3	0.121	0.172	1.98	0.486	395.0	21.5

Test Results – Vehicle 003														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4975	AsRcvd	75	1.149	1.267	12.29	2.988	462.1	18.3	0.423	0.533	7.69	1.837	501.2	17.3
5001	1	50	1.134	1.344	14.11	2.274	489.7	16.5	0.167	0.278	2.10	0.751	532.0	15.9
5118	2	50	1.140	1.310	10.33	3.260	476.5	17.1	0.272	0.396	4.77	1.321	520.3	16.1
5035	3	50	1.176	1.381	15.14	2.629	490.9	16.7	0.224	0.345	3.87	0.930	535.0	16.0
5128	4	50	1.279	1.484	12.96	3.661	485.1	16.1	0.214	0.332	3.99	1.429	524.6	15.4
5055	5	50	1.343	1.570	18.34	2.674	486.0	16.6	0.304	0.432	5.58	0.975	526.4	16.1
5005	1	75	0.932	1.079	7.93	2.146	463.6	17.8	0.209	0.328	2.67	0.676	523.7	16.1
5075	2	75	1.091	1.251	9.92	2.917	470.1	17.4	0.326	0.446	4.94	1.009	517.0	16.2
5046	3	75	1.039	1.199	10.33	2.290	467.1	17.8	0.282	0.407	4.55	0.732	522.1	16.3
5021	4	75	0.779	0.901	6.43	2.106	459.6	17.3	0.165	0.260	1.54	0.681	506.2	16.1
5013	5	75	1.034	1.194	11.22	2.036	455.2	18.1	0.401	0.545	6.32	0.679	505.9	16.7
5065	6	75	1.148	1.330	11.92	2.325	477.6	17.6	0.249	0.383	4.41	0.779	519.1	16.7
5068	6	75	1.036	1.215	10.43	2.338	461.0	18.3	0.259	0.388	4.75	0.944	526.6	16.4
5096	7	75	1.075	1.247	9.53	2.973	474.1	17.4	0.266	0.396	4.19	1.291	523.9	16.1
5103	7	75	1.027	1.214	9.41	3.059	472.0	17.5	0.269	0.380	4.49	1.203	514.2	16.4
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4975	AsRcvd	75	0.712	0.796	8.85	3.183	407.9	21.0	0.653	0.757	8.96	2.446	467.5	18.4
5001	1	50	0.547	0.664	4.51	2.294	420.9	19.8	0.473	0.606	5.26	1.492	492.6	17.0
5118	2	50	0.614	0.726	5.80	2.992	412.7	20.1	0.547	0.677	6.21	2.184	481.6	17.3
5035	3	50	0.624	0.744	5.97	2.699	427.1	19.7	0.532	0.670	6.79	1.770	496.1	17.0
5128	4	50	0.538	0.652	5.40	3.120	411.2	19.4	0.524	0.659	6.24	2.357	485.2	16.5
5055	5	50	0.626	0.748	6.73	2.513	418.8	20.0	0.608	0.755	8.55	1.751	488.4	17.1
5005	1	75	0.535	0.654	4.88	1.998	410.7	20.3	0.449	0.574	4.37	1.345	480.2	17.5
5075	2	75	0.673	0.794	7.56	2.542	410.3	20.1	0.580	0.709	6.70	1.828	477.9	17.4
5046	3	75	0.593	0.702	5.73	2.158	412.2	20.5	0.524	0.653	6.08	1.448	480.5	17.6
5021	4	75	0.472	0.582	3.84	2.016	407.5	19.7	0.377	0.482	3.19	1.345	469.3	17.2
5013	5	75	0.736	0.871	8.50	2.157	404.4	20.5	0.625	0.770	7.94	1.369	467.4	17.9
5065	6	75	0.588	0.720	6.23	2.219	411.8	20.8	0.529	0.672	6.47	1.496	480.9	17.9
5068	6	75	0.602	0.719	6.44	2.330	414.7	20.6	0.515	0.651	6.39	1.615	482.2	17.8
5096	7	75	0.624	0.752	6.07	2.791	413.2	20.1	0.532	0.671	5.82	2.053	483.1	17.3
5103	7	75	0.575	0.684	5.80	2.854	413.1	20.2	0.510	0.636	5.87	2.041	477.6	17.5

Test Results - Vehicle 004														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4896	AsRcvd	75	0.257	0.260	3.11	0.409	343.5	25.5	0.000	0.008	0.94	0.017	338.9	26.2
5347	1	50	0.325	0.391	4.05	0.816	389.8	21.5	0.014	0.025	1.13	0.023	373.5	22.7
5392	2	50	0.343	0.404	3.56	0.767	382.3	21.9	0.016	0.028	1.09	0.039	366.9	23.1
5416	3	50	0.333	0.399	6.75	0.558	387.4	21.7	0.005	0.020	1.26	0.031	367.9	23.4
5371	4	50	0.308	0.371	3.28	0.812	385.8	20.9	0.006	0.020	0.67	0.016	370.7	22.0
5378	5	50	0.329	0.390	6.21	0.537	381.7	22.0	0.010	0.024	1.25	0.053	367.3	23.3
5408	1	75	0.202	0.245	2.72	0.456	357.7	23.5	0.014	0.024	1.08	0.003	358.7	23.7
5398	2	75	0.250	0.301	3.11	0.430	360.7	23.2	0.012	0.028	1.50	0.011	365.1	23.2
5357	3	75	0.204	0.247	3.60	0.391	356.4	23.9	0.005	0.026	1.35	0.009	357.8	24.1
5344	4	75	0.189	0.228	2.25	0.451	363.7	22.3	0.011	0.019	0.54	0.010	362.9	22.5
5363	5	75	0.310	0.370	5.13	0.352	359.2	23.4	0.018	0.033	1.36	0.015	358.0	23.9
5350	6	75	0.198	0.239	4.28	0.325	358.3	24.1	0.006	0.031	1.96	0.020	367.6	23.7
5353	6	75	0.266	0.321	4.93	0.389	361.9	23.8	0.014	0.032	1.26	0.021	366.2	23.9
5333	7	75	0.243	0.292	2.82	0.431	363.6	23.2	0.010	0.025	1.20	0.009	357.6	23.8
5335	7	75	0.203	0.247	2.58	0.442	363.3	23.3	0.008	0.024	0.88	0.028	363.1	23.5
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4896	AsRcvd	75	0.001	0.014	0.76	0.041	285.9	31.0	0.054	0.062	1.34	0.105	325.3	27.2
5347	1	50	0.007	0.022	0.70	0.066	328.2	25.9	0.077	0.100	1.62	0.199	364.4	23.2
5392	2	50	0.014	0.027	0.71	0.035	315.7	26.9	0.083	0.105	1.50	0.189	356.0	23.7
5416	3	50	0.003	0.017	0.84	0.033	321.3	26.9	0.073	0.098	2.28	0.141	359.2	23.9
5371	4	50	0.005	0.019	0.65	0.060	317.2	25.7	0.068	0.093	1.21	0.193	359.2	22.7
5378	5	50	0.012	0.027	0.87	0.066	313.6	27.4	0.077	0.101	2.17	0.157	355.5	24.0
5408	1	75	0.009	0.022	0.71	0.039	311.5	27.3	0.051	0.069	1.32	0.107	345.5	24.5
5398	2	75	0.012	0.026	0.95	0.041	316.9	26.7	0.061	0.084	1.68	0.106	351.0	24.1
5357	3	75	0.012	0.027	1.10	0.054	311.2	27.7	0.048	0.072	1.75	0.100	344.7	24.9
5344	4	75	0.011	0.024	0.68	0.043	320.0	25.5	0.048	0.064	0.93	0.111	351.3	23.2
5363	5	75	0.015	0.028	1.25	0.034	316.8	27.0	0.078	0.102	2.11	0.090	346.9	24.6
5350	6	75	0.018	0.034	1.41	0.059	319.1	27.4	0.049	0.075	2.29	0.094	352.3	24.7
5353	6	75	0.025	0.038	1.32	0.062	316.3	27.6	0.069	0.093	2.04	0.109	351.6	24.8
5333	7	75	0.010	0.023	0.67	0.034	319.6	26.7	0.058	0.080	1.39	0.103	348.4	24.4
5335	7	75	0.014	0.025	0.76	0.054	318.5	26.8	0.050	0.071	1.20	0.121	351.0	24.2

Test Results - Vehicle 005														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4729	AsRcvd	75	0.261	0.282	2.69	0.341	304.9	28.7	0.039	0.058	1.14	0.070	288.3	30.7
4755	1	50	0.360	0.423	5.08	0.349	326.8	25.4	0.002	0.008	0.48	0.070	310.2	27.4
4759	2	50	0.376	0.448	4.85	0.326	325.4	25.5	0.022	0.042	0.73	0.072	314.9	26.9
4802	3	50	0.338	0.410	5.55	0.309	320.5	26.2	0.020	0.035	0.27	0.134	301.8	28.7
4747	4	50	0.416	0.484	4.09	0.362	325.6	24.6	0.026	0.047	0.75	0.038	310.0	26.3
4821	5	50	0.335	0.404	5.53	0.365	329.0	25.4	0.014	0.030	0.62	0.072	310.9	27.6
4776	1	75	0.218	0.266	2.58	0.326	301.9	27.8	0.028	0.037	0.45	0.116	303.9	28.0
4782	2	75	0.238	0.285	3.20	0.295	309.9	27.0	0.027	0.062	1.65	0.066	307.3	27.5
4733	3	75	0.230	0.280	3.51	0.272	302.2	28.1	0.021	0.036	0.69	0.040	305.3	28.3
4767	4	75	0.220	0.257	2.62	0.310	313.7	25.7	0.016	0.026	0.42	0.051	307.9	26.5
4808	5	75	0.212	0.272	3.48	0.255	301.3	28.0	0.025	0.036	0.69	0.090	301.2	28.5
4845	6	75	0.209	0.256	3.17	0.295	307.3	28.1	0.006	0.017	0.39	0.105	309.4	28.4
4855	6	75	0.223	0.273	3.60	0.260	300.6	28.7	0.019	0.036	0.66	0.059	298.7	29.4
4870	7	75	0.217	0.264	3.08	0.282	301.4	27.9	0.011	0.026	0.32	0.077	300.6	28.4
4875	7	75	0.210	0.256	2.90	0.314	303.6	27.7	0.007	0.014	0.22	0.096	306.6	27.9
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4729	AsRcvd	75	0.090	0.105	1.09	0.189	241.5	36.6	0.099	0.117	1.45	0.159	278.9	31.6
4755	1	50	0.034	0.053	1.22	0.181	264.4	32.0	0.085	0.106	1.63	0.158	301.1	28.1
4759	2	50	0.045	0.064	1.06	0.149	265.9	31.8	0.102	0.133	1.68	0.146	303.6	27.8
4802	3	50	0.048	0.073	1.14	0.150	257.5	33.4	0.094	0.123	1.60	0.175	293.5	29.2
4747	4	50	0.042	0.059	0.89	0.151	271.5	30.0	0.111	0.141	1.48	0.136	302.0	26.9
4821	5	50	0.039	0.058	1.26	0.170	260.3	32.8	0.087	0.115	1.82	0.160	300.7	28.4
4776	1	75	0.041	0.057	0.80	0.176	256.0	33.1	0.071	0.090	0.99	0.176	290.3	29.2
4782	2	75	0.054	0.073	1.56	0.238	253.5	33.2	0.078	0.111	1.95	0.161	293.0	28.7
4733	3	75	0.045	0.062	0.93	0.142	251.6	34.2	0.071	0.094	1.34	0.116	289.9	29.6
4767	4	75	0.038	0.055	1.01	0.176	256.3	31.7	0.064	0.082	1.04	0.139	295.0	27.6
4808	5	75	0.051	0.067	1.53	0.159	256.8	33.2	0.071	0.094	1.50	0.143	289.0	29.6
4845	6	75	0.037	0.061	1.42	0.145	250.8	34.8	0.057	0.079	1.25	0.156	292.9	29.8
4855	6	75	0.025	0.051	0.68	0.146	249.1	35.2	0.063	0.089	1.28	0.124	285.5	30.6
4870	7	75	0.035	0.057	1.19	0.172	253.9	33.4	0.060	0.084	1.13	0.146	287.9	29.5
4875	7	75	0.024	0.040	0.67	0.156	252.9	33.7	0.054	0.071	0.90	0.158	291.2	29.2

Test Results - Vehicle 006															
			Bag 1						Bag 2						
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4726	AsRcvd	75	0.152	0.180	3.657	0.306	401.7	21.8	0.016	0.027	0.623	0.028	361.0	24.6
4778	1	50	0.327	0.381	5.19	0.745	435.3	19.2	0.019	0.036	0.82	0.037	385.2	22.1
4770	2	50	0.315	0.368	4.42	0.605	436.7	19.1	0.012	0.026	0.73	0.053	382.2	22.2
4791	3	50	0.352	0.412	5.95	0.770	432.8	19.5	0.018	0.041	1.13	0.046	383.1	22.5
4765	4	50	0.301	0.356	4.81	0.782	423.8	18.9	0.016	0.038	0.85	0.042	382.4	21.3
4815	5	50	0.291	0.362	5.69	0.824	433.2	19.4	0.013	0.029	0.94	0.040	382.8	22.4
4781	1	75	0.144	0.180	3.72	0.380	413.8	20.3	0.020	0.042	1.20	0.047	371.3	22.9
4804	2	75	0.159	0.201	4.54	0.444	415.2	20.1	0.015	0.049	2.57	0.163	377.6	22.3
4753	3	75	0.135	0.173	4.06	0.380	414.8	20.5	0.008	0.029	1.00	0.036	373.4	23.1
4760	4	75	0.156	0.195	3.79	0.387	420.9	19.2	0.019	0.044	0.64	0.056	380.3	21.5
4823	5	75	0.108	0.156	3.77	0.391	403.0	21.1	0.010	0.037	1.68	0.076	370.1	23.1
4877	6	75	0.153	0.197	4.74	0.472	405.3	21.3	0.014	0.036	1.18	0.056	367.2	23.9
4881	6	75	0.142	0.186	4.20	0.372	413.2	20.9	0.013	0.035	0.81	0.054	371.3	23.6
4841	7	75	0.164	0.210	4.51	0.402	412.2	20.4	0.006	0.031	0.72	0.046	378.8	22.5
4849	7	75	0.144	0.182	3.62	0.349	410.9	20.5	0.013	0.032	0.64	0.050	375.3	22.7
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4726	AsRcvd	75	0.023	0.037	1.17	0.158	345.2	25.6	0.046	0.062	1.40	0.122	365.1	24.2
4778	1	50	0.025	0.049	1.75	0.323	364.4	23.2	0.085	0.111	1.98	0.263	389.8	21.7
4770	2	50	0.032	0.049	1.88	0.291	364.9	23.1	0.080	0.104	1.81	0.233	388.8	21.7
4791	3	50	0.035	0.051	1.89	0.287	356.1	24.1	0.092	0.120	2.34	0.262	386.0	22.2
4765	4	50	0.028	0.045	1.30	0.342	353.4	23.0	0.078	0.106	1.79	0.278	383.0	21.2
4815	5	50	0.018	0.047	1.97	0.316	359.1	23.8	0.072	0.103	2.21	0.279	386.8	22.1
4781	1	75	0.032	0.052	1.98	0.286	353.0	23.9	0.049	0.073	1.94	0.182	375.1	22.6
4804	2	75	0.029	0.055	2.80	0.307	348.7	24.1	0.049	0.082	3.04	0.261	377.4	22.3
4753	3	75	0.030	0.050	1.69	0.223	357.3	24.1	0.040	0.065	1.82	0.158	377.6	22.8
4760	4	75	0.030	0.054	1.53	0.244	361.4	22.5	0.051	0.078	1.54	0.176	383.5	21.2
4823	5	75	0.034	0.052	1.88	0.277	356.2	24.0	0.037	0.066	2.17	0.197	373.1	22.9
4877	6	75	0.021	0.046	1.95	0.281	346.5	25.2	0.045	0.072	2.13	0.204	369.4	23.6
4881	6	75	0.016	0.042	1.51	0.240	346.8	25.2	0.041	0.068	1.71	0.171	373.3	23.4
4841	7	75	0.019	0.048	1.26	0.249	349.3	24.4	0.042	0.073	1.66	0.175	377.6	22.5
4849	7	75	0.022	0.045	1.30	0.275	350.0	24.3	0.043	0.067	1.44	0.174	375.8	22.6

Test Results - Vehicle 007

			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4794	AsRcvd	75	0.234	0.263	1.85	0.645	436.9	20.2	0.015	0.023	0.47	0.104	465.9	19.1
4920	1	50	0.329	0.390	2.45	0.971	486.1	17.4	0.010	0.020	0.04	0.290	491.8	17.3
4953	2	50	0.454	0.547	3.13	1.378	504.1	16.7	0.000	0.026	0.03	0.345	503.1	16.9
4835	3	50	0.300	0.369	2.88	0.795	485.8	17.6	0.015	0.023	0.13	0.066	483.5	17.9
4828	4	50	0.311	0.368	2.51	0.916	479.7	16.9	0.003	0.011	0.06	0.102	478.0	17.1
4927	5	50	0.329	0.391	2.83	1.434	497.7	17.1	0.012	0.026	0.59	0.340	492.8	17.5
4895	1	75	0.253	0.281	1.95	0.788	452.3	18.7	0.012	0.021	0.08	0.136	473.6	18.0
4885	2	75	0.232	0.271	1.91	0.805	438.4	19.3	0.011	0.024	1.99	0.192	469.6	18.0
4848	3	75	0.225	0.271	1.82	0.704	446.7	19.2	0.004	0.023	0.82	0.098	480.3	18.0
4944	4	75	0.223	0.266	1.53	1.152	456.1	17.8	0.007	0.018	0.00	0.326	483.6	16.9
4956	5	75	0.233	0.283	2.22	1.151	452.7	18.9	0.013	0.032	1.06	0.411	482.3	17.8
4966	6	75	0.241	0.296	1.73	1.197	455.5	19.2	0.013	0.025	0.00	0.363	482.9	18.2
4971	6	75	0.222	0.270	1.48	1.015	453.4	19.3	0.011	0.025	0.00	0.292	478.6	18.4
4983	7	75	0.244	0.293	1.62	0.912	453.3	18.7	0.011	0.020	0.00	0.222	482.0	17.8
4989	7	75	0.239	0.288	1.69	0.828	447.6	19.0	0.014	0.026	0.00	0.167	483.1	17.7

			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4794	AsRcvd	75	0.029	0.044	0.74	0.246	385.3	23.0	0.064	0.078	0.83	0.255	437.7	20.3
4920	1	50	0.017	0.034	0.22	0.249	407.1	20.9	0.078	0.101	0.59	0.420	467.4	18.2
4953	2	50	0.002	0.036	0.46	0.672	400.5	21.2	0.094	0.137	0.79	0.649	475.1	17.9
4835	3	50	0.020	0.033	0.30	0.227	394.3	21.9	0.075	0.097	0.75	0.261	459.5	18.8
4828	4	50	0.006	0.023	0.15	0.318	393.8	20.8	0.067	0.088	0.60	0.330	455.2	18.0
4927	5	50	0.015	0.035	0.48	0.620	402.8	21.4	0.079	0.104	1.02	0.644	469.1	18.3
4895	1	75	0.029	0.032	0.45	0.228	388.1	21.9	0.066	0.078	0.57	0.296	445.7	19.1
4885	2	75	0.030	0.047	2.35	0.265	381.8	22.1	0.062	0.082	2.07	0.339	439.0	19.2
4848	3	75	0.017	0.032	0.85	0.246	390.6	22.1	0.053	0.077	1.04	0.264	448.7	19.2
4944	4	75	0.006	0.027	0.13	0.359	403.9	20.3	0.051	0.072	0.35	0.506	456.0	17.9
4956	5	75	0.028	0.056	2.41	0.463	399.2	21.4	0.063	0.090	1.67	0.579	453.4	18.9
4966	6	75	0.020	0.037	0.25	0.403	403.4	21.8	0.062	0.084	0.43	0.547	455.3	19.3
4971	6	75	0.019	0.041	0.29	0.487	401.0	21.9	0.057	0.080	0.39	0.496	452.0	19.4
4983	7	75	0.017	0.035	0.18	0.289	411.7	20.8	0.061	0.081	0.39	0.384	456.7	18.7
4989	7	75	0.019	0.040	0.26	0.432	401.1	21.3	0.062	0.084	0.42	0.377	453.2	18.9

Test Results - Vehicle 008															
			Bag 1						Bag 2						
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5136	AsRcvd	75	0.240	0.265	1.80	0.605	584.4	15.1	0.009	0.017	0.12	0.061	567.9	15.7
5169	1	50	0.380	0.436	2.32	0.519	613.4	13.8	0.014	0.019	0.08	0.033	587.3	14.5
5203	2	50	0.491	0.552	1.80	0.697	636.6	13.3	0.009	0.020	0.17	0.027	600.6	14.2
5212	3	50	0.712	0.789	7.10	0.471	644.9	13.2	0.007	0.017	0.17	0.058	595.7	14.5
5163	4	50	0.349	0.396	2.15	0.572	630.9	12.9	0.007	0.018	0.10	0.022	618.4	13.2
5235	5	50	0.431	0.482	2.53	0.618	630.8	13.5	0.005	0.013	0.34	0.060	599.9	14.4
5223	1	75	0.349	0.394	1.88	0.466	615.0	13.8	0.018	0.020	0.21	0.054	579.9	14.7
5252	2	75	0.271	0.310	1.33	0.496	598.9	14.1	0.013	0.017	0.33	0.060	584.0	14.6
5228	3	75	0.345	0.390	1.88	0.588	615.4	14.0	0.006	0.011	0.28	0.045	587.1	14.7
5207	4	75	0.250	0.289	1.55	0.520	593.3	13.7	0.007	0.013	0.16	0.024	583.9	14.0
5149	5	75	0.301	0.346	2.61	0.593	586.6	14.6	0.004	0.016	0.25	0.070	579.2	14.9
5271	6	75	0.284	0.322	1.60	0.552	581.4	15.1	0.008	0.013	0.25	0.021	578.7	15.2
5276	6	75	0.271	0.308	1.59	0.588	606.5	14.4	0.009	0.014	0.21	0.024	591.4	14.9
5184	7	75	0.252	0.291	1.78	0.528	580.5	14.7	0.013	0.022	0.11	0.035	576.2	14.9
5187	7	75	0.254	0.297	1.68	0.505	590.3	14.4	0.017	0.023	0.19	0.024	579.5	14.8
			Bag 3						FTP Composite						
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5136	AsRcvd	75	0.018	0.030	0.20	0.215	493.7	18.0	0.059	0.072	0.49	0.216	550.9	16.1
5169	1	50	0.011	0.026	0.10	0.244	495.8	17.2	0.089	0.107	0.55	0.192	567.6	15.0
5203	2	50	0.014	0.022	0.20	0.283	506.8	16.8	0.110	0.131	0.52	0.236	582.3	14.6
5212	3	50	0.014	0.028	0.29	0.177	514.0	16.8	0.155	0.180	1.64	0.176	583.5	14.8
5163	4	50	0.008	0.024	0.10	0.243	515.6	15.9	0.078	0.098	0.52	0.197	592.7	13.8
5235	5	50	0.006	0.015	0.18	0.289	517.9	16.6	0.094	0.111	0.75	0.239	583.8	14.7
5223	1	75	0.009	0.018	0.10	0.210	498.2	17.1	0.084	0.097	0.52	0.182	564.7	15.1
5252	2	75	0.009	0.020	0.25	0.289	494.3	17.2	0.065	0.078	0.51	0.213	562.5	15.1
5228	3	75	0.012	0.024	0.24	0.239	505.8	17.1	0.078	0.093	0.60	0.211	570.7	15.2
5207	4	75	0.011	0.022	0.13	0.237	503.7	16.3	0.058	0.073	0.44	0.185	563.7	14.5
5149	5	75	0.015	0.026	0.22	0.298	485.8	17.7	0.069	0.087	0.73	0.241	555.1	15.5
5271	6	75	0.008	0.020	0.19	0.209	490.5	17.9	0.065	0.079	0.51	0.183	555.0	15.8
5276	6	75	0.008	0.019	0.16	0.185	491.2	17.9	0.063	0.077	0.48	0.185	567.0	15.5
5184	7	75	0.014	0.026	0.17	0.237	494.6	17.3	0.063	0.079	0.47	0.193	554.7	15.4
5187	7	75	0.008	0.022	0.23	0.253	496.3	17.2	0.064	0.080	0.51	0.187	558.9	15.3

Test Results - Vehicle 009														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5351	AsRcvd	75	0.119	0.128	1.25	0.167	352.1	25.1	0.010	0.009	0.07	0.019	385.9	23.1
5430	1	50	0.241	0.268	1.71	0.253	433.8	19.5	0.010	0.014	0.06	0.013	450.2	18.9
5366	2	50	0.238	0.263	1.78	0.197	436.9	19.3	0.014	0.019	0.07	0.011	440.4	19.3
5413	3	50	0.232	0.264	2.41	0.227	435.5	19.7	0.006	0.006	0.13	0.016	446.8	19.4
5379	4	50	0.205	0.232	1.50	0.282	436.3	18.6	0.004	0.012	0.04	0.044	446.8	18.3
5393	5	50	0.247	0.278	2.68	0.206	434.7	19.6	0.001	0.010	0.14	0.024	442.1	19.5
5439	1	75	0.136	0.158	1.36	0.188	410.7	20.6	0.012	0.016	0.11	0.009	436.5	19.5
5372	2	75	0.119	0.138	1.15	0.192	414.5	20.4	0.002	0.010	0.23	0.010	444.5	19.1
5361	3	75	0.114	0.131	1.63	0.149	404.6	21.3	0.002	0.007	0.16	0.002	424.6	20.4
5385	4	75	0.106	0.126	1.25	0.189	408.3	20.0	0.000	0.005	0.02	0.021	435.3	18.8
5449	5	75	0.127	0.146	1.37	0.196	414.7	20.7	0.005	0.007	0.20	0.015	435.6	19.8
5421	6	75	0.138	0.161	1.55	0.189	409.2	21.4	0.008	0.010	0.03	0.020	438.7	20.1
5427	6	75	0.163	0.187	1.72	0.191	415.9	21.0	0.005	0.009	0.11	0.016	443.8	19.8
5403	7	75	0.136	0.157	1.03	0.180	413.3	20.6	0.010	0.012	0.08	0.020	435.0	19.7
5407	7	75	0.135	0.155	1.47	0.192	407.4	20.9	0.005	0.007	0.05	0.019	433.0	19.8
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5351	AsRcvd	75	0.003	0.005	0.05	0.014	302.4	29.4	0.031	0.033	0.31	0.049	355.9	25.0
5430	1	50	0.005	0.005	0.02	0.007	378.9	22.5	0.057	0.064	0.39	0.061	427.2	19.9
5366	2	50	0.009	0.015	0.05	0.017	375.4	22.7	0.059	0.068	0.42	0.051	421.9	20.1
5413	3	50	0.000	0.002	0.13	0.016	374.5	23.1	0.051	0.058	0.61	0.060	424.6	20.4
5379	4	50	0.000	0.007	0.02	0.023	377.8	21.7	0.045	0.056	0.34	0.087	425.6	19.2
5393	5	50	0.004	0.008	0.18	0.015	378.3	22.8	0.053	0.065	0.68	0.059	423.0	20.3
5439	1	75	0.006	0.010	0.08	0.016	372.4	22.9	0.036	0.044	0.36	0.048	413.5	20.6
5372	2	75	0.005	0.008	0.02	0.016	378.0	22.5	0.027	0.036	0.36	0.049	420.0	20.2
5361	3	75	0.009	0.011	0.07	0.010	365.7	23.7	0.027	0.034	0.44	0.035	404.3	21.4
5385	4	75	0.005	0.008	0.04	0.028	369.4	22.2	0.023	0.031	0.28	0.058	411.6	19.9
5449	5	75	0.002	0.009	0.20	0.013	371.5	23.2	0.030	0.036	0.44	0.052	413.7	20.8
5421	6	75	0.003	0.010	0.07	0.015	373.3	23.6	0.034	0.041	0.36	0.054	414.6	21.2
5427	6	75	0.004	0.011	0.15	0.016	371.9	23.7	0.037	0.046	0.45	0.053	418.3	21.0
5403	7	75	0.006	0.012	0.01	0.020	375.7	22.8	0.035	0.042	0.26	0.053	414.2	20.6
5407	7	75	0.004	0.007	0.04	0.017	372.9	23.0	0.032	0.037	0.34	0.054	411.2	20.8

Test Results - Vehicle 010														
			Bag 1					Bag 2						
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
25649	AsRcvd	75	0.197	0.232	2.40	0.125	469.4	18.8	0.015	0.037	0.20	0.007	467.1	19.0
4737	1	50	0.331	0.396	7.14	0.127	442.6	18.8	0.011	0.030	0.07	0.010	438.7	19.4
4746	2	50	0.318	0.382	5.22	0.127	443.4	18.8	0.023	0.042	0.16	0.002	436.6	19.5
4766	3	50	0.325	0.388	7.17	0.124	440.0	19.1	0.017	0.035	0.10	0.004	438.0	19.8
4771	4	50	0.314	0.377	6.03	0.127	441.9	18.1	0.014	0.032	0.15	0.008	434.8	18.8
4820	5	50	0.253	0.318	5.48	0.139	427.7	19.7	0.012	0.036	0.09	0.005	428.6	20.1
4787	1	75	0.177	0.218	1.98	0.122	428.8	19.7	0.022	0.041	0.09	0.013	427.7	19.9
4752	2	75	0.163	0.202	2.54	0.092	425.4	19.8	0.000	0.021	0.12	0.004	423.8	20.1
4761	3	75	0.192	0.241	2.74	0.094	422.6	20.3	0.027	0.045	0.22	0.005	426.6	20.3
4793	4	75	0.149	0.189	2.12	0.079	400.4	20.3	0.016	0.036	0.10	0.011	420.1	19.5
4807	5	75	0.176	0.226	2.67	0.083	406.8	20.9	0.018	0.036	0.07	0.010	419.3	20.6
4862	6	75	0.142	0.193	2.63	0.092	408.5	21.3	0.012	0.040	0.15	0.005	420.9	20.9
4871	6	75	0.175	0.223	2.72	0.111	413.4	21.0	0.017	0.043	0.24	0.004	409.3	21.5
4840	7	75	0.139	0.190	2.37	0.092	404.2	21.0	0.000	0.032	0.13	0.001	421.3	20.3
4844	7	75	0.173	0.216	2.62	0.092	402.0	21.0	0.010	0.034	0.15	0.007	418.4	20.4
			Bag 3					FTP Composite						
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
25649	AsRcvd	75	0.028	0.053	0.29	0.023	377.7	23.5	0.056	0.082	0.68	0.036	443.0	20.0
4737	1	50	0.012	0.030	0.06	0.014	351.7	24.2	0.078	0.106	1.53	0.035	415.6	20.4
4746	2	50	0.015	0.038	0.17	0.012	356.3	23.9	0.082	0.111	1.21	0.030	416.0	20.4
4766	3	50	0.017	0.036	0.12	0.014	346.2	25.0	0.081	0.109	1.57	0.031	413.2	20.8
4771	4	50	0.013	0.033	0.14	0.015	358.5	22.8	0.076	0.104	1.37	0.035	415.3	19.6
4820	5	50	0.011	0.034	0.17	0.016	343.6	25.1	0.062	0.094	1.23	0.035	405.0	21.2
4787	1	75	0.021	0.040	0.15	0.047	349.2	24.4	0.054	0.078	0.50	0.045	406.4	20.9
4752	2	75	0.010	0.029	0.17	0.022	350.0	24.3	0.037	0.061	0.63	0.027	403.8	21.0
4761	3	75	0.025	0.044	0.14	0.011	352.8	24.5	0.061	0.086	0.72	0.025	405.5	21.3
4793	4	75	0.017	0.035	0.10	0.018	344.5	23.8	0.044	0.068	0.52	0.027	395.3	20.7
4807	5	75	0.015	0.038	0.10	0.019	343.4	25.1	0.050	0.076	0.62	0.027	395.8	21.7
4862	6	75	0.015	0.041	0.17	0.017	344.3	25.5	0.040	0.072	0.67	0.026	397.3	22.1
4871	6	75	0.013	0.035	0.23	0.020	339.8	25.9	0.049	0.078	0.75	0.031	391.1	22.4
4840	7	75	0.009	0.038	0.13	0.019	343.4	24.9	0.031	0.066	0.60	0.025	396.3	21.5
4844	7	75	0.014	0.036	0.21	0.022	338.7	25.2	0.045	0.072	0.68	0.029	393.1	21.7

Test Results - Vehicle 011														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5354	AsRcvd	75	0.165	0.181	1.12	0.072	420.6	21.1	0.015	0.014	0.00	0.014	420.8	21.2
5431	1	50	0.259	0.295	0.99	0.126	458.2	18.5	0.011	0.017	0.00	0.012	435.2	19.6
5412	2	50	0.344	0.387	1.69	0.173	453.6	18.6	0.013	0.018	0.00	0.021	437.9	19.4
5397	3	50	0.248	0.284	1.71	0.111	451.6	19.0	0.011	0.014	0.00	0.001	433.8	20.0
5370	4	50	0.246	0.284	1.26	0.147	463.4	17.6	0.019	0.021	0.00	0.023	442.8	18.5
5426	5	50	0.208	0.242	1.48	0.101	452.7	18.9	0.014	0.014	0.00	0.007	435.4	19.8
5404	1	75	0.091	0.107	0.75	0.106	424.4	20.0	0.006	0.017	0.00	0.004	432.8	19.7
5448	2	75	0.089	0.105	0.77	0.142	421.3	20.1	0.006	0.012	0.00	0.010	432.8	19.7
5443	3	75	0.085	0.102	0.68	0.135	420.1	20.6	0.006	0.011	0.00	0.004	427.2	20.3
5435	4	75	0.077	0.094	0.86	0.109	423.8	19.3	0.011	0.012	0.00	0.006	432.7	18.9
5374	5	75	0.099	0.116	0.93	0.101	422.8	20.3	0.008	0.013	0.00	0.010	434.5	19.8
5380	6	75	0.091	0.107	0.68	0.098	424.1	20.7	0.010	0.010	0.00	0.006	429.9	20.5
5382	6	75	0.087	0.105	1.01	0.098	421.2	20.8	0.004	0.011	0.00	0.008	430.0	20.5
5386	7	75	0.074	0.089	0.72	0.099	420.9	20.3	0.005	0.009	0.00	0.007	430.2	19.9
5388	7	75	0.082	0.098	0.99	0.104	414.4	20.6	0.012	0.016	0.00	0.012	429.9	19.9
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5354	AsRcvd	75	0.010	0.010	0.00	0.019	347.9	25.6	0.045	0.047	0.23	0.028	400.8	22.2
5431	1	50	0.001	0.006	0.00	0.053	360.6	23.7	0.060	0.072	0.20	0.047	419.5	20.3
5412	2	50	0.004	0.008	0.00	0.104	351.1	24.2	0.079	0.092	0.35	0.075	417.2	20.4
5397	3	50	0.004	0.009	0.00	0.066	357.2	24.3	0.058	0.069	0.35	0.042	416.4	20.8
5370	4	50	0.007	0.012	0.00	0.034	358.9	22.8	0.063	0.073	0.26	0.052	424.0	19.3
5426	5	50	0.003	0.007	0.00	0.004	354.7	24.3	0.051	0.059	0.31	0.026	416.8	20.6
5404	1	75	0.008	0.010	0.00	0.079	358.3	23.8	0.024	0.034	0.15	0.046	410.6	20.8
5448	2	75	0.001	0.008	0.00	0.036	359.6	23.7	0.022	0.030	0.16	0.044	410.3	20.7
5443	3	75	0.002	0.009	0.00	0.054	354.4	24.4	0.022	0.029	0.14	0.045	405.7	21.3
5435	4	75	0.008	0.009	0.00	0.041	352.2	23.3	0.024	0.028	0.18	0.037	408.8	20.0
5374	5	75	0.002	0.009	0.00	0.037	356.7	24.2	0.025	0.033	0.20	0.037	410.7	21.0
5380	6	75	0.003	0.006	0.00	0.047	353.8	24.9	0.025	0.029	0.14	0.036	407.8	21.6
5382	6	75	0.006	0.008	0.00	0.009	354.6	24.8	0.021	0.030	0.21	0.027	407.5	21.6
5386	7	75	0.007	0.007	0.00	0.027	349.4	24.5	0.020	0.025	0.15	0.032	406.1	21.1
5388	7	75	0.006	0.008	0.00	0.032	355.5	24.1	0.025	0.031	0.20	0.036	406.2	21.1

Test Results - Vehicle 012														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4993	AsRcvd	75	0.245	0.263	1.63	0.092	445.2	19.8	0.032	0.032	0.00	0.003	447.1	19.9
5133	1	50	0.170	0.201	2.08	0.069	485.8	17.4	0.011	0.017	0.01	0.006	452.0	18.9
5142	2	50	0.065	0.081	0.39	0.115	464.7	18.3	0.004	0.012	0.05	0.069	455.8	18.7
5079	3	50	0.206	0.243	3.67	0.129	496.5	17.2	0.010	0.017	0.02	0.006	468.2	18.5
5073	4	50	0.156	0.186	1.39	0.202	485.3	16.8	0.015	0.021	0.00	0.112	458.7	17.9
5018	5	50	0.224	0.263	3.37	0.083	490.7	17.4	0.011	0.015	0.00	0.048	455.0	18.9
5111	1	75	0.100	0.120	0.95	0.105	453.6	18.7	0.010	0.019	0.01	0.024	465.8	18.3
5037	2	75	0.094	0.116	1.26	0.115	440.1	19.2	0.007	0.012	0.00	0.055	464.5	18.3
5006	3	75	0.086	0.106	0.76	0.078	453.7	19.0	0.011	0.017	0.00	0.039	449.8	19.3
5124	4	75	0.069	0.080	0.27	0.137	450.1	18.2	0.012	0.015	0.00	0.104	453.2	18.1
5155	5	75	0.081	0.110	1.18	0.100	440.8	19.5	0.001	0.009	0.20	0.091	452.1	19.1
5053	6	75	0.087	0.108	0.85	0.064	452.0	19.4	0.011	0.015	0.00	0.004	462.1	19.1
5056	6	75	0.093	0.114	0.87	0.056	454.0	19.3	0.007	0.013	0.01	0.012	460.4	19.1
5091	7	75	0.070	0.089	0.59	0.076	459.4	18.6	0.014	0.020	0.00	0.022	464.1	18.4
5102	7	75	0.074	0.095	0.57	0.073	453.8	18.8	0.008	0.012	0.01	0.014	460.8	18.6
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4993	AsRcvd	75	0.017	0.025	0.11	0.024	382.7	23.2	0.072	0.078	0.37	0.027	429.0	20.7
5133	1	50	0.017	0.025	0.10	0.028	397.0	21.5	0.046	0.057	0.47	0.025	443.9	19.2
5142	2	50	0.012	0.021	0.08	0.038	393.0	21.7	0.019	0.029	0.13	0.070	440.4	19.3
5079	3	50	0.007	0.015	0.06	0.010	395.7	21.9	0.050	0.063	0.79	0.032	454.1	19.0
5073	4	50	0.015	0.019	0.00	0.069	392.6	20.9	0.044	0.055	0.29	0.119	446.1	18.3
5018	5	50	0.010	0.015	0.00	0.023	387.0	22.3	0.055	0.066	0.70	0.048	443.7	19.4
5111	1	75	0.013	0.022	0.10	0.040	405.5	21.0	0.030	0.041	0.23	0.046	446.7	19.1
5037	2	75	0.012	0.020	0.04	0.122	377.7	22.5	0.026	0.036	0.27	0.086	435.6	19.5
5006	3	75	0.011	0.020	0.11	0.015	390.3	22.2	0.027	0.036	0.19	0.040	434.3	19.9
5124	4	75	0.010	0.019	0.03	0.024	389.0	21.1	0.023	0.030	0.06	0.089	434.9	18.8
5155	5	75	0.016	0.026	0.19	0.144	393.3	21.9	0.022	0.035	0.40	0.107	433.5	19.9
5053	6	75	0.007	0.017	0.08	0.031	397.5	22.1	0.026	0.035	0.20	0.023	442.2	19.9
5056	6	75	0.012	0.022	0.13	0.035	399.6	22.0	0.026	0.036	0.22	0.028	442.4	19.9
5091	7	75	0.011	0.023	0.09	0.018	394.0	21.7	0.025	0.035	0.15	0.032	443.8	19.3
5102	7	75	0.011	0.020	0.14	0.058	386.3	22.1	0.023	0.032	0.16	0.038	438.9	19.5

Test Results - Vehicle 013														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5150	AsRcvd	75	0.195	0.252	1.81	0.299	690.6	12.8	0.028	0.082	0.39	0.020	684.6	13.0
5211	1	50	0.353	0.436	3.28	0.546	727.5	11.6	0.024	0.079	0.46	0.021	713.0	12.0
5173	2	50	0.297	0.375	2.02	0.547	729.4	11.6	0.033	0.093	0.53	0.025	703.9	12.1
5170	3	50	0.360	0.449	4.43	0.562	767.0	11.2	0.031	0.091	0.50	0.013	718.7	12.0
5247	4	50	0.359	0.436	3.03	0.392	727.3	11.2	0.025	0.070	0.46	0.022	694.7	11.8
5196	5	50	0.340	0.412	4.83	0.508	724.6	11.8	0.031	0.082	0.42	0.021	706.8	12.2
5240	1	75	0.202	0.267	1.78	0.341	700.3	12.1	0.014	0.067	0.44	0.018	703.2	12.1
5222	2	75	0.229	0.295	1.99	0.345	683.4	12.4	0.034	0.082	0.46	0.017	686.5	12.4
5261	3	75	0.220	0.285	2.74	0.282	691.4	12.4	0.014	0.061	0.40	0.019	696.9	12.4
5208	4	75	0.183	0.244	1.80	0.391	697.7	11.7	0.025	0.074	0.38	0.015	695.6	11.8
5201	5	75	0.211	0.273	3.00	0.430	699.5	12.2	0.010	0.050	0.43	0.048	704.2	12.2
5227	6	75	0.192	0.259	2.51	0.356	689.8	12.7	0.026	0.076	0.51	0.015	703.4	12.5
5231	6	75	0.212	0.281	2.73	0.388	694.8	12.6	0.028	0.082	0.53	0.014	699.9	12.6
5158	7	75	0.194	0.258	2.06	0.333	681.0	12.5	0.000	0.088	0.49	0.020	684.5	12.5
5160	7	75	0.174	0.241	1.71	0.324	682.0	12.5	0.032	0.093	0.48	0.018	693.6	12.3
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5150	AsRcvd	75	0.028	0.066	0.34	0.078	580.8	15.3	0.063	0.113	0.67	0.094	657.4	13.5
5211	1	50	0.018	0.056	0.27	0.067	613.8	13.9	0.091	0.147	0.99	0.142	688.8	12.4
5173	2	50	0.019	0.058	0.27	0.061	600.2	14.2	0.084	0.142	0.77	0.143	680.7	12.5
5170	3	50	0.026	0.065	0.33	0.068	630.8	13.7	0.098	0.158	1.27	0.142	704.5	12.3
5247	4	50	0.015	0.051	0.30	0.079	610.4	13.4	0.091	0.140	0.95	0.114	678.3	12.0
5196	5	50	0.019	0.052	0.33	0.059	595.0	14.5	0.092	0.142	1.31	0.133	679.8	12.6
5240	1	75	0.018	0.058	0.31	0.069	604.7	14.1	0.054	0.106	0.68	0.099	675.5	12.6
5222	2	75	0.021	0.056	0.28	0.056	602.4	14.1	0.071	0.119	0.73	0.096	662.7	12.8
5261	3	75	0.016	0.048	0.36	0.043	598.6	14.5	0.057	0.104	0.87	0.080	668.7	12.9
5208	4	75	0.019	0.055	0.34	0.076	612.3	13.4	0.056	0.104	0.66	0.110	673.2	12.1
5201	5	75	0.040	0.079	0.36	0.078	614.3	14.0	0.060	0.104	0.94	0.135	678.6	12.7
5227	6	75	0.017	0.055	0.37	0.055	615.2	14.3	0.058	0.108	0.88	0.097	676.4	13.0
5231	6	75	0.016	0.054	0.38	0.049	613.0	14.3	0.063	0.116	0.94	0.101	674.9	13.0
5158	7	75	0.003	0.065	0.38	0.079	590.3	14.5	0.041	0.117	0.79	0.101	657.9	13.0
5160	7	75	0.017	0.063	0.40	0.078	591.6	14.4	0.057	0.115	0.71	0.098	663.2	12.9

Test Results - Vehicle 014														
			Bag 1						Bag 2					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4891	AsRcvd	75	0.158	0.159	1.11	0.150	471.0	18.8	0.007	0.013	0.03	0.091	462.5	19.2
4996	1	50	0.246	0.286	1.91	0.284	499.0	17.0	0.015	0.021	0.00	0.012	483.4	17.6
5017	2	50	0.263	0.302	1.47	0.277	491.4	17.2	0.015	0.020	0.00	0.000	483.1	17.6
4952	3	50	0.231	0.274	2.58	0.228	493.6	17.4	0.006	0.013	0.00	0.037	477.7	18.1
5002	4	50	0.293	0.341	3.22	0.201	496.6	16.3	0.007	0.013	0.00	0.022	492.2	16.6
5078	5	50	0.226	0.271	2.97	0.229	487.1	17.5	0.019	0.025	0.00	0.017	481.6	17.9
5009	1	75	0.134	0.159	0.96	0.168	483.8	17.6	0.012	0.018	0.00	0.004	482.3	17.7
4959	2	75	0.134	0.160	1.17	0.180	481.8	17.6	0.015	0.022	0.00	0.013	471.4	18.1
4931	3	75	0.192	0.219	1.38	0.207	479.7	18.0	0.021	0.026	0.03	0.021	468.5	18.5
5029	4	75	0.099	0.121	0.83	0.133	454.1	18.0	0.019	0.023	0.00	0.047	467.2	17.5
5106	5	75	0.323	0.359	1.55	0.177	485.4	17.6	0.016	0.021	0.02	0.009	503.6	17.1
4943	6	75	0.121	0.149	1.47	0.201	477.0	18.4	0.010	0.016	0.00	0.015	472.7	18.6
4948	6	75	0.180	0.208	1.26	0.143	472.7	18.5	0.016	0.021	0.00	0.004	470.7	18.7
5061	7	75	0.121	0.151	1.05	0.162	484.8	17.6	0.009	0.016	0.00	0.060	488.2	17.5
5064	7	75	0.115	0.135	1.27	0.152	480.5	17.7	0.008	0.015	0.00	0.009	479.6	17.8
			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
4891	AsRcvd	75	0.009	0.013	0.08	0.015	387.3	23.0	0.039	0.043	0.27	0.082	443.6	20.0
4996	1	50	0.008	0.020	0.00	0.057	420.1	20.3	0.061	0.075	0.40	0.081	469.2	18.2
5017	2	50	0.015	0.021	0.03	0.106	417.8	20.4	0.066	0.078	0.31	0.087	466.8	18.2
4952	3	50	0.006	0.014	0.00	0.008	415.6	20.8	0.053	0.068	0.53	0.069	464.0	18.6
5002	4	50	0.008	0.014	0.00	0.238	430.3	19.0	0.067	0.082	0.67	0.119	476.1	17.2
5078	5	50	0.003	0.025	0.20	0.052	416.4	20.7	0.058	0.076	0.67	0.071	464.9	18.5
5009	1	75	0.010	0.021	0.00	0.041	422.1	20.2	0.037	0.048	0.20	0.048	466.0	18.3
4959	2	75	0.005	0.014	0.00	0.093	407.7	20.9	0.037	0.048	0.24	0.069	456.0	18.6
4931	3	75	0.014	0.023	0.11	0.043	413.5	20.9	0.054	0.065	0.33	0.066	455.7	19.0
5029	4	75	0.014	0.019	0.00	0.019	397.2	20.6	0.034	0.042	0.17	0.057	445.3	18.4
5106	5	75	0.017	0.025	0.12	0.024	428.6	20.1	0.080	0.092	0.36	0.048	479.2	18.0
4943	6	75	0.007	0.018	0.01	0.019	408.5	21.6	0.032	0.044	0.31	0.055	456.0	19.3
4948	6	75	0.013	0.020	0.01	0.015	407.8	21.6	0.049	0.060	0.26	0.036	453.8	19.4
5061	7	75	0.012	0.024	0.11	0.004	428.2	20.0	0.033	0.046	0.25	0.066	471.0	18.2
5064	7	75	0.013	0.020	0.05	0.045	423.1	20.2	0.032	0.041	0.28	0.049	464.3	18.4

Test Results - Vehicle 015															
			Bag 1						Bag 2						
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5269	AsRcvd	75	0.167	0.188	1.38	0.157	431.8	20.5	0.008	0.018	0.00	0.095	420.0	21.2
5327	1	50	0.109	0.131	1.13	0.051	456.9	18.6	0.015	0.020	0.00	0.046	431.5	19.8
5315	2	50	0.213	0.241	1.35	0.170	471.4	18.0	0.008	0.014	0.00	0.041	433.6	19.6
5291	3	50	0.172	0.200	1.64	0.100	402.3	21.4	0.006	0.010	0.00	0.029	401.2	21.6
5303	4	50	0.172	0.201	1.31	0.160	470.9	17.3	0.005	0.007	0.00	0.033	433.7	18.9
5325	5	50	0.238	0.269	1.80	0.142	480.4	17.8	0.006	0.012	0.00	0.041	437.1	19.7
5290	1	75	0.097	0.114	0.67	0.118	449.5	18.9	0.004	0.010	0.00	0.046	432.2	19.7
5320	2	75	0.121	0.139	0.75	0.133	438.7	19.3	0.002	0.010	0.02	0.034	421.4	20.2
5311	3	75	0.118	0.141	1.29	0.100	430.3	20.0	0.010	0.015	0.00	0.050	428.4	20.2
5338	4	75	0.097	0.117	1.07	0.128	443.9	18.4	0.008	0.015	0.00	0.033	427.7	19.2
5341	5	75	0.137	0.161	1.59	0.109	439.4	19.5	0.007	0.010	0.00	0.040	428.7	20.1
5329	6	75	0.158	0.185	1.28	0.121	441.3	19.8	0.005	0.012	0.00	0.028	426.2	20.7
5332	6	75	0.118	0.141	1.24	0.116	442.4	19.8	0.003	0.011	0.00	0.041	427.4	20.6
5294	7	75	0.091	0.105	0.75	0.119	440.7	19.4	0.000	0.009	0.00	0.054	431.2	19.9
5301	7	75	0.106	0.127	0.94	0.128	445.0	19.2	0.002	0.012	0.00	0.036	433.5	19.7

			Bag 3						FTP Composite					
Test	Fuel	Temp	NMHC	HC	CO	NOX	CO2	MPG	NMHC	HC	CO	NOX	CO2	MPG
5269	AsRcvd	75	0.004	0.013	0.00	0.067	360.4	24.7	0.040	0.052	0.29	0.100	406.1	21.9
5327	1	50	0.009	0.015	0.01	0.028	367.6	23.2	0.033	0.042	0.24	0.042	419.2	20.3
5315	2	50	0.004	0.010	0.00	0.020	365.2	23.3	0.050	0.060	0.28	0.062	422.6	20.1
5291	3	50	0.010	0.015	0.04	0.016	374.9	23.1	0.042	0.050	0.35	0.040	394.2	21.9
5303	4	50	0.001	0.009	0.02	0.018	360.6	22.7	0.039	0.048	0.28	0.055	421.3	19.4
5325	5	50	0.004	0.010	0.00	0.025	362.9	23.8	0.054	0.065	0.37	0.058	425.7	20.2
5290	1	75	0.007	0.015	0.00	0.026	363.8	23.5	0.024	0.033	0.14	0.055	417.0	20.4
5320	2	75	0.009	0.012	0.01	0.026	365.0	23.3	0.029	0.038	0.17	0.053	409.5	20.8
5311	3	75	0.010	0.014	0.00	0.031	357.4	24.2	0.033	0.041	0.27	0.055	409.3	21.1
5338	4	75	0.008	0.014	0.04	0.023	371.5	22.0	0.026	0.036	0.23	0.050	415.6	19.7
5341	5	75	0.004	0.011	0.00	0.041	368.6	23.4	0.033	0.042	0.33	0.055	414.4	20.8
5329	6	75	0.006	0.015	0.02	0.033	370.5	23.8	0.037	0.049	0.27	0.049	414.1	21.2
5332	6	75	0.006	0.013	0.01	0.020	368.0	23.9	0.028	0.039	0.26	0.051	414.2	21.2
5294	7	75	0.004	0.011	0.01	0.020	363.9	23.5	0.020	0.029	0.16	0.058	414.7	20.6
5301	7	75	0.003	0.013	0.02	0.030	368.8	23.2	0.024	0.036	0.20	0.053	418.1	20.5