General Information

TITLE: The Impact of a 10% Ethanol Blended Fuel on the Exhaust Emissions of Tier 0 and Tier 1 Light Duty Gasoline Vehicles at 35º F

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SUBJECT: Evaluation of the use of 10% Ethanol.

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Executive Summary

A study to evaluate the effects of oxygenated fuels on motor vehicle emissions at low ambient temperature was conducted by the Colorado Department of Public Health and Environment, Mobile Sources Section from April 1998 through December 1998. The purpose of the oxygenated fuel evaluation was to examine the effectiveness of oxygenated fuel as a CO reduction strategy on a cross section of late model motor vehicles. Questions were raised concerning the emission reduction potential of oxygenated fuels as a means to reduce CO in a 1996 report by the National Research Council entitled “Toxicological and Performance Aspects of Oxygenated Motor Fuels” . The council pointed out that very little data had been collected on the impact of oxygenated fuel on motor vehicle generated CO at low temperatures. The CDPHE took the necessary actions to initiate a low temperature evaluation. In order to assure a large cross section of expertise into the development of the study an Oxygenated Fuel Evaluation Design Committee was formed. The Committee was comprised of representatives from the state and federal government, the petroleum industry, automobile manufacturers and higher education. A consultant from the Denver University’s Statistics Department was also engaged to provide expertise in that area.

The oxygenated fuel evaluation was designed to cover four major areas with a unifying goal of being “representative of the real world”. The first area was the temperature at which the testing would be conducted. A temperature of 35°F was selected because that represents the temperature at which Denver experiences the highest ambient CO concentrations. A temperature range of 35-40 °F is used in the State Implementation Plan (SIP) and is referred to as the design day temperature.

The second consideration was the test fuel to be used. Both the non-oxygenated and oxygenated test fuels used in the study utilized the same base stock. These fuels were refined locally and considered typical of this refinery based on the base stock common to both fuels. The oxygenated fuel selected was a 10% ethanol blend because ethanol has been used in 95% of the fuel distributed for the required oxygenated fuel program during the past several winters in Denver. The base fuel was blended with 10% ethanol to produce the oxygenated test fuel. The base fuel was also blended with reformate to increase octane and produce the mid grade test fuel. The oxygenated fuel received from the refinery was more volatile in the mid range of the distillation curve than would normally be expected for a 10% ethanol blend fuel. The impact of the increased volatility on the test results has not been quantified. However, the emissions benefits shown in this study are probably conservative because of the mid range volatility factor.

The third area of design involved two criteria; the selection of test vehicles representative of the latest federal certification requirements and the selection of vehicles as representative as possible of the in-use fleet operating in Denver. Meeting the first criterion helped assure that the latest emission control technology was evaluated in the study. Two federal certification levels for motor vehicles were evaluated during the study, Tier 0 and Tier 1. Tier 0 represents the certification standards used up to 1995. Tier 1 standards were phased in over a two year period starting in 1994. Tier 1 standards are more stringent for HC and NOx emissions but meeting these requirements may also result in lower CO emissions.

Meeting the second criterion was approached by dividing the total sample equally into both Tiers. Both Tiers contained eight LDVs or passenger cars and four LDTs or vehicles such as pick-up trucks and sport utility vehicles (SUVs) which are certified as light trucks. The vehicle selection was based on a review of registration data from the greater Denver metropolitan area. Test vehicle model years of 1991 through 1997 were selected for both being representative of the federal certification requirements and because models from these years make up the vast majority of the in-use fleet and represent the largest contribution to the area's total vehicle miles traveled (VMT). The test vehicles that comprised both tiers were selected to be as representative as possible of Denver's fleet within the constraints of the study. In addition to typical Tier 0 and Tier 1 vehicles, one LEV (Low Emitting Vehicle) and six abnormally high CO emitting vehicles were tested.

The last factor was the selection of test cycles. Three test cycles were used in the evaluation and provided a wide range of driving conditions to evaluate the oxygenated fuel effectiveness. The first test was the classical Federal Test Procedure (FTP) which is based on typical urban driving patterns. This test procedure is used to verify that new vehicles meet applicable federal emissions regulations. A second test, the Unified Cycle, is similar to the FTP in that the driving cycle is made up of three phases and is conducted in a similar manner. This cycle utilizes higher speed and acceleration rates and is presently being evaluated as a cycle more representative of today's driving conditions. The third test cycle, the REPO5 driving schedule, represents the small segment of today's driving that is very aggressive. The test includes severe accelerations and decelerations and speeds up to 80 mph. The exhaust emissions analyses conducted on all test cycles were unburned hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), carbon dioxide (CO_2) and the determination of fine particulate (PM_{10} and smaller) emissions. Based on the above analyses of HC, CO and CO_2, fuel economy was also calculated.

The results of the testing are summarized in the table below. Only the statistically significant values are listed and the LEV is not included because statistical significance cannot be determined for one vehicle.

Summary of Statistically Significant Test Results

	SET	LDVs	LDTs
	Δ, (%Δ)	Δ, (%Δ)	Δ, (%Δ)
CO (gm/mi)			
Both Tiers (24 Vehs)	-0.97,(-11.1%)	-0.86,(-10.8%)	NoSD
Tier 0 (12 Vehs)	NoSD	NoSD	NoSD
Tier 1 (12 Vehs)	?	-0.74,(-15.8%)	NoSD
High Ems (6 Vehs)	?	-	-
HC (gm/mi)			
Both Tiers (24 Vehs)	-0.09,(-15.7%)	-0.08,(-15.2%)	NoSD
Tier 0 (12 Vehs)	-0.14,(-17.3%)	-0.11,(-15.9%)	NoSD
Tier 1 (12 Vehs)	-0.04,(-11.6%)	-0.05,(-13.8%)	NoSD
High Ems (6 Vehs)	?	-	-
NOx (gm/mi)			
Both Tiers (24 Vehs)	NoSD	+0.05,(+7.11%)	NoSD
Tier 0 (12 Vehs)	NoSD	NoSD	NoSD
Tier 1 (12 Vehs)	?	+0.07,(+19.3%)	NoSD
High Ems (6 Vehs)	NoSD	-	-
PM (mgm/mi)			
Both Tiers (24 Vehs)	-3.31,(-36.0%)	-2.23,(-30.1%)	?
Tier 0 (12 Vehs)	-5.24,(-39.7%)	-3.32,(-32.2%)	NoSD
Tier 1 (12 Vehs)	-1.38,(-26.6%)	-1.14,(-25.4%)	NoSD
High Ems (6 Vehs)	NoSD	-	-
MPG (mi/gal)			
Both Tiers (24 Vehs)	-0.315,(-1.45%)	-0.370,(-1.49%)	-0.207,(-1.32%)
Tier 0 (12 Vehs)	-0.367,(-1.70%)	-0.490,(-1.97%)	NoSD
Tier 1 (12 Vehs)	-0.264,(-1.20%)	-0.249,(-1.00%)	-0.292,(-1.80%)
High Ems (6 Vehs)	NoSD	-	-

Δ, (%Δ) = Absolute, (percentage) changes which are statistically significant at the 95% confidence level
? = Change which is only statistically significant at the 90% confidence level
NoSD = Change which is not statistically significant at the 90% confidence level
- = No data

The study results for the FTP showed that overall, a CO reduction was observed with the use of the oxygenated fuel. Average subset CO reductions in the -11% range were achieved for all sixteen LDVs as well as the eight LDTs tested. The changes were statistically significant at the 95% confidence level (level of significance $\alpha = 0.05$) for the LDVs and the LDVs plus LDTs combined but were not statistically significant at the 90% confidence level ($\alpha = 0.10$) for the LDTs alone. Breaking the total sample into sets corresponding to the respective Tiers shows differences that appear to be related to the certification standards and may be influenced by mileage accumulations as well. The CO results for the LDVs plus the LDTs for each Tier also show CO reductions in the -11% range with only the Tier 1 changes being statistically significant at the 90% confidence level. The Tier 1 vehicles however showed improved base fuel emissions performance and decreased sensitivity to the oxygenated fuel as evidenced by CO emission rates less than one half those of Tier 0 and a smaller absolute grams per mile reduction from the oxygenated fuel. The reason that Tier 1 can show a statistically significant reduction although its absolute reduction is much smaller is that Tier 0's reductions are so much more variable than Tier 1's. This causes a -11.02% reduction for Tier 0 to not be statistically significant at 90% while a -11.22% reduction for Tier 1 is statistically significant. This was indicated by smaller absolute changes in CO that varied between increases and decreases from the base fuel values. The absolute CO reduction in grams per mile achieved appears to be strongly influenced by both the Tier 0/Tier 1 certification requirements and mileage accumulation. Tier 0 vehicles realized a -1.5 grams per mile reduction as compared to Tier 1 with a reduction of -0.44 grams per mile. (Both reductions were about -11%). Tier 0 vehicles with higher odometer readings and higher emissions showed the greatest benefit from the oxygenated fuel. The eight vehicles with the highest base fuel CO emission rates were all Tier 0 and accounted for 83% of the total CO reduction observed in this study even though not all of the eight showed a reduction in CO.

No composite CO test value was calculated for the Unified Cycle therefore CO results are discussed on a phase basis. This cycle was conducted as a hot test meaning there was no cold start associated with it. Because of the more aggressive nature of this cycle, CO emissions were higher overall with Tier 1 vehicles having emission rates from one fourth to one half those of Tier 0. The trends seen with the FTP were also evident with the Unified Cycle with a decrease in CO emissions generally occurring with the oxygenated fuel. The Tier 0 set showed CO changes ranging from a positive 0.1 grams per mile (+1.4%) for phase 1 to a negative 2.6 grams per mile (-27.4%) for phase 3. (Only the phase 3 reduction was statistically significant at the 95% confidence level). Tier 1 CO emissions performance was more consistent with CO reductions ranging from -0.50 to -0.73 grams per mile (-21.2% to -25.9%). Statistically significant changes were at the 90% confidence level for phase 1 and at the 95% level for phases 2 and 3. The eight vehicles with the highest CO emission rates accounted for approximately three quarters of the total CO reduction. Of those eight vehicles, the Tier 0 vehicles accounted for the majority with the highest emissions.

The effect of the oxygenated fuel was similar for the REPO5. Even higher CO values were observed with this test due to the aggressive driving required. The Tier 0 set of vehicles had a CO reduction of -2.1 grams per mile (-15.9%) which was statistically significant at the 90% confidence level. The Tier 1 vehicles once again had lower overall CO emissions and showed a decrease in CO emissions of -0.37 grams per mile (-5.6%) which was not statistically significant at 90%. Seven of the eight highest emitters were Tier 0 vehicles and six of those accounted for 70.6% of the total CO reduction achieved.

The use of the oxygenated fuel resulted in an overall decrease of HC emissions in all but one category for the REPO5. For the FTP, an average reduction in HC emissions of approximately -16.5% was seen with the oxygenated fuel for the vehicles in this study. Statistically significant reductions at the 95% confidence level were indicated for the Tier 0 and Tier 1 sets of LDVs and LDTs combined as well as for the Tier 0 and Tier 1 LDVs. HC reductions ranged from a low of -7.0% for the Tier 1 LDTs to a high of -19.4% for the Tier 0 LDTs. The HC reductions for the LDTs in both sets were not statistically significant at the 90% confidence interval.

For the Unified Cycle, HC reductions were observed for all three phases and across all vehicle categories. HC reductions for the REPO5 were indicated across all vehicle categories except the Tier 1 LDTs which showed essentially no change. The same trend shown for CO was also shown for HC. The eight vehicles with the highest HC emissions consistently showed the most benefit from the oxygenated fuel by accounting for between 73 and 97 percent of the total emission reduction achieved.

The use of the oxygenated fuel resulted in a small overall increase in NOx emissions. Fifteen out of the twenty four vehicles showed an increase in FTP NOx emissions which averaged +0.09 grams per mile. The average overall change in NOx for all twenty-four vehicles was +0.04 grams per mile (+5.6%). The NOx increase shown for all the LDVs was statistically significant at the 95% confidence level. The NOx increase was more evident for the Tier 1 vehicles. Statistically significant NOx changes at the 90% and 95% confidence levels were shown for the Tier 1 set and the Tier 1 LDVs respectively. The Tier 1 vehicles did exhibit much lower emission rates for all pollutants. This improved emissions performance appears to lead to an increased sensitivity with the oxygenated fuel that results in a NOx increase. Tier 0 showed greater NOx emissions variability which included both increases and decreases. The LDVs showed a very small NOx increase and the LDTs showed NOx reductions. No statistically significant NOx differences were indicated for Tier 0.

The FTP PM emissions were reduced overall with the oxygenated fuel. For the FTP, a PM reduction of -36.0% was achieved. The PM differences for the FTP are statistically significant at the 90% confidence level for the Tier 0 and Tier 1 combined LDTs and at the 95% confidence level for both the Tier 0 and Tier 1 sets and their respective LDVs. The more aggressive Unified Cycle had average baseline PM emissions rates both variable and relatively low of 4.9 and 2.0 milligrams per mile for both the Tier 0 and Tier 1 sets with no statistically significant differences by either Tier or vehicle type. The REPO5 resulted in base fuel PM emission rates ranging from 7.5 to 25.3 milligrams per mile with both increases and decreases shown for the various LDV/LDT subsets. No statistically significant differences by Tier or vehicle type were identified.

Fuel economy with the oxygenated fuel showed an overall decrease. A decrease is not unexpected as the oxygenated fuel has approximately 3% less energy content due to the addition of the less energy dense ethanol. The fuel economy loss ranged between -0.12 mpg (-0.8%) to -0.49 mpg (-1.98%) for the FTP. The highest indicated fuel economy loss was -0.87 mpg (-4.9%) and occurred during phase 3 of the Unified Cycle. The differences indicated for fuel economy were statistically significant for the majority of the cases at the 95% or 90% confidence level.

Six high emitter vehicles were procured and tested to determine the effect of the oxygenated fuel for higher than normal HC and CO emission rates associated with these vehicles. The high emitters responded to the oxygenated fuel and showed reductions in both CO and HC. The high emitters had FTP CO values that ranged from 30 to 350 grams per mile. The absolute reductions varied among the high emitters and the percent reduction for the FTP ranged from -8.9% to -35.2%. Statistically significant changes were identified for the FTP in the composite and phase 2 at the 90% and in phase 3 at the 95% confidence levels. For the Unified Cycle the changes in CO realized in phases 2 and 3 were statistically significant at the 95% confidence level. The changes in CO for the REPO5 were also statistically significant at the 95% confidence level. The FTP HC reduction with the oxygenated fuel was -19.6% and was statistically significant at the 90% level. The HC changes for Phase 2 of the Unified Cycle and for the REPO5 were statistically significant at the 95% confidence level.

The original plan included the testing of at least two Low Emitting Vehicles (LEVs). Only one was procured and tested. The FTP CO emissions showed an increase of +24% with the ethanol blend. However, baseline FTP CO emissions were only 0.75 grams per mile, the lowest recorded for the study. CO emission reductions, in the -40% range were observed for the more aggressive tests. With the oxygenated fuel, HC emissions were reduced for all of the test cycles and NOx increased over all of the test cycles. Baseline FTP PM emissions were very low (6 mg/mile) but still showed an -18% reduction. PM emissions decreased for the Unified Cycle but increased for the REPO5. Fuel economy penalties were observed for all test cycles except a +0.2% mpg increase on REPO5.

For a tabular summary of the overall results, please see Tables 25 through 29 on pages 47 through 52.

List of Abbreviations and Acronyms Used in This Report

505	The first 505 seconds of the urban dynamometer driving schedule
AQIRP	Air Quality Improvement Research Program
BTU	British Thermal Unit
CDPHE	Colorado Department of Public Health and Environment
CARB	California Air Resources Board
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CVS	Constant Volume Sampler
CRC	Coordinating Research Council
EPA	Environmental Protection Agency
FTP	Federal Test Procedure
g/mi	Grams per mile
GM	General Motors
LA-4	The Urban Dynamometer Driving Cycle (UDDS)
LDT	Light Duty Truck
LDV	Light Duty Vehicle i.e. Passenger car
LVW	Loaded Vehicle Weight - The curb weight of the vehicle plus 300 pounds
mg/mi	Milligrams per mile
Mobile 5a	EPA Mobile Emissions Model
NAAQS	National Ambient Air Quality Standards
NOx	Oxides of Nitrogen
OEM	Original Equipment Manufacturer
PM	Particulate Matter
PM_{10}	Particulate matter having an aerodynamic diameter less than 10 microns (μ)
(R+M)/2	Numerical average of gasoline's research and motor octane rating
REPO5	A driving schedule representing aggressive driving outside FTP boundaries
SHED	Sealed Housing Evaporative Determination
SIP	State Implementation Plan
THC	Total Hydrocarbons
UDDS	Urban Dynamometer Driving Cycle
Unified Cycle	A driving cycle designed to be more representative of "real world" driving than the UDDS

1. Introduction

In 1988 Colorado introduced the nation's first mandatory winter oxygenated fuels program. The oxygenated fuels program is intended to reduce carbon monoxide (CO) emissions from mobile sources. It is one of several control strategies incorporated into Colorado's State Implementation Plan (SIP). The decision to implement an oxygenated fuel program as a CO control strategy was based upon testing programs conducted between 1981 and 1988. The studies were conducted using randomly selected, in-use motor vehicles that represented the majority of Denver's fleet during that time period. The studies were conducted at 75 °F and showed a significant decrease in both total hydrocarbon (THC) and CO emissions. The EPA mobile model in use at the time, Mobile 3, indicated that CO reductions ranging from -8 to -11 percent were obtainable from the fleet with the use of oxygenated fuels containing a minimum of 1.5 percent oxygen by weight. Subsequent program years have specified higher oxygen concentrations which have resulted in increasing CO reduction benefits.

In 1996 a National Research Council Report raised the question of air quality benefits associated with the use of oxygenated fuels at low ambient temperatures. The report indicated that the vast majority of studies comparing the emissions performance of a non-oxygenated fuel to an oxygenated one had been conducted at nominal test temperatures of 75 °F. The point taken was that while testing conducted under standard laboratory conditions and protocols does provide valid and reliable data, the same conclusions drawn from that data may not apply under wintertime conditions. Very little data are available on the exhaust emissions effects of oxygenated fuels at low ambient temperatures with late model vehicles.

Studies on the efficacy of oxygenated fuels at low ambient temperatures are limited as to the number of vehicles and the model years evaluated and they have yielded varying results. One low temperature study conducted under the direction of the Coordinating Research Council and reported by Most (1989) had a sample of sixteen vehicles. The model years ranged from 1979-1988, which represented a wide cross section of emissions control technologies. The testing was conducted at sea level as well as at high altitude (5411 ft) at test temperatures of 35, 50 and 75 °F. The largest oxygenated fuel benefit was associated with the older technology vehicles. Vehicles equipped with progressively advanced emission control and engine management systems showed less benefit and in some cases, an increase in CO emissions. The increase in CO with the newest adaptive learning technology on 1986-88 vehicles was predominately at the high altitude condition. One drawback of this study was that the test vehicles had to meet the applicable model year federal emission standards at the time of the study. Compliance with this requirement resulted in test vehicles which were not necessarily representative of the in-use fleet. In 1994 the American Petroleum Institute (Lax 1994) sponsored a study that evaluated the effects of three different oxygenates at various concentrations at 35, 55 and 80°F. The test vehicles ranged in model years from 1981 through 1989 and represented six technology classifications. The vehicles with the older emission control technology showed the greatest emissions benefit. The CO reductions observed were greatest at 55°F and were reduced by approximately one third at 35 °F.

Knapp, et al. 1998, conducted a study that evaluated the effect of a 10% ethanol blend on the emissions of eleven vehicles at 75, 20, 0 and -20 °F. The vehicles ranged in model year from 1977 to 1994. Only three of the vehicles, a 1988, a 1989 and a 1994, were tested at 20 °F. The CO reductions ranged from -4.7 to -12.5 percent at this temperature.[1] CO reductions diminished as test temperatures decreased from 0 to -20 °F. At 0 °F, eight out of the eleven vehicles had CO reductions greater than those seen at -20 °F.

Mulawa, et al. 1997, conducted a study in Fairbanks, Alaska to determine the effect of a 10% ethanol splash blended fuel at 20, 0 and -20°F. Test results showed that that FTP CO emissions increased with decreasing temperature and that the use of the ethanol blend tended to offset this increase. At 20°F the use of the oxygenated fuel showed mixed results on the three vehicles tested. For CO emissions, reductions were indicated by two of the three vehicles. The study also studied the effect of the oxygenated fuel on PM_{10} emissions with similar results. PM_{10} emission rates were reduced on two of the three vehicles.

The intent of this study was to determine the impact of an oxygenated fuel at typical Denver winter time temperatures, on the emissions and fuel economy of late model motor vehicles. The in-use fleet is continually undergoing change as older vehicles are being replaced with newer vehicles that are equipped with more sophisticated, efficient and durable engine management and emissions control systems. These newer vehicles are certified to meet more stringent exhaust emissions standards over a longer period of time. No data are available on the emissions performance of these vehicles when operated on oxygenated fuel at reduced temperatures. The primary goal of this study was to collect the emissions data from vehicles with the latest technology and assist in the decision process to determine the future role of oxygenated fuel as an effective CO reduction strategy. A supplement to this goal includes the assessment of oxygenated fuel on the regulated emissions of unburned hydrocarbons and oxides of nitrogen as well as on fuel economy and PM_{10} emissions. A secondary goal was to evaluate the impact of oxygenated fuel on vehicles with high exhaust emissions.

2. Oxygenated Fuels Assessment Design Committee

In order to provide answers to the above issues and other questions, the Colorado Department of Public Health and Environment (CDPHE) formed an Oxygenated Fuel Assessment Design Committee. The design committee was composed of representation from state and federal government, the automotive and oil industry and higher education. The committee was charged with designing an evaluation that would address the questions and concerns in the introduction. The members of the design committee are listed in Appendix A.

[1] Throughout this report numbers indicating a reduction will be preceded by a minus sign.

3. Experimental

The study was conducted by the Mobile Sources Section of the Air Pollution Control Division at the Aurora Vehicles Emissions Technical Center. The study started in April 1998 following a laboratory upgrade that included the installation of a 48 inch diameter Horiba electric light duty vehicle chassis dynamometer in the cold cell and an R-22 refrigeration system capable of supporting vehicle testing down to 0 °F. The program tested three sets of vehicles, two of the sets were based on federal certification standards, and the third was a set of high emitters. The vehicles were tested on the 48 inch electric dynamometer at winter temperatures over three different driving schedules using commercially available winter fuels.

Driving Schedules

Three driving schedules or cycles were used in this study. The cycles were; the Urban Dynamometer Driving Schedule (UDDS) which is the basis for the Federal Test Procedure (FTP), the Unified cycle and the REPO5. These test cycles incorporate progressively higher speeds and acceleration rates. The added test cycles provided data on the effects of oxygenates under non-FTP driving conditions requiring wide open throttle and open loop engine control. The FTP provided the basis for the evaluation. This procedure provides a constant for any comparisons against past or future test programs. FTP data are also the principal inputs for EPA's MOBILE model and are required to generate comparable predicted emission rates from the different fuels. The FTP was not conducted in its entirety. No evaporative emissions assessment was made in this study, therefore the Sealed Housing Evaporative Determination (SHED) test and associated fuel tank heat build were omitted.

The Unified Cycle was designed by the California Air Resources Board (CARB) to provide a more accurate representation of real world driving and to generate more representative data for emissions inventory purposes. The Unified cycle is similar to the FTP in that it is a three phase test, but phase duration and speeds are quite different from those in the FTP. Like the FTP, the Unified cycle is intended to be conducted from a cold start condition in order to provide data on cold start emissions. For the purposes of this study however, the Unified cycle was conducted from a hot running start rather than a cold start condition. The additional time required to re-soak the vehicle for a minimum of twelve hours following the FTP was prohibitive.

The REPO5 was developed as part of the FTP revisions required in the 1990 Clean Air Act Amendments. The REPO5 driving cycle represents aggressive driving with both high speeds and very high acceleration rates. The REPO5 has been shortened from 1400 seconds to 600 seconds and has been renamed the USO6. The USO6 is a required driving schedule in the Supplemental FTP. The REPO5 was used in its entirety for this evaluation in order to assess the effects of oxygenated fuels under aggressive driving conditions and provide additional information for emissions modeling. This cycle contains acceleration conditions requiring wide open throttle and subsequently, maximum fuel enrichment. These driving conditions typically generate additional CO, HC and PM emissions. Table 1 presents a comparison of the key characteristics of each driving cycle used in the study. The speed versus time trace for each of these driving schedules is contained in Appendix B.

Table 1
Driving Schedule Comparison

	FTP	FTP BAG 1	FTP BAG 2	UNIFIED CYCLE	UC BAG 1	UC BAG 2	REPO5
Duration (seconds)	1372	505	867	1435	300	1135	1400
Distance (miles)	7.5	3.6	3.9	9.8	1.2	8.6	20.0
Average Speed (mph)	19.5	25.6	16.0	24.6	14.2	27.4	51.5
Max Speed (mph)	56.7	56.7	34.3	67.2	41.1	67.2	80.3
Max Acceleration (mph/sec)	3.3	3.3	3.3	6.9	5.8	6.9	8.5

NOTE: The same driving schedule is used for both Bag 1 and Bag 3 for the FTP and the Unified Cycle.

Test Fuels

The main focus of the study was to evaluate oxygenated fuels under "representative, real world" wintertime conditions. In keeping with that focus, the test fuels used were commercial, mid grade winter fuels refined in the Denver area. The test fuels were provided by a local refinery and were considered typical for this refinery based on the base blendstock common to both fuels. . The non-oxygenated fuel was the same as the fuel sent to the Western slope of Colorado where oxygenated fuel requirements are not in effect. This would probably be the same fuel that would be used in the front range area if there were not an oxygenated fuel program. The oxygenated test fuel contained ethanol at 10% by volume. Because ethanol represents approximately 95 percent of the oxygenates used in the Greater Denver area no other oxygenates were tested. As shown in Table 2, the properties of the two fuels were generally well matched. The one exception being the T-50 point for the oxygenated fuel. Depending on the blendstocks available to the refinery, the addition of 10% ethanol by volume results in a T-50 point approximately 30 °F lower than the non-oxygenated base fuel and results in increased volatility in the mid range of the distillation curve. The T-50 point for the oxygenated test fuel was 53 °F less than the non-oxygenated test fuel. Although the resultant increase in mid range volatility has the potential to affect both emissions and driveability, no driveability problems were encountered with the 24 Tier 0 and Tier 1 vehicles tested in the program. It is not known how much impact the higher volatility may have had on exhaust emissions but if HC and CO exhaust emissions were affected, the reductions shown in the study will tend to be smaller than they might have been. Table 2 gives the fuel properties of the non-oxygenated and oxygenated test fuels.

Table 2
Test Fuel Properties

Test Description	Non-oxygenated	Oxygenated
Specific Gravity	0.7347	0.7294
Reid vapor pressure (psi)	13.1	13.7
Distillation (°F)		
IBP	83	87
5%	95	99
10%	106	108
20%	128	122
30%	151	135
40%	178	145
50%	206	153
60%	235	202
70%	266	241
80%	299	278
90%	335	324
95%	370	360
EP	420	416
Hydrocarbon Type (L.V.%)		
Aromatics	32.3	30.1
Olefins	14.2	14.3
Saturates	53.6	55.7
Benzene	1.31	0.90
Oxygenates (V %)		
Ethanol	<0.1	10.2
All others	<0.1	<0.1
Oxygen content (Wt %)	<0.2	3.5
Lead (g/gal)	<0.002	<0.002
Sulfur, total by x-ray spectrometry (Wt %)	0.0186	0.0190
Octane		
Research Octane	92.3	92.4
Motor Octane	82.9	82.8
R+M/2	87.6	87.6

The fuels used were mid grade with an (R+M)/2 octane rating of 87.6. Regular fuels with an octane rating of 85 make up approximately 55-60% of the Denver area retail fuel sales and would have been used if the only emissions test used in the evaluation was the FTP. Additional test cycles, with higher speeds and acceleration rates combined with requirements by several auto manufacturers to use a minimum 87 octane fuel necessitated the use of a mid grade fuel. Two samples of each test fuel were randomly selected and submitted to an independent laboratory for analysis. The averages calculated from each set of analyses were then used in the calculation of net heating values which were used in the fuel economy calculations. Appendix C contains a summary of the procedures used to determine fuel economy.

Test Temperature

A test temperature of 35 °F was used to represent ambient conditions where CO reductions are needed to meet National Ambient Air Quality Standards (NAAQS). The highest ambient CO readings in Denver typically occur at 35-45 °F. This is reflected in Denver's CO SIP where the design day temperature is 35 °F. Test vehicles were prepped, soaked and tested at 35 °F and engine oil temperatures were recorded prior to the start of the FTP. Temperatures were monitored continuously during all phases of the testing and average temperatures calculated. The average temperature for all FTPs was 35.9 °F.

Test Vehicles

Four different sets of vehicles were tested in the program. The first two sets were made up of model years 1991 through 1997 and contained 12 vehicles each. These two sets represented two different levels of emissions certification and were defined by Tier 0 and Tier 1 Federal certification levels. The phasing in of Tier 1 standards started in 1994, with full compliance required by model year 1996. Table 3 shows the certification values associated with each Tier and vehicle category. The third set consisted of high emitting vehicles. The composition and procurement of this set will be discussed below. The fourth set was Low Emitting Vehicles or LEVs. Due to vehicle availability and time constraints, only one LEV was tested.

In addition to Tier 0/Tier 1 requirements, 1994 and later LDVs and LDTs had additional Federal requirements in that they had to meet Cold CO standards at 20 °F. LDVs and LDTs up to a 3750 pound LVW were required to meet a 10 g/mi standard and a 12.5 g/mi standard applied to LDTs with an LVW greater than 3750 pounds.

Table 3
Federal Certification Standards for Tier 0 / Tier 1

Passenger Car (LDV)	**STANDARDS**		
	HC	CO	NOx
Tier 0	0.41	3.4	1.0
Tier 1	0.25*	3.4	0.4
Light Duty Truck (LDT)			
Tier 0	1.0	14	1.2 - 1.7**
Tier 1	0.32*	4.4 - 5.0**	0.7 - 1.1**

*   NMHC (Non-methane hydrocarbons)
** Standard dependent on Loaded Vehicle Weight (LVW)

Selection of vehicles for the first two test sets was made based on obtaining a representative sample of Tier 0 and Tier 1 vehicles. The sample was designed to represent the Denver fleet within the size constraints of the total test program. Each set was further subdivided into light duty vehicles (LDVs) and light duty trucks (LDTs). Registration data from 103 ZIP codes that make up the Greater Denver Metro area was analyzed and showed that light duty trucks make up nearly 39% of the 1991 through 1997 light duty vehicle/light duty truck population. Based on the indicated LDV - LDT distribution, each set was made up of 8 LDVs and 4 LDTs.

Because of the relatively small number of test vehicles, a stratified random sample was used to obtain vehicles. Registration data from each set was further broken down and analyzed to determine an appropriate representative sample. Representative vehicles were selected using two criteria, the first being the frequency of makes and models by year and the second, the use of specific engines across different makes and models. Representative vehicles were then randomly procured from the in-use vehicle fleet. Tables 4 and 5 show the vehicles tested in each Tier. Table 4 shows one deviation from the 1991-1997 model year criteria. That one exception is a 1990 Honda Accord. A problem with the initial extraction of vehicles from the registration data base resulted in a small number of owners of 1990 model year vehicles receiving letters. This vehicle was procured in response to the initial mailing. Since the vehicle was certified to Tier 0 standards and represented a significant portion of the in-use fleet it was included in the study and its inclusion does not detract from the study goals.

Table 4
Tier 0 Test Vehicles

Light Duty Vehicles					
Vehicle Number	Model Year	Make	Model	Engine	Odometer
OFO98V1	1993	Toyota	Corolla	1.8	20150
OFO98V2	1990	Honda	Accord	2.2	92586
OFO98V3	1991	Ford	Escort	1.8	109295
OFO98V4	1991	Honda	Civic	1.5	110927
OFO98V7	1993	Ford	Taurus	3.8	79183
OFO98V20	1992	Toyota	Camry	2.2	88112
OFO98V23	1994	Chevrolet	Cavalier	3.1	46944
OFO98V26	1993	Saturn	SC2	1.9	34578
Light Duty Trucks					
OFO98T11	1993	Ford	Explorer	4.0	44112
OFO98T12	1991	Chevrolet	Blazer	4.3	122759
OFO98T15	1993	Jeep	Cherokee	4.0	36929
OFO98T28	1992	Chevrolet	Suburban	5.7	63119

Table 5
Tier 1 Test Vehicles

Light Duty Vehicles					
Vehicle Number	Model Year	Make	Model	Engine	Odometer
OF198V5	1996	Ford	Taurus	3.0	38267
OF198V6	1996	Saturn	LS 2	1.9	11978
OF198V9	1995	Honda	Civic	1.5	52636
OF198V19	1997	Chevrolet	Cavalier	2.4	22286
OF198V21	1997	Toyota	Camry	2.2	23045
OF98V22	1996	Honda	Accord	2.2	29885
OF198V24	1995	Pontiac	Bonneville	3.8	43817
OF198V25	1996	Subaru	Legacy	2.2	19389
Light Duty Trucks					
OF198T00	1997	Dodge	Caravan	3.0	7863
OF198T18	1996	Ford	Explorer	4.0	33724
OF198T27	1996	Chevrolet	Blazer	4.3	42610
OF198T29	1997	Ford	Expedition	5.4	14076

Of the twenty four vehicles tested, all were equipped with three way catalytic converters and twenty one had port fuel injection systems. One LDV and two LDTs from the Tier 0 set were equipped with throttle body fuel injection. Average odometer readings for Tiers 0 and 1 respectively were; 70,726 and 28,298 miles. The LDVs in both sets had the higher average odometer readings.

Vehicle Procurement

The vehicles selected to best represent the fleet were sorted from the registration data base using VIN criteria of model year, make, model and engine. The data were matched to owner's names and addresses. The owners were then sent a package that identified the voluntary nature of the study and its purpose. The package consisted of a solicitation letter explaining the study, an attachment with commonly asked questions and answers and a postage paid card for reply. This package was sent to approximately 50 vehicle owners at a time. Potential test vehicles were solicited and scheduled for an acceptance inspection based on returned post cards indicating a positive response. A sample of the procurement package is provided in Appendix D.

High Emitter Procurement

As mentioned above, one of the goals of the study was to assess the impact of an oxygenated fuel on ten vehicles classified as "high emitters". For the purpose of this study a high emitter was defined as a 1991 or newer passenger car or light truck with an I/M-240 CO value of 30 or 60 g/mi respectively. Prospective test vehicles were identified each day by examining the Enhanced I/M program's test data base from the previous day and sorting out vehicles that met the above criteria. VINs were than matched with registration records in order to obtain the owners name and address. From the registration information an attempt was made to obtain telephone numbers in order to contact the owner quickly before repairs were made to the vehicle. When an owner was contacted, the purpose of the program was explained along with the incentives offered for participating. The incentives included a free, late model loaner vehicle plus $5.00 per day, up to a maximum of $60.00, or if no loaner was required $25.00 per day, up to a maximum of $300.00. The vehicle was also returned to the owner with a full tank of fuel. In the last few months of the program free repairs were also offered. Despite these efforts only five high emitters were procured and tested. Three potential high emitters were rejected when they were tested at the laboratory and passed back to back I/M-240 tests. One vehicle was rejected because the oil pressure light was on upon arrival at the lab. The five vehicles tested were Tier 0 certified. In order to test at least one Tier 1 certified vehicle, a state owned 1994 Chevrolet Lumina LDT was identified and brought into the program. Malfunctions were introduced into the vehicle to cause it to fail an I/M-240 and it served as the sixth high emitter.

Vehicle Preparation

Potential test vehicles received an incoming inspection upon arrival at the laboratory. The inspection documents the physical condition of the vehicle and is used to determine if it is safe to test. Vehicles were rejected for excessive fluid leaks, worn tires, major exhaust system leaks or other major problems which could result in a mechanical failure during testing. In addition to the normal inspection, "high emitters" were also subjected to an I/M-240 test to verify the CO failure. Vehicles accepted into the study did not undergo any maintenance that would affect emissions performance. Maintenance was limited to items such as the repair of minor exhaust leaks or replacing studded snow tires. Each vehicle also received an oil and oil filter change using OEM filters. Only oil meeting the manufacturers specifications was used. The fuel tank sending unit/fuel pump assembly was modified to allow for continuous monitoring of fuel temperature and to facilitate draining for fuel changes. Fuel tank integrity was verified prior to the start of vehicle preconditioning. Modified units were replaced with new OEM parts and fuel tank integrity was again verified before returning the vehicle to the owner.

Vehicle Preconditioning

Test vehicles underwent extensive preconditioning prior to testing on each fuel to minimize any potential emissions effects that could result from fuel carry over. The initial test fuel to be used with each vehicle was randomly selected before the vehicle was accepted into the program. Statistical analysis after testing was completed found that there were no significant effects upon emissions due to fueling order at the 95% ($\alpha = 0.05$) confidence level. The preconditioning was based on a procedure described in Appendix V of SAE Paper 912320 entitled " Description of Auto/Oil Air Quality Improvement Research Program" and was recommended by the automobile manufacturers. The vehicle preconditioning and test sequence used in this study is contained in Appendix E.

Vehicle Testing

Each vehicle underwent a minimum of two complete test sequences on each fuel. The test sequence consisted of; a cold start FTP, a hot running start 505, a hot running start Unified Cycle and a hot running start REPO5. In order to assure the vehicle was stabilized following the reading of the sample bags from the prior test, it was operated at 50 mph for two minutes, returned to idle and then the next test was immediately started. The need for a third test sequence was based on test repeatability criteria established by Painter and Rutherford in SAE paper 920319 and was only applied to the composite FTP results. The method used was to determine the ratio of the larger to the smaller test value for each pair of pollutants and require a third test when the ratios exceeded the following values; HC - 1.33, CO - 1.70, and NOx - 1.29. In addition to these criteria an additional requirement was placed on CO in that a third test would be required if the difference in the FTP composite values exceeded 2.8 g/mi. Because of the potential variability with high emitters at least three test sequences were conducted on each fuel. Test results from either the two or three runs for each fuel were averaged and the average value was used in the final statistics.

There were four exceptions to this procedure. The first was test vehicle OF098T11 where the first FTP test data were removed from the oxygenated fuel test statistics because of abnormally high HC, CO and NOx bag 1 emission values. No reason for the problem could be determined. The average of the next two FTPs was used for this vehicle as there was good agreement between these tests. The second was test vehicle OF198V9. A problem with the hydrocarbon analyzer resulted in a loss of HC data for the first non-oxygenated FTP. Two additional FTPs were conducted. The third instance involved test vehicle OF198T29. Data from the first test sequence (non-oxygenated fuel) was not used because the appropriate dynamometer coefficients were not entered. The fourth instance was with vehicle # OF198T27. The first REPO5 run which was on the oxygenated fuel showed a very high PM emission rate which was not consistent with subsequent test values. This data point was not used in the final average as it was concluded this was not a fuel effect. In the first Unified Cycle run a higher PM emissions rate was also observed for this vehicle. After examining the data it was concluded that the high emission rate was most likely the result of the thermal transients and high exhaust flow rates associated with the REP05.

Regulated gaseous emission rates were determined for THC, CO and NOx. CO_2 emission rates were also determined as was fuel economy for each test. THC values were determined with a flame ionization detector (FID). The instrument was calibrated in accordance with CFR 40 Part 86 requirements and no correction was applied to account for the small change in instrument response due to the oxygenated fuel. Emission rates were also determined for particulate matter (PM, 10μ and smaller) for the FTP, the Unified Cycle and the REPO5. All test results can be found in Appendix F and all test statistics are in Appendix G.

During the FTP, particulate filters were collected for each phase. For the Unified Cycle and the REPO5 particulates were collected on a single filter. Particulate samples were drawn off the dilution tunnel via an isokinetic nozzle and passed through a University

Research Glassware PM_{10} cyclone separator before being collected on a 37 mm, 2µ Teflo filter. A mass flow controller was used to assure a constant PM sample system flow. Exhaust flow from the vehicle was transferred to the CVS system through a heated and insulated transfer line. The transfer line was heated to 225 °F to minimize water condensation during the cold start portion of the test. CVS system flow was maintained at a nominal 640 SCFM by a critical flow venturi. The 640 SCFM flow rate was used to minimize the chance of condensation being formed in the sample system during the more aggressive driving associated with the REPO5.

Based on concerns expressed by other researchers and the high volatility of the test fuels being used, steps were taken to minimize the buildup of heat in the fuel tank and subsequent fuel weathering which can occur over multiple test sequences. The first step was to fill fuel tanks to 70 percent of capacity rather than the 40 percent required in certification testing. In addition, three Hartzell cooling fans were used during the FTP and Unified Cycle. One Hartzell was used to provide air flow for the radiator and two fans provided underbody air flow to facilitate fuel tank cooling. During the REPO5, an additional Hartzel fan was used to increase air flow through the radiator. Fuel tanks were fitted with thermocouples and fuel temperature was monitored continuously. The highest fuel temperatures were recorded at the end of the REPO5 and they averaged 57 °F. The maximum temperature observed for the Tier 0 and Tier 1 vehicles was 86 °F.

Statistical Analysis

Because there was a large degree of vehicle to vehicle variability in base fuel emission levels, even among vehicles of similar types and technology, a statistical method known as "Delta of Means" was employed. In this method the average oxygenated fuel emissions level for all vehicles within the group being examined is compared to the average base fuel (non-oxygenated) level for the group. Relative or percent changes are calculated from the absolute change in the group averages. The alternative which would be to determine the relative change for each vehicle first and then calculate an average of the relative changes ("Mean of Percent Deltas") would give undue weight to individual vehicles with large relative (and quite possibly small absolute) changes in emission levels.

In order to determine whether or not a change in mean levels was significant at a particular confidence level, a two sided confidence interval was constructed around the mean of the absolute changes based upon the standard deviation of the changes, the number of vehicles in the group and the appropriate value of the Student's t statistic for the sample size and degree of confidence desired. If the confidence interval included the value zero, the difference could not be considered statistically different from no change and therefore the change was not statistically significant at that level of confidence. For this report two confidence levels were examined. Changes which were statistically significant at a 95% confidence level ($\alpha = 0.05$) were considered to be likely to have real effects upon the total population of vehicles of similar type and technology. Changes which were not statistically significant at a 90% confidence level ($\alpha = 0.10$) were considered to be unlikely to have real effects. The effects of changes which were statistically significant only at a 90% confidence level were considered to be inconclusive.

Results and Discussion

The principal purpose of this study was to assess the impact of a 10% ethanol blended winter fuel on the exhaust emissions of Tier 0 and Tier 1 vehicles at 35 °F. The impact of the ethanol blend on CO emissions was of particular interest as this was the pollutant addressed in the National Research Council Report. The assessment included three different driving schedules to maximize information on oxygenated fuel effects over increasingly aggressive driving schedules.

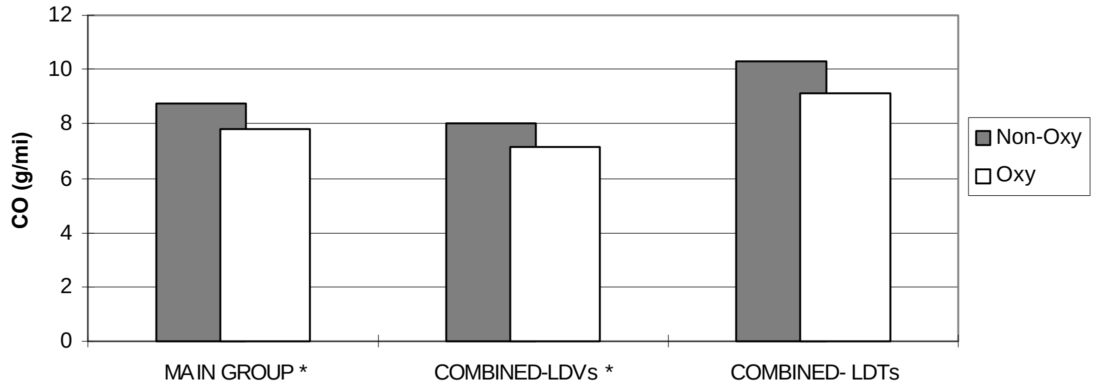
CO emissions in general, were reduced by the use of oxygenated fuel. However, the absolute sizes and the relative significance of the reductions varied according to factors such as vehicle certification level (Tier 0 or Tier 1), vehicle type (car or truck) and the initial emissions rate. The following sections contain specific results and explore some of the details responsible for these variations. The initial discussion will cover the main study group of twenty-four non high emitting vehicles. This main group consists of eight LDVs and four LDTs in each of the two certification Tier sets. Evaluating the CO effects on the entire main group eliminates the effects of smaller sample sizes and the corresponding impact on statistical significance. As the entire fleet of tested vehicles is broken down into smaller and smaller subsets, the effect of individual vehicles on small sample sets becomes an increasingly important factor affecting both emissions reductions and their significance. In several cases one truck out of four or one car out of eight significantly altered the results.

The main group of non high emitting vehicles will be examined first (high emitters will be addressed in another section). This group will be analyzed by Tier and vehicle type subsets and, as mentioned above, the traditional cold start FTP will be examined first followed by the Unified Cycle and the REPO5.

4. Oxygenated Fuel Effect on CO Emissions

CO Emissions - FTP Results Overall

Analysis of the FTP data shows an overall reduction in composite CO emissions with the 10% ethanol fuel. Figure 1 shows the changes in CO emissions for the main group of twenty four vehicles, which consisted of sixteen LDVs and eight LDTs. The data show grams per mile (g/mi) CO reductions of -0.97 (-11.1%) for the complete main group, -0.86 (-10.8%) for the LDVs and -1.2 (-11.5%) for the LDTs. The CO reductions for the complete main group as well as for the LDVs are statistically significant at the 95% confidence level.



* Statistically Significant at the 95% Confidence Level

Figure 1. The effect of a 10% ethanol blended fuel on the FTP composite CO emissions for the main group and its LDV/LDT components.

The data show that the majority of the CO reductions observed occur on vehicles with the highest emission rates. As the emission rates decrease so do the absolute CO reductions. As an example see Figure 2, which shows that ordering the vehicles by emission rate, highest to lowest, that the eight vehicles with the highest base (non-oxygenated) CO emissions accounted for a major portion of the overall CO reduction. The baseline CO emissions for these vehicles ranged from 30.5 to 8.8 g/mi and averaged 17.5 g/mi.

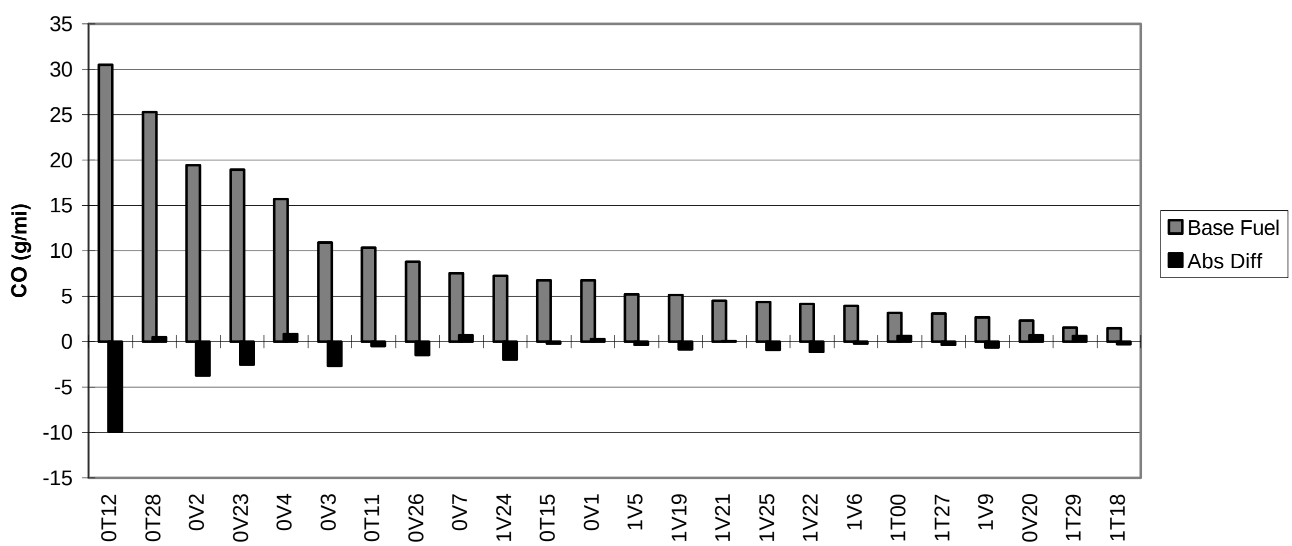
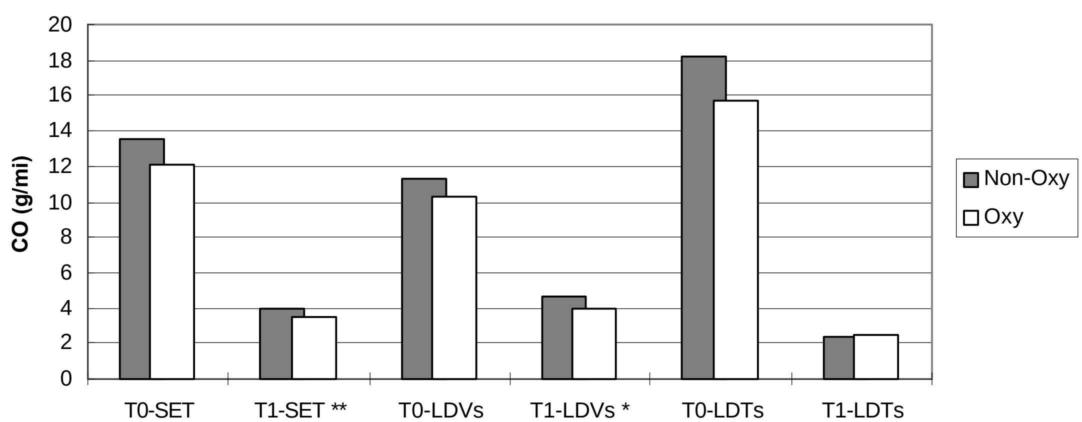


Figure 2. FTP base fuel CO emissions rates and the associated absolute change in CO due to the oxygenated fuel.

These vehicles when switched to oxygenated fuel accounted for 83 percent of the total CO reduction realized for the main group. These vehicles were all Tier 0 certified and included 3 trucks. One of the vehicles, Tier 0 truck #12, accounted for over one half of the reductions from the eight higher CO emitters. But even if that vehicle is excluded, the other seven vehicles would account for 69 percent of the reductions from the remaining 23 vehicles. Vehicles with lower base fuel emission rates realized smaller overall CO reductions. The eight lowest emission rates ranged from 1.5 to 4.2 g/mi and averaged 2.8 g/mi. They accounted for only 2.5 percent of the total CO reduction. This group was comprised of 3 Tier 1 LDVs, 4 Tier 1 LDTs and one Tier 0 LDV.

CO Emissions - FTP Results by Certification Tier

Analysis of the FTP data for both the Tier 0 and Tier 1 sets shows an overall reduction in the FTP composite CO emissions with the 10% ethanol fuel. The changes in the average FTP composite CO emissions resulting from the oxygenated fuel are shown in Figure 3. CO reductions occurred for all situations except the Tier 1 LDTs. For Tier 0 vehicles the absolute emissions reductions were larger than Tier 1's. The Tier 0 vehicles tended to be a little more variable in their emissions performance so although the relative percent reductions were not too different between the Tiers, the number of statistically significant differences were fewer for Tier 0. The Tier 0 vehicles showed an absolute CO emission reduction of -1.5 g/mi (-11.0%) however, the reductions were not statistically significant, even at the 90% confidence level, for either the set or the LDV / LDT subsets.



* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

Figure 3. The effect of oxygenated fuel on FTP CO emissions for Tier 0 and Tier 1.

One statistically significant CO reduction was indicated for Tier 0. The reduction was at the 90% confidence level for the LDVs and applied to the second phase of the FTP. The absence of statistical significance for the FTP is due to the variable emissions performance of the Tier 0 vehicles. The variability is demonstrated by four of the eight LDVs and one of the four LDTs which show an increase in FTP CO emissions with the ethanol blend. Increases in individual vehicle's CO emissions occurred during all phases of the FTP but the highest frequency occurred during the cold start or bag one of the FTP. The cold start portion of the test is where a reduction in CO emissions for each vehicle would be expected, due to the open loop operation that occurs during the cold start portion of the test. Although the individual vehicle response to the oxygenated fuel varied, the largest overall CO reduction for the LDVs occurred during the cold start. The LDTs also showed a large decrease in cold start CO emissions. However the largest decrease came in phase 3 for these vehicles. Table 6 provides an overall summary of the changes in Tier 0 CO emissions. The table shows the absolute changes (Δ) which are the difference between the non-oxygenated values and the oxygenated fuel values and the percent changes (%Δ) associated with this difference. These changes are calculated as the differences from the mean of the non-oxygenated values to the mean of the oxygenated values divided by the mean of the non-oxygenated values. (%Δ of the Means).

Table 6
Absolute and Percent Change in FTP CO Emissions for Tier 0

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
FTP	-1.50	-11.0	-0.98	-8.7	-2.54	-13.9
Bag 1	-3.62	-7.6	-3.35	-8.2	-4.17	-6.9
Bag 2	-0.27	-7.3	-0.37 **	-10.8	-0.06	-1.4
Bag 3	-2.21	-33.1	-0.36	-9.6	-5.91	-47.1

Δ = Absolute in grams per mile
** Statistically Significant at the 90% Confidence Level

Over one half of the 1.5 g/mi CO reduction for the Tier 0 set and all of the average reduction for the LDTs can be attributed to one LDT. Test vehicle OF098T12 had the highest base fuel FTP CO emissions of the set (30.5 g/mi) and showed substantial CO reductions of -16.7 and -22.2 g/mi for bags 1 and 3 on the oxygenated fuel. This vehicle had over 122,700 miles on the odometer and no check engine light or service engine indication was evident.

Table 7 shows a set of data similar to Table 6 but has this LDT removed from the analysis. This table shows the impact that one vehicle which exhibits large emission changes when the fuel is changed can have on a small sample. Note that the FTP %Δ for the set goes from a -11.0% to a -6.1% and the FTP and bags 1 and 2 for the LDTs go from a reduction to an increase.

Table 7
Absolute and Percent Change in FTP CO Emissions for Tier 0
without test vehicle OF098T12

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
FTP	-0.73	-6.1	-0.98	-8.7	-0.07	-0.5
Bag 1	-2.44	-5.5	-3.35	-8.2	+0.003	+0.006
Bag 2	-0.23	-6.6	-0.37 **	-10.8	+0.17	+5.0
Bag 3	-0.39	-9.6	-0.36	-9.6	-0.48	-9.4

Δ = Absolute in grams per mile
** Statistically Significant at the 90% Confidence Level

As shown in Figure 3 the Tier 1 vehicles had a much lower emission rate than Tier 0. As a result of the lower emission rates these vehicles appear less sensitive to the oxygenated fuel. This is indicated by the smaller absolute differences shown in Table 8. The Tier 1 set showed a smaller absolute FTP CO reduction (-0.44 g/mi) but the percent change is both larger and significant at the 90% confidence level. The LDV FTP CO reduction is significant at the 95% confidence level. The Tier 1 vehicles exhibited less variability in CO emissions and only one LDV and two LDTs showed an increase in FTP CO emissions.

The enhanced emissions performance of the Tier 1 set is apparent by the changes in the cold start emission rates. Non-oxygenated cold start (bag 1) emission rates for the Tier 1 set are less than 30% of the Tier 0 rates. The absolute change in bag 1 CO for the set due to the oxygenated fuel is less than one-fourth the size of the Tier 0 reduction. The Tier 1 LDTs demonstrated a slightly negative response to the oxygenated fuel showing a small increase (+1.12 g/mi) in CO emissions for the cold start. The lower overall emission rates may be attributable to refinements in emissions control technology and engine management system calibrations required to meet the Cold CO standards and the more stringent Tier 1 standards. The lower average mileage may also have had an effect. Table 8 provides an overall summary of the CO changes for Tier 1.

Table 8
Absolute and Percent Change in FTP CO Emissions for Tier 1

	SET		LDVs		LDTs	
Tier 1	Δ	% Δ	Δ	% Δ	Δ	% Δ
FTP	-0.44 **	-11.2	-0.74 *	-15.8	+0.17	+7.1
Bag 1	-0.76	-5.5	-1.70 **	-10.7	+1.12	+11.2
Bag 2	-0.24	-24.8	-0.34	-24.6	-0.04	-27.2
Bag 3	-0.58 *	-30.4	-0.78 *	-31.3	-0.17	-24.0

Δ = Absolute in grams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

CO Emission - Unified Cycle Results

The Unified Cycle was developed by CARB to provide a more accurate representation of real world driving and generate more representative data for emissions inventory purposes. The data collected for this cycle shows that under the test conditions of higher speeds and acceleration rates with the vehicle at operating temperature, the use of the oxygenated fuel generally resulted in CO reductions. The Unified cycle is similar to the FTP in that it is a three phase test, but phase duration, speeds and acceleration rates are quite different from the FTP as shown in Table 1. The Unified cycle is intended to be conducted from a cold start condition in order to provide data on cold start emissions. However, due to time constraints, soaking the vehicles again for a second cold start test was not feasible. Because of this the test results provided below were obtained from a hot running start rather than a cold start condition.

No composite Unified cycle values are provided as an appropriate weighting of the three phases has not yet been determined. Because of this no direct comparison of CO emissions is made to the FTP composite CO value. In addition no bag 1 comparisons are made because the FTP bag 1 was a cold start whereas bag 1 for the Unified Cycle was a hot running start. However, a comparison can be made between CO emissions for the second and third phases of both tests. Table 9 shows the average CO emission rates for phases 2 and 3 from both tests for the Tier 0 and 1 sets (LDVs and LDTs combined). As might be expected because of the higher speeds and acceleration rates, CO emissions were greater for both phases of the Unified Cycle. What is also shown is that the absolute CO reduction is essentially the same between the same phases for both tests for the Tier 0 set. The Tier 1 set follows the same pattern but shows a smaller absolute reduction for phase 2 of the FTP than is evidenced for the Unified Cycle.

Table 9
Absolute and percent change between the averaged LDV plus LDT CO emissions of phase 2 and 3 of the FTP and Unified Cycle

	Tier 0				Tier 1			
FTP	NonOxy	Oxy	Δ	%Δ	NonOxy	Oxy	Δ	%Δ
Bag 2	3.68	3.41	-0.27	-7.3	0.96	0.72	-0.24	-24.8
Bag 3	6.69	4.48	-2.21	-33.1	1.9	1.32	-0.58	-30.4
U.C.								
Bag 2	6.58	6.29	-0.29	-4.4	3.24	2.51	-0.73	-22.6
Bag 3	9.42	6.84	-2.58	-27.4	2.59	2.04	-0.55	-21.2

Vehicles with the highest base fuel CO emissions again showed the greater benefit from the oxygenated fuel. This trend was observed throughout all phases of the Unified Cycle. The eight highest emitters were essentially the same vehicles with seven out of the eight being present in all phases. Not all of the highest emitters showed consistent CO reductions. Three out the eight showed increases in CO for phases 1 and 2 but all vehicles showed a CO reduction for the phase 3 hot restart portion of the test. Tier 0 vehicles accounted for the majority with six out the eight for phases 1 and 2 and seven out of eight for phase 3. The percentages of the total CO emissions reduced per phase by these vehicles were; 73.2, 69.7 and 78.8 for phases 1 though 3 respectively.

Figure 4 shows that CO reductions with the oxygenated fuel were achieved for Tier 1 LDVs in all three phases and for the Tier 0 vehicles with the exception of phase 1. Four out of the eight Tier 0 LDVs accounted for an unexplained +0.57 g/mi increase in CO emissions on the ethanol blended fuel for the hot running start used for phase 1. For phase 3 the Tier 0 LDVs did show a statistically significant CO reduction at the 95% confidence level. The -2.3 g/mi reduction shown for phase 3 was influenced by one vehicle, OF098V23, which had a -6.5 g/mi CO reduction. This reduction is in contrast to seven out of the eight vehicles which had CO reductions for this phase averaging -1.7 g/mi with none greater than -3.8 g/mi. The Tier 1 LDVs average phase 3 CO emission reductions of -0.7 g/mi was statistically significant at the 90% confidence level.

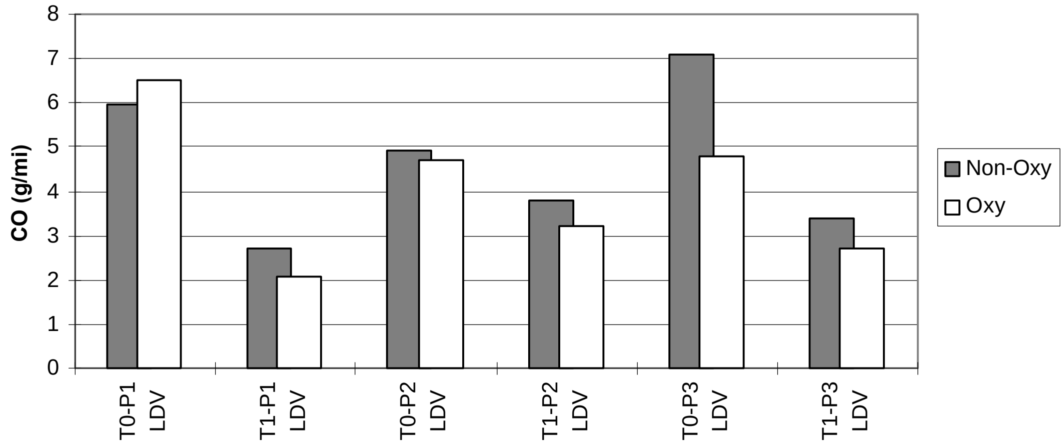


Figure 4. The effect of oxygenated fuel on the CO emissions of Tier 0 and Tier 1 LDVs for each phase of the Unified Cycle.

Figure 5 depicts the relatively small CO reductions, less than -1 g/mi, shown by the Tier 0 and 1 LDTs for all phases with the exception of Tier 0 phase 3. The -3 g/mi CO reduction shown for this phase by the Tier 0 LDTs was due again, to test vehicle OF098T12. The CO reduction of -9 g/mi realized by this vehicle accounted for the majority of the observed CO reduction. None of the CO reductions for the LDTs were statistically significant at the 90% confidence level.

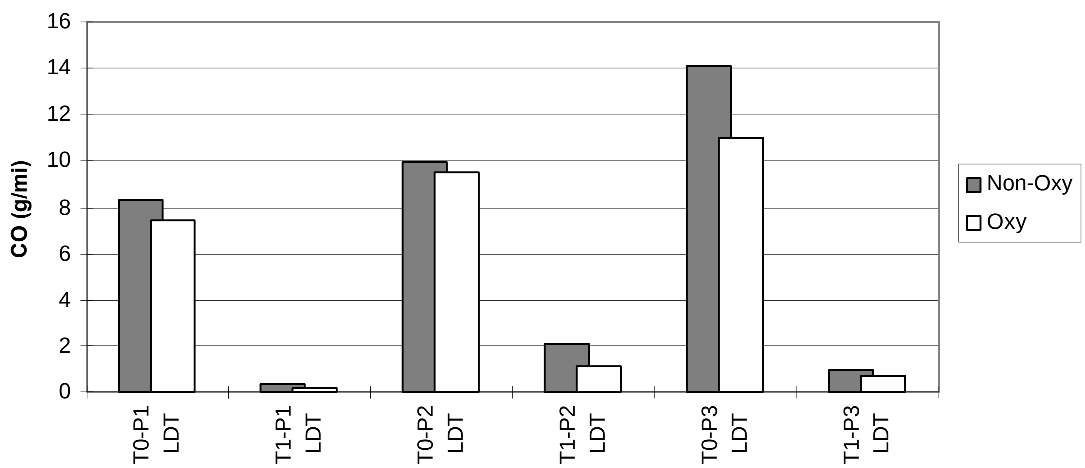


Figure 5. The effect of oxygenated fuel on the CO emissions of Tier 0 and Tier 1 LDTs for each phase of the Unified Cycle.

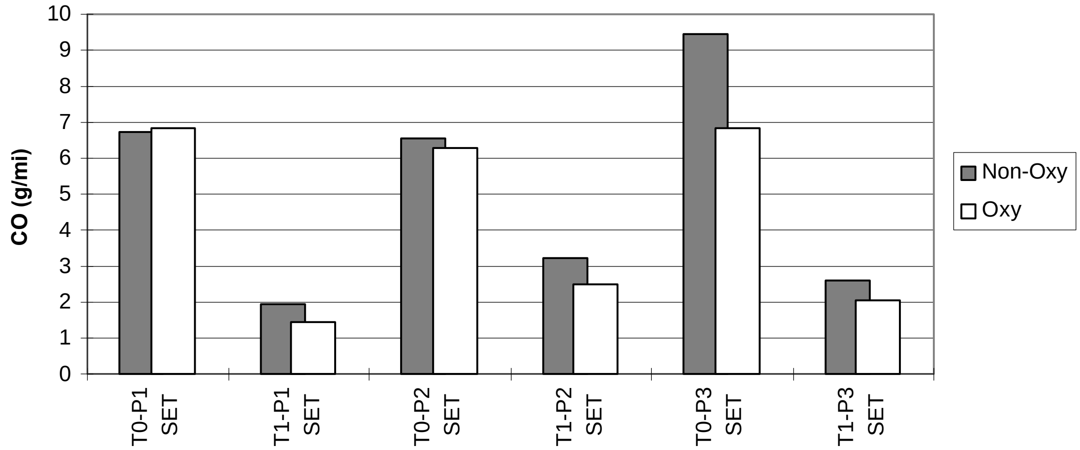


Figure 6. The effect of oxygenated fuel on the CO emissions of the Tier 0 and Tier 1 sets for each phase of the Unified Cycle.

Figure 6 presents the CO impact of the oxygenated fuel for the LDVs and LDTs combined into their respective Tier 0 and 1 sets. The Tier 1 set had less emissions variability and showed less sensitivity to the oxygenated fuel. The CO reductions achieved by this set are less than -0.75 g/mi for each phase. The change in CO for phase 1 is statistically significant at the 90% confidence level while the changes for phases 2 and 3 are significant at the 95% confidence level.

The CO emissions for Tier 0 were more variable than those of Tier 1. The Tier 0 set showed a slight CO increase in phase 1, a -0.29 g/mi decrease for phase 2 and a -2.6 g/mi reduction for phase 3. The phase 3 CO change was the direct result of the CO reductions achieved by the individual LDV and LDT previously discussed. The phase 3 Tier 0 changes were statistically significant at the 95% level. Table 10 provides an overall summary of both Tier 0 and Tier 1 CO emissions for the Unified Cycle.

Table 10
Absolute and Percent Change in Unified Cycle CO Emissions for Tier 0 and Tier 1

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
Bag 1	+0.09	+1.4	+0.57	+9.5	-0.85	-10.2
Bag 2	-0.29	-4.4	-0.21	-4.3	-0.45	-4.5
Bag 3	-2.58 *	-27.4	-2.31	-32.6	-3.12	-22.1
Tier 1						
Bag 1	-0.50 **	-25.9	-0.66	-24.4	-0.18	-50.7
Bag 2	-0.73 *	-22.6	-0.61	-15.9	-0.98	-46.8
Bag 3	-0.55 *	-21.2	-0.71 **	-20.7	-0.24	-25.0

Δ = Absolute in grams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

CO Emissions - REPO5 Results

The REPO5 is a very aggressive driving schedule designed to capture the emissions resulting from speeds up to 80 mph and acceleration rates nearly three times that of the FTP. CO reductions were observed in all cases with the oxygenated fuel. This test cycle, like the Unified Cycle was conducted as a hot running start. Again as might be expected the average base fuel CO emissions increased for the REPO5 because of the aggressive nature of the test. Table 11 provides average LDV plus LDT base fuel and oxygenated fuel CO emission rates for bags 2 and 3 of the FTP and Unified Cycle plus the REPO5 for the Tier 0 and 1 sets. Also provided are the changes in absolute CO emissions and the resulting percent differences. Even with the higher emissions rates, the absolute differences achieved with the oxygenated fuel remain fairly constant when compared to phase 3 of the FTP and Unified Cycle.

Table 11
Absolute and percent change comparison between the averaged CO emissions of phase 2 and 3 of the FTP and Unified Cycle and the REPO5

	Tier 0				Tier 1			
FTP	NonOxy	Oxy	Δ	Δ %	NonOxy	Oxy	Δ	Δ %
Bag 2	3.68	3.41	-0.27	-7.3	0.96	0.72	-0.24	-24.8
Bag 3	6.69	4.48	-2.21	-33.1	1.90	1.32	-0.60	-30.4
U.C.								
Bag 2	6.58	6.29	-0.29	-4.4	3.24	2.51	-0.73	-22.6
Bag 3	9.42	6.84	-2.58	-27.4	2.59	2.04	-0.55	-21.2
REPO5								
	12.97	10.91	-2.06	-15.9	6.51	6.14	-0.37	-5.6

The benefit of the oxygenated fuel was evidenced again when examining the change in CO emissions for the eight vehicles with the highest base fuel CO emissions. Six out of the eight vehicles accounted for 70.6 % of the CO reduction realized by all the test vehicles for REPO5. The two vehicles that had a CO increase also showed a CO increase on one or more phases of the Unified Cycle. Figure 7 shows that both the Tier 0 and 1 sets as well as their respective LDV and LDT subsets had CO reductions when using the oxygenated fuel. Tier 0 had the highest CO emission rates and the greatest CO

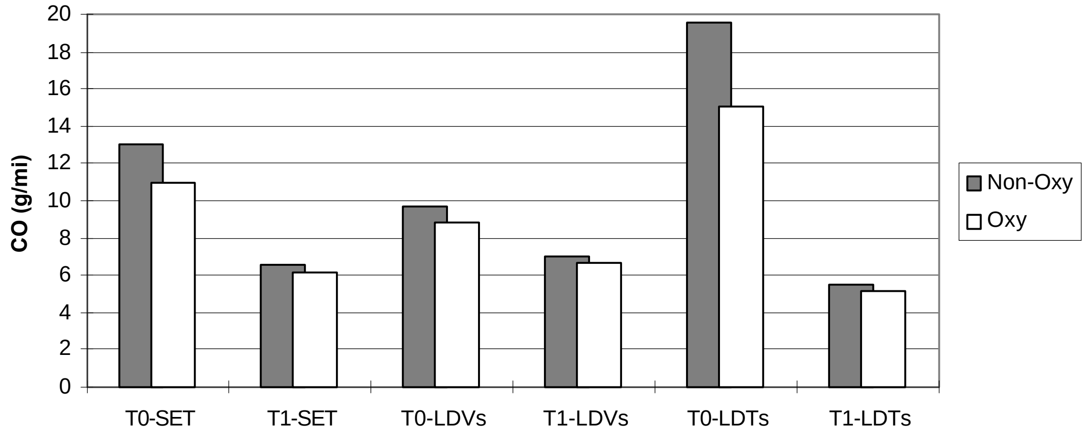


Figure 7. The effect of oxygenated fuel on the REPO5 CO emissions for Tier 0 and Tier 1 vehicles.

reduction with the oxygenated fuel. Once more, the Tier 0 LDT CO reduction is mainly due to test vehicle OF098T12 which again showed a -9.5 g/mi CO decrease with the oxygenated fuel. The only statistically significant changes in CO for this test cycle were at the 90% confidence level for the Tier 0 trucks and the Tier 0 set. It is also interesting to note that the average Tier 0 emission rates from the REP05 are fairly close to the average cold start FTP composite CO emission rates. Tier 1, as a whole and its subsets showed higher emission rates on the REPO5 than any of the other test cycles. Even on this aggressive cycle these vehicles showed little variability in CO emissions and minimal CO sensitivity to the ethanol blend.

Table 12
Absolute and Percent Change in REPO5 Cycle CO Emissions for Tier 0 and Tier 1

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
REPO5	-2.06 **	-15.9	-0.87	-9.0	-4.44	-22.7
Tier 1						
REPO5	-0.37	-5.6	-0.38	-5.5	-0.34	-6.1

Δ = Absolute in grams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

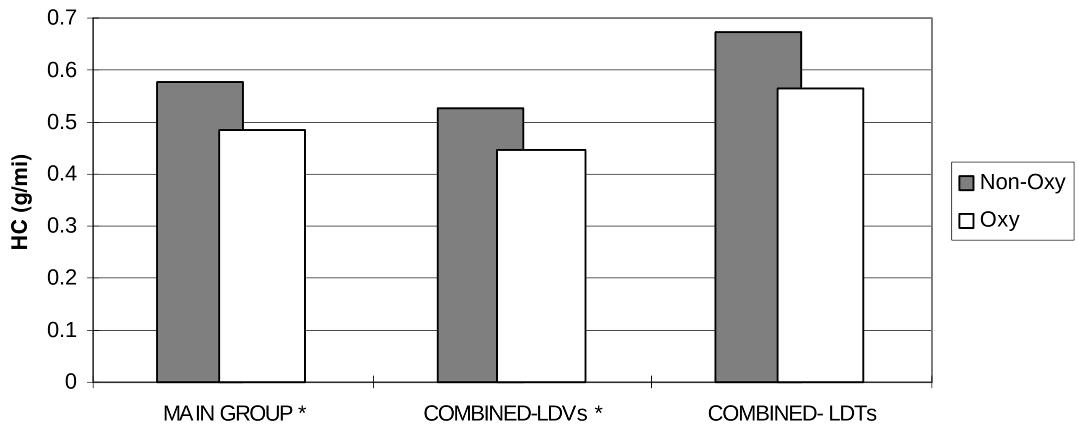
5. Oxygenated Fuel Effect on HC Emissions

HC Emissions - FTP Overall Results

FTP HC emissions also showed an overall reduction with the 10% ethanol blend. Figure 8 represents the changes in HC emissions for the main group of 24 vehicles. The main group is comprised of both Tier 0 and Tier 1 vehicles. The test results show reductions in HC emissions (g/mi) of -0.09 for the main group of twenty four vehicles, -0.08 for the sixteen

LDVs and -0.11 for the eight LDTs. The percent change associated with these HC reductions are -15.7%, -15.2% and -16.4% respectively and are statistically significant at the 95% confidence level for the main group and the LDVs.

Examination of the main group's emission rates reveals that the vehicles with the highest emission rates achieved the greatest reductions with the oxygenated fuel (see Figure 9). The vehicles with the eight highest base fuel (non-oxygenated) FTP HC emission rates (all Tier 0 except for one) accounted for 73% of the total HC reduction with the oxygenated fuel. Again vehicle #12, a Tier 0 truck, contributed almost one half of the reduction from the eight higher HC emitters but the other seven still would account for 58% of the emissions from all of the vehicles except #12. As with FTP CO emissions, vehicles with the lower emissions rates showed less benefit from the oxygenated fuel.



* Statistically Significant at the 95% Confidence Level

Figure 8. The effect of a 10% ethanol blended fuel on FTP HC composite emissions for Tier 0 and Tier 1 vehicles that make up the main group.

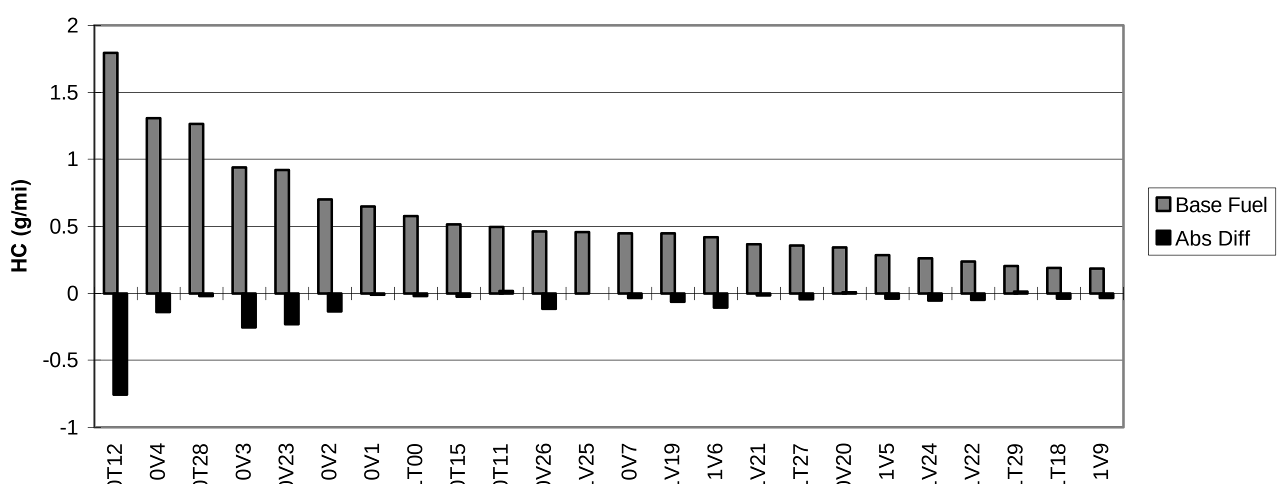
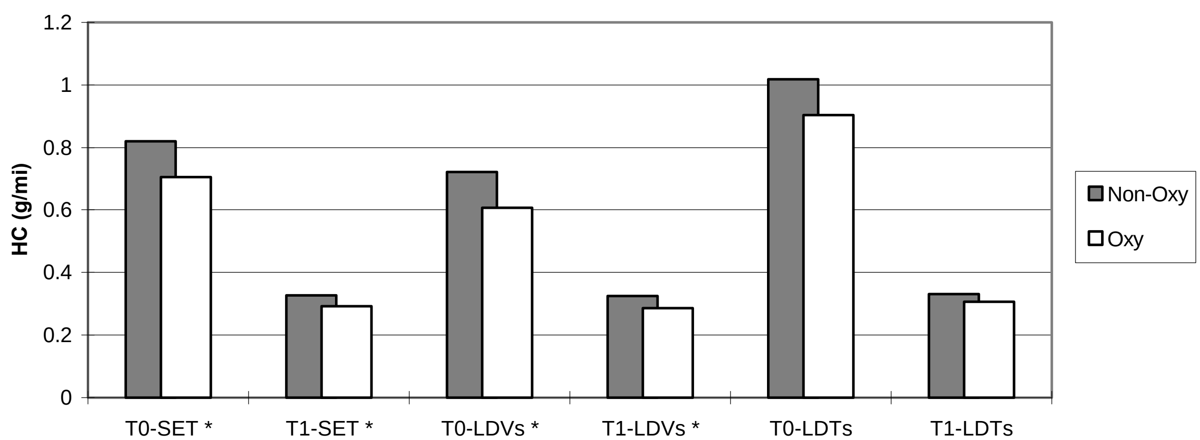


Figure 9. FTP base fuel HC emission rates and the associated absolute change in HC due to the oxygenated fuel.

HC Emissions - FTP Results by Certification Tier

The unburned hydrocarbon (HC) emissions data from the FTP also show an overall reduction due to the use of the oxygenated fuel. As shown in Figure 10 below, a reduction in FTP HC composite emissions was achieved for both the Tier 0 and Tier 1 vehicles. The larger absolute emission reduction was shown by the Tier 0 vehicles, and the change was statistically significant at the 95% confidence level. The largest HC reductions were realized in the Tier 0 cold start (bag 1) for the LDVs. The largest reduction for the LDTs was shown in bag 3 for the Tier 0. Bag 3 reflects a hot restart which occurs after a 10 minute period with the engine shut off. The Tier 0 vehicles exhibited a little less emissions variability for HC than for CO which accounted for the statistical significance. Only one LDV and one LDT showed an increase in FTP HC emissions. The frequency of the HC increases was much less and was not focused on bag 1 but was more evenly distributed throughout all three FTP phases. Like Tier 0, the largest reductions were in bag 1. Unlike Tier 0, emissions increased during bag 2 for all the Tier 1s and bag 3 increased for the LDTs. Those increases were small and only one Tier 1 vehicle, an LDT, showed an increase in HC for the composite FTP. As was the case for CO, test vehicle OF098T12 had the highest base fuel FTP HC emissions of either Tier (1.8 g/mile) and showed substantial HC reductions of -0.97 and -1.94 g/mile for bags 1 and 3 on the oxygenated fuel.



* Statistically Significant at the 95% Confidence Level

Figure 10. Oxygenated fuel effects on FTP HC emissions for Tier 0 and Tier 1.

Table 13 provides an overall summary of the changes in Tier 0 and Tier 1 HC emissions. The table shows the absolute changes (Δ) which are the difference between the non-oxygenated values and the oxygenated fuel values and the percent changes (%Δ) associated with this difference as well as which changes were statistically significant. Note that none of the differences associated with the LDTs were statistically significant. Note also that for the LDTs bag 2, the percentage change seems large (+72.3%) but the absolute increase was small (+0.009 g/mi) and the base fuel HC emissions rate (0.012 g/mi) was less than one half the base rate of Tier 1 LDVs.

Table 13
Absolute and Percent Change in FTP HC Emissions for Tier 0 and Tier 1

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
FTP	-0.14 *	-17.3	-0.11 *	-15.9	-0.20	-19.4
Bag 1	-0.38 *	-13.8	-0.43 *	-16.2	-0.30	-9.7
Bag 2	-0.02	-10.9	-0.03 **	-16.9	-0.002	-0.9
Bag 3	-0.19	-36.7	-0.04	-13.0	-0.48	-51.3
Tier 1						
FTP	-0.04 *	-11.6	-0.05 *	-13.8	-0.02	-7.0
Bag 1	-0.19 *	-13.2	-0.20 *	-15.0	-0.15	-10.0
Bag 2	+0.005	+22.2	+0.004	+11.8	+0.009	+72.3
Bag 3	-0.009	-9.0	-0.02 *	-15.7	+0.01	+13.9

Δ = Absolute in grams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

HC Emissions - Unified Cycle Results

The unburned hydrocarbon (HC) emissions data from each phase of the Unified Cycle show an overall reduction due to the use of the oxygenated fuel. Figure 11 shows that reductions in HC emissions were seen for both the Tier 0 and Tier 1 vehicles. The vehicles with the highest HC emissions showed the most benefit from the oxygenated fuel. The eight vehicles, out of the group of 24, with the highest HC emissions for phases 1, 2 and 3 accounted for 97%, 89% and 89% of the total HC reductions achieved. Not all of the vehicles with the highest emissions showed a reduction for each phase. Phases 1 and 2 had two and one vehicles respectively that showed an increase in HC emissions with the oxygenated fuel. The average phase 3 base fuel emission rate for the eight highest emitters was 1.7 and 3 times greater than the averages for phases 1 and 2. Phase 3 realized the largest g/mi HC reduction and the eight highest vehicles in Phase 3 all showed HC reductions with the oxygenated fuel.

Figure 11 shows the changes in the average HC emission rates for both the Tier 0 and Tier 1 LDVs. The Tier 0 LDVs showed a very small HC reduction for the hot running start phase 1. This set of vehicles showed a +0.57 g/mi CO emissions increase for phase 1. Statistically significant changes at the 90% confidence interval were shown for the Tier 1 LDVs for phases 2 and 3.

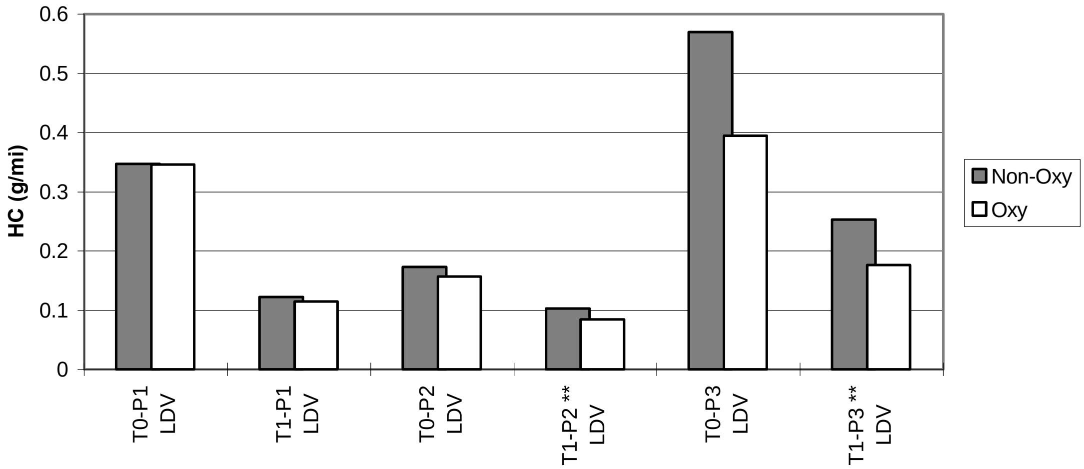


Figure 11. The effect of oxygenated fuel on the HC emissions of Tier 0 and Tier 1 LDVs for each phase of the Unified Cycle.

Figure 12 shows the changes in the average HC emission rates for the Tier 0 and 1 LDTs. The Tier 1 LDTs have much lower emission rates than the Tier 0 LDTs and show a smaller emissions benefit from the oxygenated fuel. None of the HC reductions for the LDTs were statistically significant at the 90% confidence level.

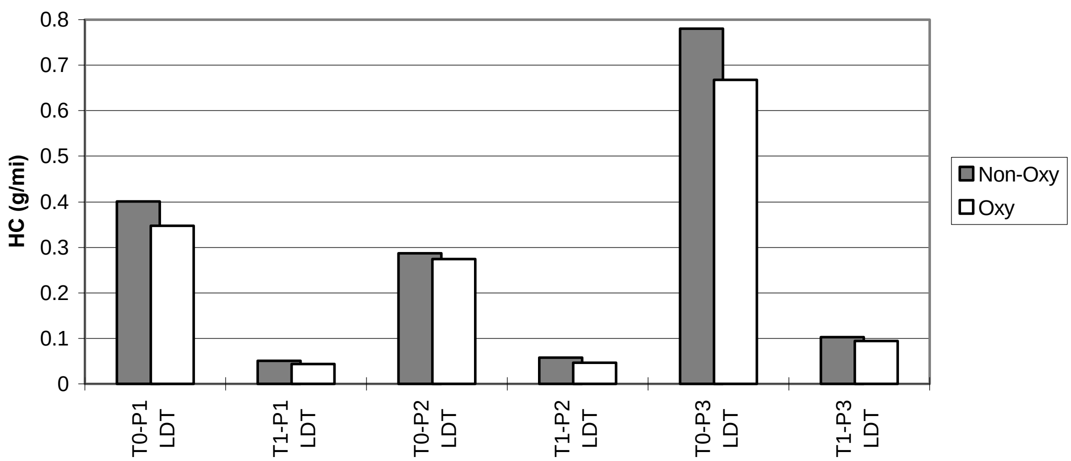


Figure 12. The effect of oxygenated fuel on the HC emissions of Tier 0 and Tier 1 LDTs for each phase of the Unified Cycle.

Figure 13 presents the averaged HC emissions comparison for the total Tier 0 and Tier 1 sets. The lower average emissions of the Tier 1 set are a result of the very low LDT emission rates. The Tier 0 and Tier 1 sets showed essentially the same reduction in HC emissions for phase 2. However the only the changes that were statistically significant were those for Tier 1. The Tier 1 changes were statistically significant at the 95% level for phase 2 and the 90% level for phase 3.

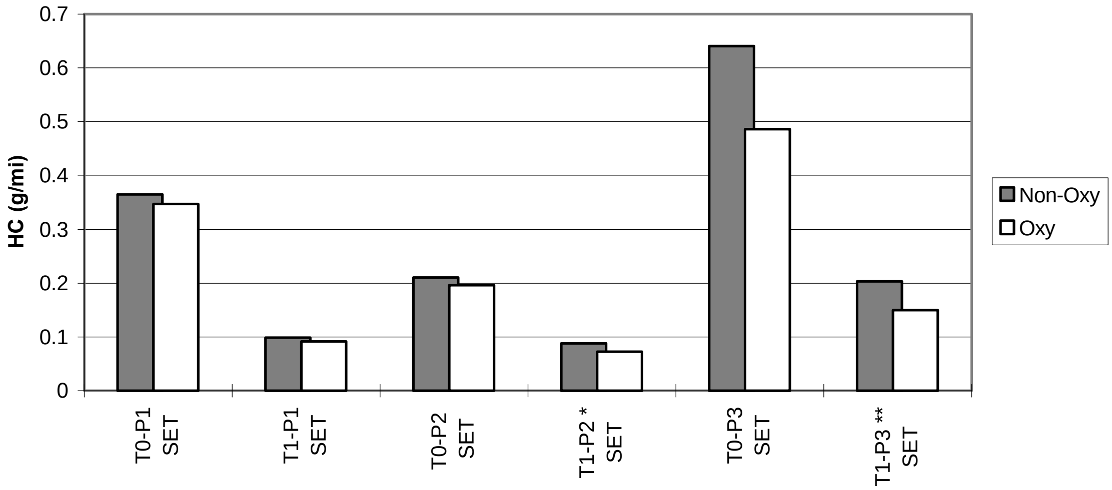


Figure 13. The effect of oxygenated fuel on the HC emissions of Tier 0 and Tier 1 sets for each phase of the Unified Cycle.

Table 14 provides an overall summary of both Tier 0 and Tier 1 HC emissions for the Unified Cycle.

Table 14
Absolute and Percent Change in Unified Cycle HC Emissions for Tier 0 and Tier 1

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
Bag 1	-0.018	-4.9	-0.0005	-0.1	-0.053	-13.2
Bag 2	-0.015	-7.2	-0.017	-9.6	-0.013	-4.4
Bag 3	-0.154 *	-24.1	-0.175	-30.8	-0.112	-14.4
Tier 1						
Bag 1	-0.007	-7.1	-0.007	-5.7	-0.007	-14.1
Bag 2	-0.016 *	-17.9	-0.018 **	-17.4	-0.011	-19.7
Bag 3	-0.054 **	-26.6	-0.077**	-30.4	-0.008	-7.3

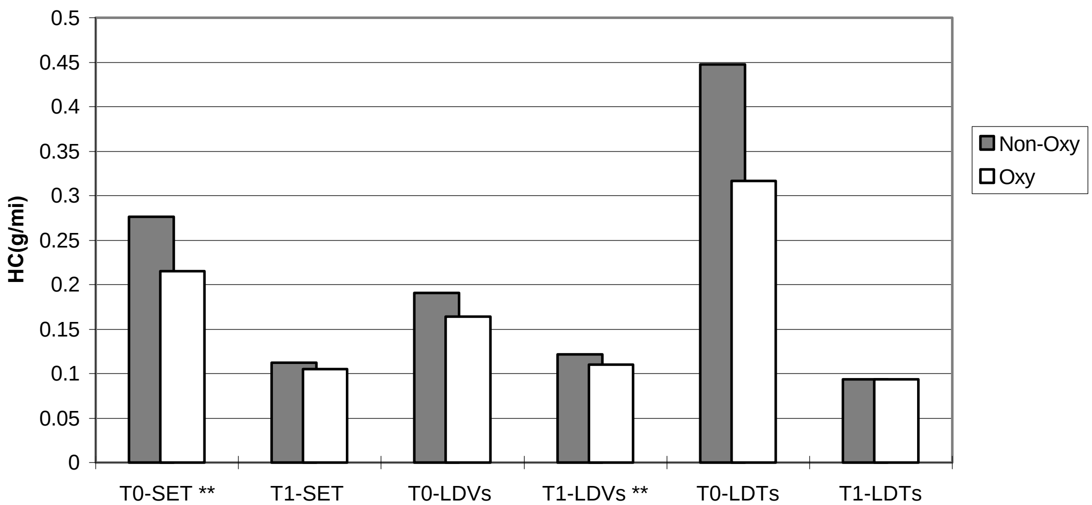
Δ = Absolute in grams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

<u>HC Emissions - REPO5 Results</u>

The unburned hydrocarbon (HC) emissions data from the REPO5 Cycle show an overall reduction due to the use of the oxygenated fuel. Reductions in HC emissions as indicated in Figure 14, were shown for both the Tier 0 and Tier 1 vehicles with the only exception being the Tier 1 LDTs. The Tier 1 LDTs showed no change in HC emissions with the oxygenated fuel.

Ordering the test vehicles by HC emission rates and totaling the indicated reductions shows these vehicles with the highest emissions get the maximum benefit with the oxygenated fuel. The eight highest emitters accounted for 81% of the total hydrocarbon emissions reduction. Six out of these eight vehicles are Tier 0 and test vehicle OF098T12 again showed the largest change.

As mentioned in the Unified Cycle discussion, not all vehicles show an emissions reduction with the oxygenated fuel. Certain vehicles in both Tier 0 and Tier 1 show a consistent sensitivity to the oxygenated fuel which is shown by an increase in emissions. Other vehicles such as OF098T12 show large HC and CO reductions. Overall, as shown in Figure 14, the general trend is an emissions decrease.



** Statistically Significant at the 90% Confidence Level

Figure 14. The effect of oxygenated fuel on the HC emissions of Tier 0 and Tier 1 sets when operated on the REPO5 Cycle.

Table 15 provides an overall summary of both Tier 0 and Tier 1 HC emissions for the REPO5 Cycle.

Table 15
Absolute and Percent Change in the REPO5 Cycle HC Emissions for Tier 0 and Tier 1

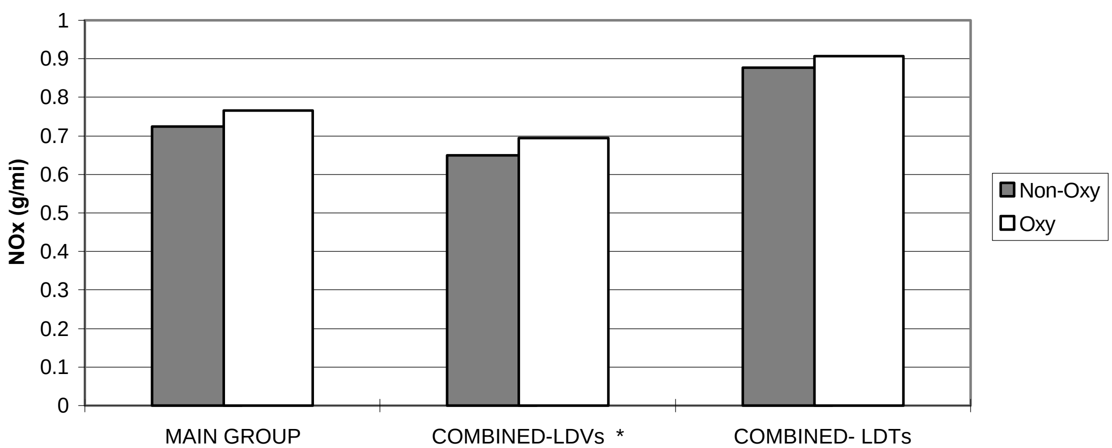
	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
REPO5	-0.062 **	-22.3	-0.027	-14.2	-0.131	-29.2
Tier 1						
REPO5	-0.008	-6.8	-0.012 **	-9.5	-0.0002	+0.18

Δ = Absolute in grams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

6. Oxygenated Fuel Effect on NOx Emissions

<u>NOx Emissions - FTP Overall Results</u>

Past studies have shown that the use of an oxygenated fuel typically results in an increase in NOx emissions. Such an increase was again borne out in this study where FTP NOx emissions demonstrated an overall increase with the oxygenated fuel. Figure 15 shows the effect of the oxygenated fuel on the main group as well as on the LDV and LDT segments. For the main group, fifteen out of the twenty four vehicles showed an increase in NOx emissions. The increases ranged from +0.007 to +0.44 but only averaged +0.094 g/mi. The average overall change for vehicles in this group was a +0.041 g/mi increase (+5.6%). The difference in NOx emissions for the LDVs was +0.046 g/mi, (+7.1%) and is statistically significant at the 95% confidence level. The LDT segment showed a +0.03 gram per mile (+3.4%) increase which was not statistically significant.

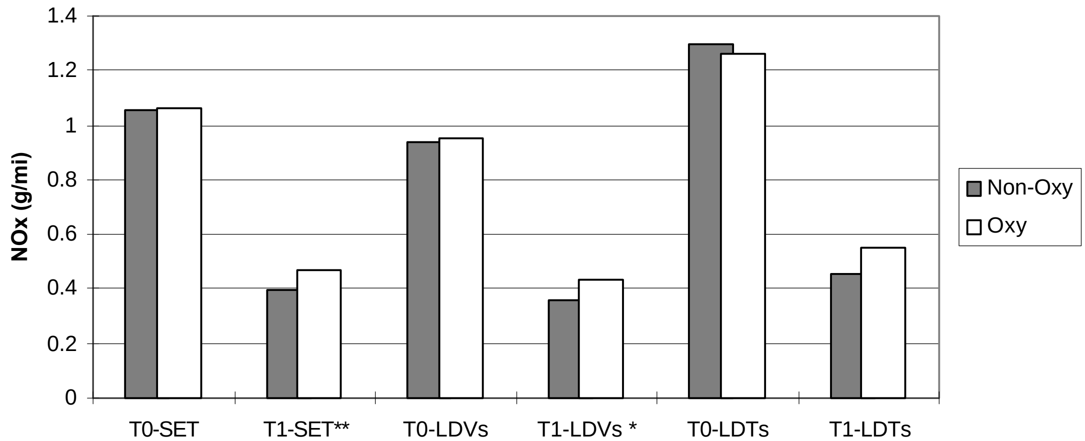


* Statistically Significant at the 95% Confidence Level

Figure 15. The effect of a 10% ethanol blended fuel on FTP NOx composite emissions for Tier 0 and Tier 1 vehicles that make up the main group.

<u>NOx Emissions - FTP Results by Certification Tier</u>

Overall, both Tier 0 and Tier 1 vehicles showed an increase in NOx emissions when operated on the oxygenated fuel. The exception was the Tier 0 LDTs which showed a small decrease in the FTP composite NOx value. The Tier 0 vehicles had no significant changes and appeared to be less sensitive to the oxygenated fuel than Tier 1 vehicles. Tier 0 vehicles showed an overall NOx decrease for the cold start portion of the test of the FTP. The Tier 0 NOx emission rates for the LDTs decreased for both the cold start and the second bag of the FTP. The decrease in NOx for bag 1 was the result of test vehicle OF098T12. Three out the four LDTs showed an increase in NOx but this vehicle showed a large decrease in NOx for the cold start. For Tier 1, NOx increases were realized for all phases of the test. Figure 16 shows the oxygenated fuel effect on NOx emissions rates for both Tiers. As shown, the Tier 1 vehicles have both non-oxygenated and oxygenated NOx emissions less than one half of those of Tier 0 and the magnitude of the NOx changes are greater than the Tier 0 changes. The change in the emission rates for the Tier 1 set and the LDVs were statistically significant at the 90% and 95% confidence levels respectively. The lower base fuel emissions rates may be attributable to the lower NOx standard to which these vehicles are certified as well as the lower accumulated miles of this set.



* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

Figure 16. Oxygenated fuel effects on FTP NOx emissions for Tier 0 and Tier 1.

The absolute changes in emission rates and the resulting percent change for FTP NOx emissions are presented in Table 16.

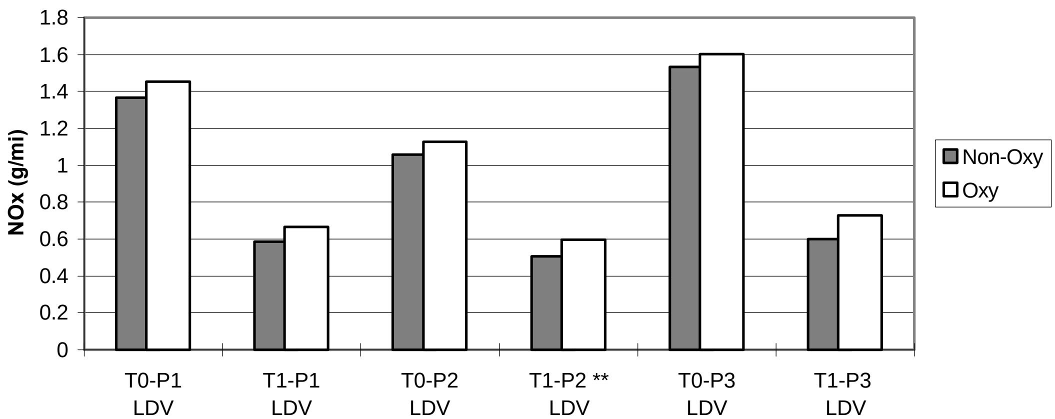
Table 16
Absolute and Percent Change in FTP NOx Emissions for Tier 0 and Tier 1

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
FTP	+0.004	+0.4	+0.023	+2.4	-0.035	-2.7
Bag 1	-0.081	-5.1	-0.057	-4.5	-0.129	-5.8
Bag 2	+0.013	+1.7	+0.031	+4.2	-0.023	-2.7
Bag 3	+0.050 **	+4.2	+0.066 **	+6.2	+0.017	+1.2
Tier 1						
FTP	+0.078 **	+19.8	+0.069 *	+19.3	+0.094	+20.6
Bag 1	+0.131 **	+14.8	+0.122 *	+16.0	+0.149	+13.1
Bag 2	+0.067 **	+36.0	+0.051 *	+30.5	+0.099	+44.1
Bag 3	+0.057	+13.9	+0.064 *	+15.1	+0.042	+11.2

Δ = Absolute in grams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

NOx Emissions - Unified Cycle Results

The same trend of increasing NOx emissions shown for the FTP with the oxygenated fuel is also evident with the Unified Cycle. Figures 17, 18 and 19 show the differences between the averaged NOx emissions for the two fuels for the LDVs, LDTs and the entire Tier 0 and Tier 1 sets. In all cases for the LDVs and the sets, an increase in NOx emissions is shown. Exceptions to the increase are seen in Figure 18 for the Tier 0 LDTs. These vehicles show a slight decrease in NOx emissions across all three phases. The decrease is driven by Test vehicle OF098T12 which showed a large decrease in NOx emissions for all three phases.



** Statistically Significant at the 90% Confidence Level

Figure 17. Oxygenated fuel effects on The Unified Cycle NOx emissions for Tier 0 and Tier 1 LDVs.

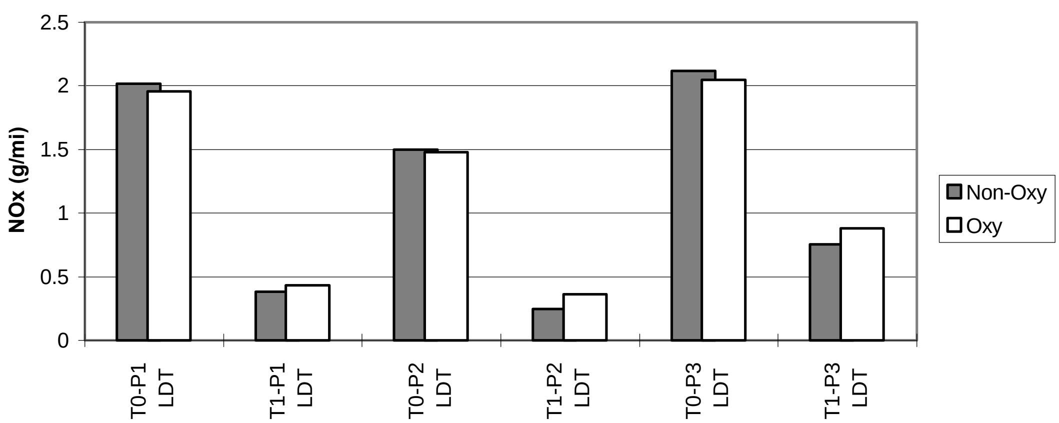
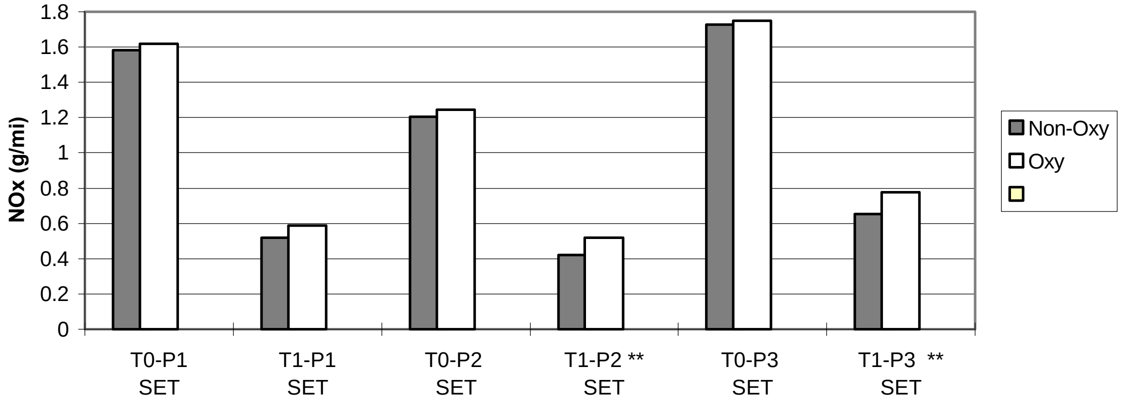


Figure 18. Oxygenated fuel effects on the Unified Cycle NOx emissions for Tier 0 and Tier 1 LDTs.



* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

Figure 19. Oxygenated fuel effects on the Unified Cycle NOx emissions for Tier 0 and Tier 1 total sets.

The NOx differences for Tier 0 LDTs are shown in Table 17. If the NOx test results from test vehicle OF098T12 are removed the deltas (Δ) become; +0.025, +0.05 and + 0.06 g/mi for the three phases. This again emphasizes the influence that one vehicle which exhibits large emission changes when the fuel is changed can have on a small sample.

Table 17
Absolute and Percent Change in the Unified Cycle NOx Emissions for Tier 0 and Tier 1 sets and LDV/LDT subsets

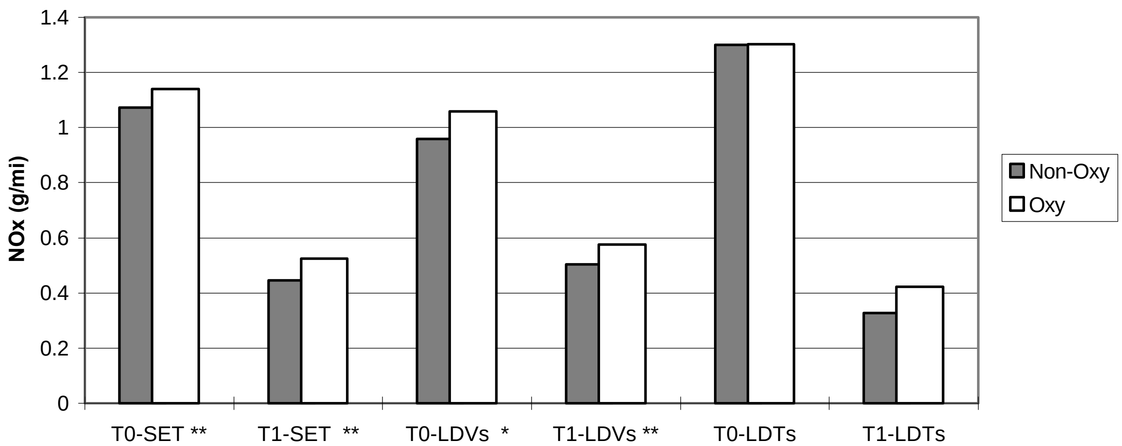
	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
Bag 1	+0.035	+2.2	+0.085	+6.2	-0.064	-3.2
Bag 2	+0.040	+3.3	+0.069	+6.6	-0.019	-1.3
Bag 3	+0.024	+1.4	+0.072	+4.7	-0.072	-3.4
Tier 1						
Bag 1	+0.068	+13.2	+0.079	+13.4	+0.048	+12.6
Bag 2	+0.074 **	+16.6	+0.093 **	+18.4	+0.036	+11.0
Bag 3	+0.126	+19.3	+0.126	+20.9	+0.127	+16.8

Δ = Absolute in grams per mile
** Statistically Significant at the 90% Confidence Level

NOx Emissions - REPO5 Results

The data show an increase in REPO5 NOx emissions for all categories when using the oxygenated fuel. The increases ranged from +0.003 to +0.08 g/mi as shown in Table 18. The REPO5 is a very aggressive driving cycle. The rapid accelerations require wide open throttle which results in maximum fuel enrichment. The periods of maximum enrichment are probably responsible for the relatively small increases in NOx observed. The Tier 0

LDTs showed a +0.003 g/mi (+3 mg/mi) NOx increase. Test vehicle OF098T12 showed a decrease in NOx whereas the other three vehicles showed an increase. If the results from the one vehicle are removed, the overall increase is +0.06 g/mi. The changes were statistically significant at the 95% confidence level for the Tier 0 LDVs and at the 90% level for both the Tier 0 and 1 sets as well as and the Tier 1 LDVs as shown in Figure 20.



* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

Figure 20. Oxygenated fuel effects on the REPO5 Cycle NOx emissions for Tier 0 and Tier 1 total sets.

Table 18
Absolute and Percent Change in the REPO5 Cycle NOx Emissions for Tier 0 and Tier 1 sets and the LDV/LDT subsets

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
REPO5	+0.067 **	+6.2	+0.099 *	+10.3	+0.003	+0.3
Tier 1						
REPO5	+0.080 **	+18.0	+0.072 **	+14.3	+0.095	+29.2

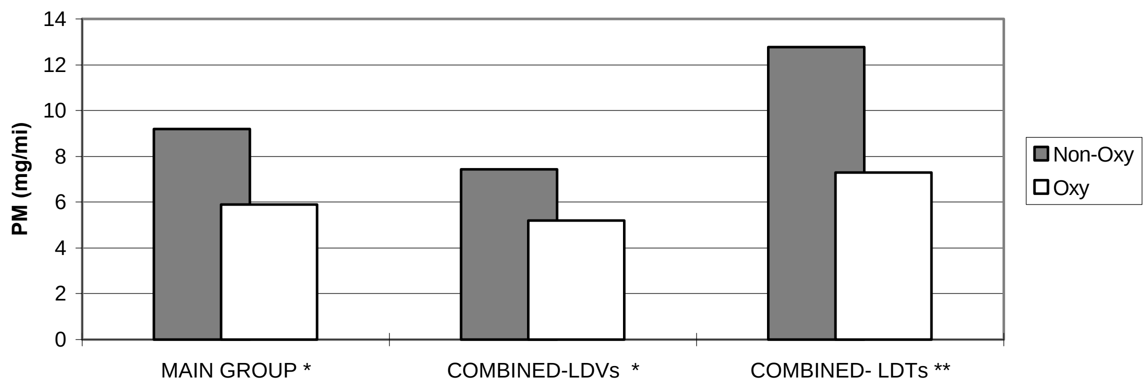
Δ = Absolute in grams per mile
* Statistically Significant at the 90% Confidence Level
** Statistically Significant at the 90% Confidence Level

7. Oxygenated Fuel Effect on PM Emissions

PM Emissions - FTP Overall Results

The average FTP emission rate of particulate matter (PM) showed an overall reduction with the oxygenated fuel as shown in Figure 21. The data show PM emission reductions in milligrams per mile (mg/mi) of -3.3 for the main group, -2.23 for the total LDVs and -5.5 for the LDTs. These absolute reductions reflect -36.0%, -30.1% and -42.8% reductions respectively. The reductions for the main group and LDVs are statistically significant at the 95% confidence level with the LDTs being significant at the 90% confidence level.

In Figure 22 it can be seen that if the PM emission rates for all vehicles are sorted from highest to lowest and the changes are examined, the eight highest emitters account for 71% of the total PM reduction achieved with the use of the oxygenated fuel. Seven out of the eight vehicles with the highest PM emissions were Tier 0. Test vehicle OF098T12 once again showed not only the highest PM emissions rate on the base fuel (36.2 mg/mi) but also the largest reduction (-24.6 mg/mi) which amounted to almost one half of the PM reductions from the eight higher PM emitting vehicles. Also, as was the case for CO and HC, the other seven vehicles would account for 56 percent of the PM reductions from all vehicles except #12. As previously shown for both CO and HC, the vehicles with the lowest emission rates showed less benefit from the oxygenated fuel.



* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

Figure 21. The effect of a 10% ethanol blended fuel on FTP PM composite emissions for the Tier 0 and Tier 1 vehicles and the main group.

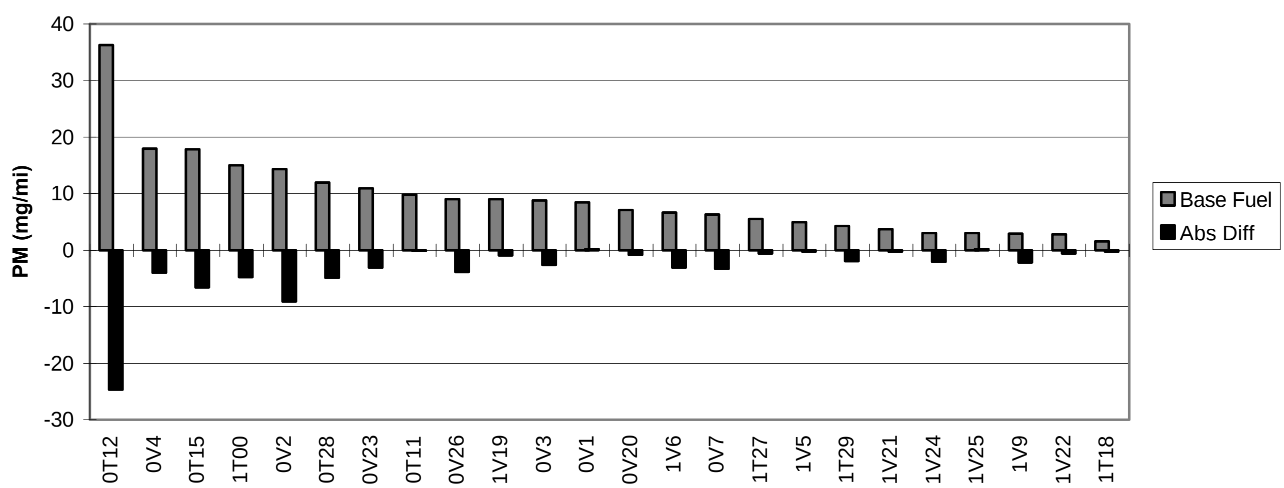
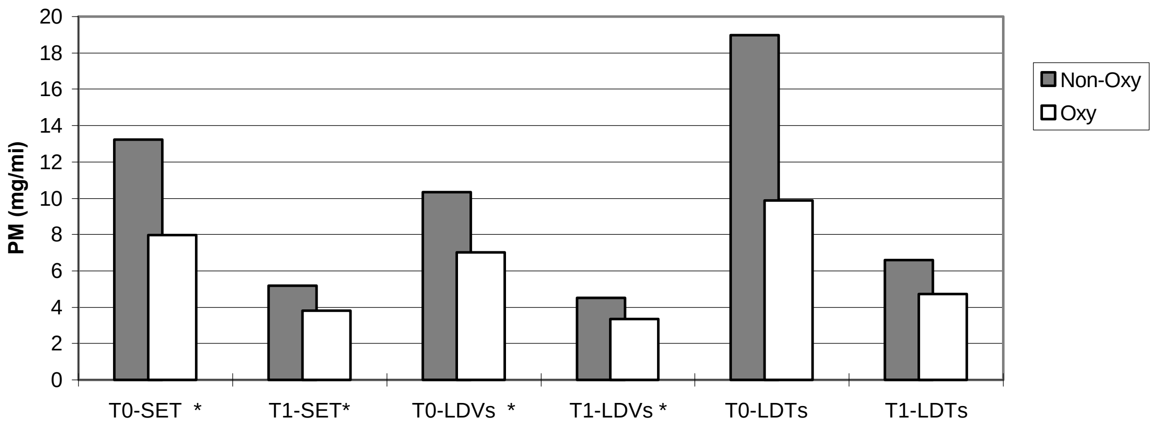


Figure 22. FTP base fuel PM emission rates and the associated change due to the oxygenated fuel.

PM Emissions - FTP Results by Certification Tier

As shown in Figure 23 below, PM emissions showed a decrease for all categories of Tier 0 and Tier 1. The larger absolute PM reductions were achieved from the Tier 0 LDVs and LDTs. As mentioned above, the high average PM emissions rate and the large reduction shown for the LDTs is mainly due to test vehicle OF098T12. For both Tiers and for both LDVs and LDTs the largest PM emission reductions occurred during the cold start or bag 1. The Tier 0 LDVs and LDTs showed average PM reductions during the cold start of -18.2 and -27.8 mg/mi. The Tier 1 vehicles with their lower emission rates still showed PM reductions of -5.5 and -9.0 mg/mi for phase 1. During bags 2 and 3 of the FTP both of which occur with a stabilized fully warmed up engine, little or no PM reduction benefit was derived from the oxygenated fuel.



* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

Figure 23. The effect of oxygenated fuel on FTP PM emissions for Tier 0 and Tier 1.

Table 19 provides an overall summary of both Tier 0 and Tier 1 PM emissions. Note that the absolute differences and percent changes for the Tier 0 LDTs are being driven by test vehicle OF098T12.

Table 19
Absolute and Percent Change in FTP PM Emissions for Tier 0 and Tier 1

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
FTP	-5.24 *	-39.7	-3.32 *	-32.2	-9.08	-47.9
Bag 1	-21.36 *	-42.6	-18.16 *	-42.4	-27.77	-42.8
Bag 2	-0.14	-6.6	+0.52	+32.6	-1.48 *	-45.0
Bag 3	-2.68	-43.6	+0.56	+23.8	-9.16	-66.8
Tier 1						
FTP	-1.38 *	-26.6	-1.14 *	-25.3	-1.87	-28.4
Bag 1	-6.63 *	-30.6	-5.47 *	-29.9	-8.95	-31.5
Bag 2	+0.07	+11.1	-0.01	-1.7	+0.23	+45.6
Bag 3	-0.16	-11.3	-0.002	-0.2	-0.47	-28.7

Δ = Absolute in milligrams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

PM Emissions - Unified Cycle Results

The data show that the differences in PM emissions resulting from the use of oxygenated fuel to be both relatively small and variable. The Unified Cycle was conducted from a hot running start rather than a cold start. PM emissions from a fully warmed up vehicle are usually very low. In addition, the first and third phases of this cycle are 300 seconds in length which limits the sampling time. These factors led to the use of a single filter to collect PM emissions from all three phases of the Unified Cycle. PM emission rates, overall were quite low as indicated in Figure 24. The average base fuel PM emission rates for Tier 0 and 1 sets were 4.9 and 2.0 mg/mi. The differences observed with the use of the oxygenated fuel are shown in Table 20. None of the changes, either for the sets or the vehicle subsets comprising them were statistically significant at the 90% confidence interval.

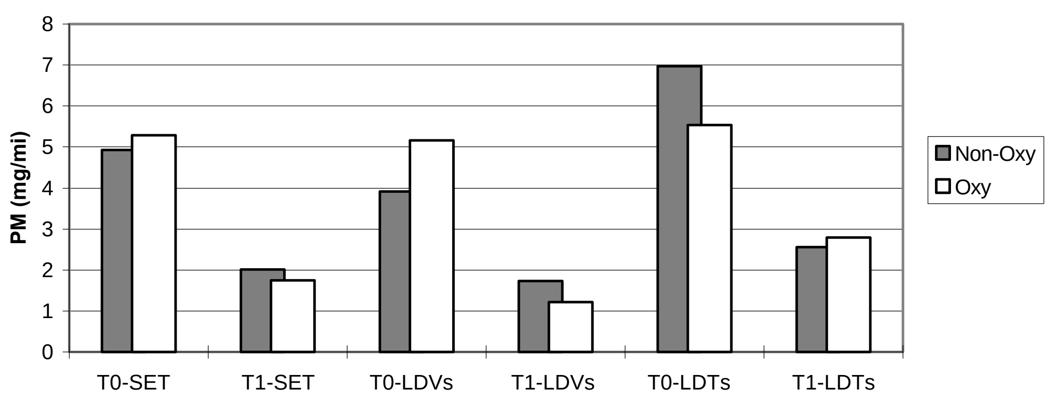


Figure 24. Oxygenated fuel effects on the Unified Cycle emissions for Tier 0 and Tier 1 total sets and their subsets.

Table 20
Absolute and Percent Change in the Unified Cycle PM Emissions for Tier 0 and Tier 1 sets and the LDV/LDT subsets

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
U.C.	+0.36	+7.2	+1.25	+32.0	-1.43	-20.6
Tier 1						
U.C.	-0.26	-13.0	-0.51	-29.6	+0.24	+9.5

Δ = Absolute in milligrams per mile

PM Emissions - REPO5 Results

PM samples for the REPO5 were also collected on a single filter. The REPO5 represents driving conditions that are considerably more aggressive than the FTP or Unified Cycle. Figure 25 shows the averaged emissions for both fuels and the categories that make up each Tier. The overall reductions shown for Tier 0 were once again driven by the LDTs. Two out of the four LDTs showed large PM reductions when using the oxygenated fuel. The opposite is seen for Tier 1 with the increased PM emissions caused by the LDTs with all four showing an increase in PM emissions with the oxygenated fuel. Comparing the REPO5 to the Unified Cycle results shows the effects of the more aggressive driving required in the REPO5. The averaged emissions from all Tier 0 and 1 categories from the REPO5 range from 3.5 to 4.8 times greater than those of the Unified Cycle.

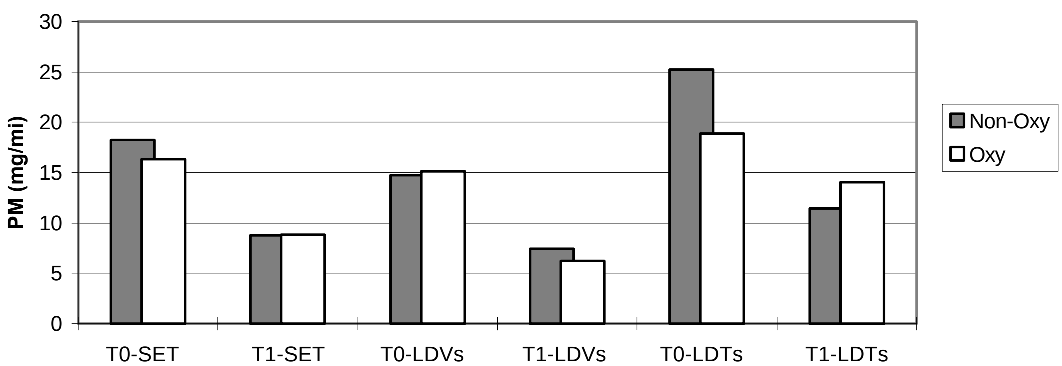


Figure 25. Oxygenated fuel effects on the REPO5 Cycle PM emissions for Tier 0 and Tier 1 total sets and their subsets.

Table 21
Absolute and Percent Change in the REPO5 Cycle PM Emissions for
Tier 0 and Tier 1 sets and the LDV/LDT subsets

	SET		LDVs		LDTs	
Tier 0	Δ	% Δ	Δ	% Δ	Δ	% Δ
REPO5	-1.90	-10.4	+0.35	+2.4	-6.42	-25.4
Tier 1						
REPO5	+0.05	+0.5	-1.23	-16.4	+2.59	+22.6

Δ = Absolute in milligrams per mile

8. Oxygenated Fuel Effect on Fuel Economy

Fuel Economy - Overall Results

Fuel economy overall showed a decrease with the oxygenated fuel. This is to be expected because of the lower heating value or energy content of the 10% ethanol blend. The dilution of a base hydrocarbon fuel with 10% ethanol results in a reduction of the energy content of approximately 3%. Calculations based on the test fuels used in this program showed an estimated average reduction of -3.4% in the btu/gallon for the ethanol blend.

The overall fuel economy trend showed a reduction ranging from -0.8% to -2.4% which is equivalent to a loss of -0.12 to -0.6 miles per gallon for the FTP and the REPO5 respectively. The actual change in fuel economy varied among the test cycles. For the composite FTP the change ranged from -1.2 % (-0.26 mpg) for the Tier 1 vehicles to -1.7% (-0.37 mpg) for Tier 0. Individual vehicle results showed fuel economy changes ranging from an increase of +1 mpg to a decrease of -1.8 mpg for Tier 0 vehicles and a positive 0.29 to a negative 0.67 mpg for Tier 1. Of the twelve Tier 0 vehicles, ten showed a decrease in fuel economy. One LDV and one LDT showed increases of +0.37 and +0.24 mpg each. The overall increase in FTP fuel economy was driven by phase 1, the cold start, and phase 3, the hot restart after the 10 minute soak, where additional fuel enrichment was evident. One Tier 1 LDV showed an overall increase of +0.2 mpg. FTP composite fuel economy changes were statistically significant for both Tiers, both as a set and for the LDVs at the 95% confidence level. The change for the Tier 1 LDTs was also statistically significant at the 95% confidence level.

REPO5 fuel economy changes ranged from a -1.3% (-0.32 mpg) for the Tier 0 set to -2.4 % (-0.6 mpg) for the Tier 1 set. Three Tier 0 vehicles showed a fuel economy improvement on the ethanol blend ranging from +0.16 to +0.65 mpg. All Tier 1 vehicles showed a decrease in fuel economy with individual vehicle values ranging from -0.09 to -0.94 mpg. Statistically significant changes at the 95% confidence level were shown for Tier 0 LDVs and at the 90% confidence level for the set. For Tier 1 the changes were statistically significant at the 95% confidence level for the set as well as for the LDVs and LDTs.

Unified Cycle fuel economy differences with the oxygenated fuel followed similar trends as shown above with one exception. The exception was for the third phase of the cycle and applied only to the Tier 1 set. For this test cycle segment, a fuel economy decrease of -0.87 mpg or -4.9% was indicated. The phase 2 fuel economy changes were statistically significant at the 95% confidence level for the Tier 0 set and LDVs and for the LDTs at the 90% level. For Tier 1 the changes were statistically significant at the 95% confidence level for the set for all three phases, for phases 2 and 3 for the LDVs and for phases 1 and 2 for the LDTs. All other fuel economy changes were statistically significant at the 90% confidence level.

9. Oxygenated Fuel Effect on High Emitters

High Emitting Vehicles

Only one high emitting Tier 1 vehicle could be procured for this study so that vehicle will be included with the five Tier 0 high emitters for the following discussion of results. In addition, vehicle OF098H14, a Tier 0 LDV, was not tested on the REPO5 test due to concerns about the reliability of its engine on the most demanding test cycle.

High Emitter FTP CO Emissions

In Figure 26 it can be seen that three of the vehicles had moderately high CO emission levels, two vehicles had very high CO levels and the sixth vehicle fell somewhere in between. In fact, vehicle numbers OF098H8, OF098H14, and OF098H17 were only marginal failures when identified by the I/M 240. Vehicle number OF098H31 was a definite failure and OF098H32 was a gross emitter. The last vehicle, number OF198H36 was a normal Tier 1 mini-van which was deliberately altered for this study to cause high emissions. Not only were the CO emission levels for the two highest emitting vehicles 7 to 10 times higher than the average of the three marginal failures (35.5 g/mi), their emission reductions were also about 7 times greater than the average reductions for the marginal (-7.53 g/mi). Table 22 presents the absolute reductions as well as the relative percent reductions for each vehicle. It is interesting to note that although the highest emitters had the largest absolute reductions, their average percent reductions (-17.61 %) were not very different from the average for the other four vehicles (-15.02 %). Overall the six high emitters experienced a -23.3 g/mi and a -16.9% reduction in CO on oxygenated fuel.

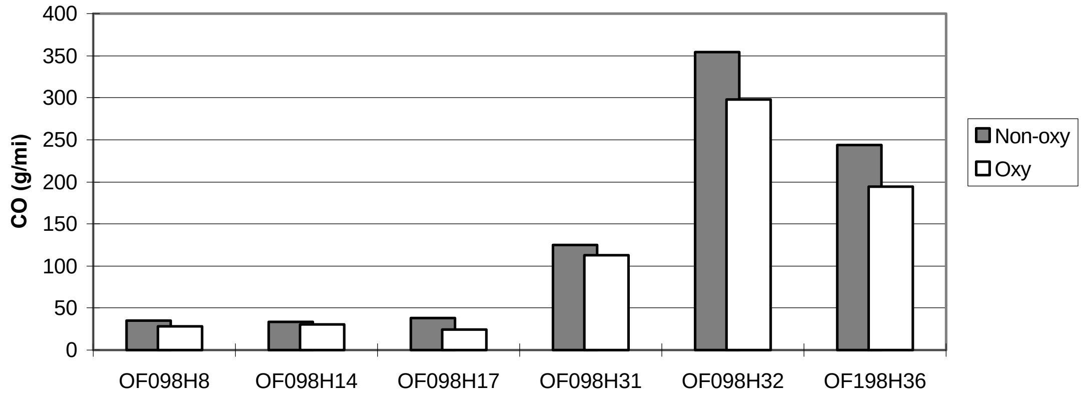


Figure 26. Absolute CO emissions for the base and oxygenated fuels for each of the high emitters.

If the FTP CO emissions are examined on a phase by phase basis the same pattern tends to hold. For the two high emitting vehicles, bag 1, 2 and 3 baseline emissions were all 5 to 10 times higher than the corresponding bags for the other four vehicles. The same is true for the emission reductions except that bag 3 for the high emitters is only 3 times as great as the four lower emitters. If the +16.6 g/mi increase for vehicle 31 in bag 1 is overlooked, the pattern holds too for relative reductions in all three bags - the four lower emitters' average percent reductions were nearly the same as the two high emitters. They all were within the range of -13% to -25% reductions. For the entire group of six vehicles the average CO reduction of -14.1% for bag 3 was statistically significant at the 95% confidence level. At the 90% level significant reductions were seen for both the FTP composite and bag 2. Only bag 1 was not significant, possibly due to the +16.6 g/mi increase by vehicle #31.

<u>High Emitter Unified and REPO5 CO Emissions</u>

The same patterns of emission levels and reductions that were observed in the FTP were also found generally in the Unified and REPO5 tests for CO. The same three vehicles had much higher emissions on both fuels and one of them, vehicle # 32, had much larger reductions as well. Unlike the FTP however, one of the other highest emitters, vehicle # 31, had only average reductions on both tests. The third, vehicle # 36, also had an average reduction on the REPO5 but a very small increase in CO on oxygenated fuel on the Unified test. Percentage reductions were somewhat more varied than they were for the FTP but they still seemed to be more consistent than the absolute reductions and, with the exception of the one +1.4% increase, were in the range of -5% to -40%. Phases 2 and 3 of the Unified test as well as the REPO5 test showed significant reductions in CO at the 95% confidence level.

<u>High Emitter FTP HC Emissions</u>

HC, like CO, was very high for vehicles 32 and 36 and about one third as high for the remaining four vehicles both on non-oxygenated fuel as well as oxygenated (see Figure 27.

Likewise, Table 22 shows that the absolute HC reductions for the two high emitters were about 7 times as great as the four other vehicles.

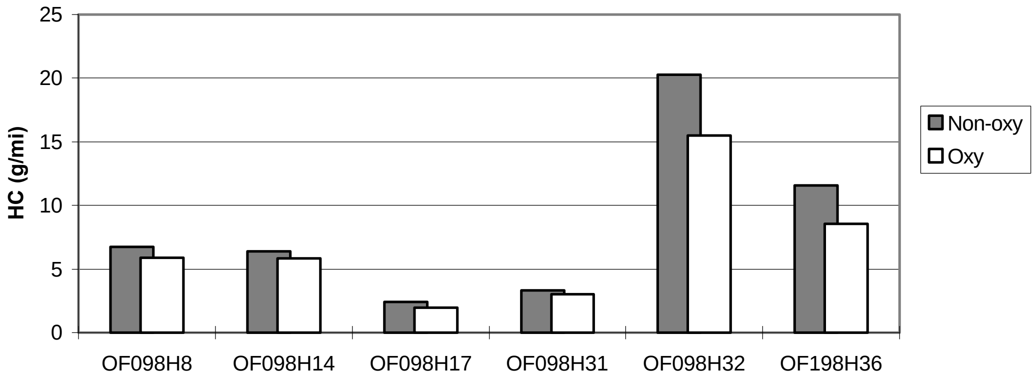


Figure 27. Absolute HC emissions for the base and oxygenated fuels for each of the high emitter vehicles.

Table 22 shows that for the high emitting set, HC emissions were reduced by -0.66 g/mi or -19.6%. At this point the comparison with CO breaks down. Vehicles 8 and 14 had bag 1 HC emissions comparable to the high emitters but relatively small decreases. Their percent decreases were so small that they also lowered the composite percent reductions for vehicles 8 and 14. As a result the average decreases for the composite emissions for the four lower emitters were only about one half as great as the two high emitters and the average bag 1 percent decreases were only one tenth of the high emitter's. Only the bag 3 average reduction of -20.5% for all 6 vehicles was statistically significant at the 95% level. At the 90% level the composite HC reductions were statistically significant. The bag 1 standard deviation is quite large and precludes significant differences for that phase.

When the high emitting vehicles were grouped according to vehicle type the two highest emitters along with vehicle #8 fell into the group of three minivans. The LDVs included two of the three lower emitters plus vehicle #31 which was relatively low to moderate. Accordingly, emissions and reductions were similar to the divisions between high and low emitters mentioned above. The average LDT emissions were about 3 times higher and the average reductions were 4 to 5 times greater than the LDVs. Again the bag 1 increase in both HC and CO for vehicle #31 substantially affected the LDV averages but if not for that, all of the percent changes would have been very comparable between LDVs and LDTs. Table 22 contains the absolute and relative changes for each phase of the FTP as well as the composite. It also shows those values for the LDV and LDT subsets (statistical significance was not calculated for high emitting LDVs and LDTs).

Table 22
Absolute and Percent Change in FTP Emissions for High Emitting Vehicles

	SET		LDVs		LDTs	
CO	Δ	% Δ	Δ	% Δ	Δ	% Δ
FTP	-23.3 **	-16.9	-9.4	-14.3	-37.3	-17.7
Bag 1	-22.4	-12.9	-1.0	-1.1	-43.8	-17.0
Bag 2	-30.0 **	-19.5	-13.5	-21.9	-46.6	-18.9
Bag 3	-11.4 *	-14.1	-8.0	-14.9	-14.8	-13.7
HC						
FTP	-1.66 **	-19.6	-0.44	-11.0	-2.87	-22.4
Bag 1	-2.28	-15.1	-0.19	-2.3	-4.37	-20.0
Bag 2	-1.81	-22.9	-0.49	-17.6	-3.12	-24.0
Bag 3	-0.91 *	-20.5	-0.55	-17.8	-1.27	-21.9

Δ = Absolute in grams per mile
* Statistically Significant at the 95% Confidence Level
** Statistically Significant at the 90% Confidence Level

High Emitter Unified and REPO5 HC Emissions

The emissions patterns that were observed in the FTP did not follow through in the Unified and REPO5 tests for HC like they did for CO. Neither the absolute levels nor the reductions from the three highest emitters were much greater than the lower emitters. Like the FTP however, there were no emission increases other than bag 1 of the Unified test for vehicle # 31 which also occurred during the FTP. Also, the percent reductions were again fairly consistent ranging from -10% to just over -30%. Phase 3 of the Unified test and the REPO5 both showed significant reductions in HC at the 95% confidence level.

High Emitter FTP, Unified and REPO5 NOx Emissions

Absolute NOx emission levels for the high emitting vehicles were not so clearly dichotomous as were the CO and HC emissions. Vehicle #32 which had been among the three highest CO and HC emitters was the lowest of all six high emitting vehicles for NOx on all three tests. Changes in emission levels were even less like the changes for other pollutants. On the FTP only one vehicle, number 17, had a reduction in NOx with oxygenated fuel. That reduction was about -13%. The other five increased from +10% to +35%. On the Unified test two of the lower CO/HC emitters increased almost +60% but three other vehicles decreased -3%, -5% and -35%. On the REPO5 test, of the two vehicles with large increases on the Unified, one showed a +105% increase, the other, number 14, was not tested because of engine reliability concerns as mentioned above. The same three vehicles which showed reductions on the Unified had reductions of -0.5%, -27% and -11% respectively. The only statistically significant change in NOx for the high emitters was a +32% increase in phase 1 of the FTP and that was at the 90% confidence level.

High Emitter FTP, Unified and REPO5 PM Emissions

Particulate emissions for the six high emitting vehicles very closely resembled the HC emissions for those vehicles. The three higher emitters were much higher absolutely, especially during the FTP and both the absolute and the percentage reductions more closely matched the corresponding HC numbers than any others. None of the reductions in particulates for the high emitting vehicles was statistically significant.

High Emitter FTP, Unified and REPO5 Fuel Economy

Fuel economy levels for the six high emitting vehicles did not show any clear relationship to emission levels except that the two highest emitting LDTs had the lowest fuel economy readings. The relative levels from vehicle to vehicle did remain consistent from test to test however. The changes in fuel economy were small and depended upon the test. For the four lowest emitters on CO and HC, out of eleven tests (FTP, Unified and REPO5 for 3 vehicles, FTP and Unified for #14), there were four decreases in fuel economy on the FTP and three on the Unified but there were four increases - three on the REPO5 and one on the Unified. These changes ranged from just under a +2% increase to just over a -2% decrease. The two highest CO/HC emitters however had +9.7% and +7.6% increases on the FTP but one of them had +4.5% and +6.2% increases on the Unified and REPO5 while the other had -5.1% and -3.2% decreases on these two tests with oxygenated fuel. There were no statistically significant differences in fuel economy for any of the tests or phases for the high emitting vehicles.

10. Low Emissions Vehicle

Tables 23 and 24 reveal that the effects of oxygenated fuel on the LEV (Low Emissions Vehicle) were inconclusive. Among the reasons for this are the facts that, for the most part, the baseline emissions were very low to begin with, the changes were small and only one vehicle was tested greatly reducing the database. The effects which were observed were as follows. For CO the effects were mixed. There was a +24% increase in FTP CO emissions but there were -40% decreases in Unified and REPO5 levels. The magnitude of the FTP CO increase was partly due to the baseline emissions level being the lowest of all 30 vehicles tested. The Unified and REPO5 reductions may well have been due to the fact that those driving cycles included a lot of wide open throttle operation. Changes in HC emissions were small, -7%,-1% and -14% decreases on the FTP, Unified and REPO5 tests respectively and these changes were based on the lowest or next to lowest baseline emission levels of all vehicles tested. NOx emission changes were also based on the lowest or next to lowest baseline levels and ranged from a +11% increase on the FTP to a +90% increase on the Unified.

PM emission changes, like CO, were mixed but the directions were opposite from CO. On the most demanding cycle, the REPO5, there was a +42% increase in PM while on the less aggressive FTP and Unified cycles there were -18% and -29% decreases. The REPO5 tests especially may have been affected by preceding tests. It is possible that heavy particulate emissions from high emitting vehicles may have become “hung up” in the sampling system and then been dislodged by the large temperature and volume excursions associated with the REPO5. This appeared to occur for the first test sequence on oxygenated fuel so those results were excluded from the Unified and REPO5 data sets. There may have been similar effects however on the second series of tests on non-oxygenated fuel and, to a lesser extent, the second series on oxygenated fuel but it was not apparent in the emissions readings. Fuel economy effects were very similar to the other vehicles tested. There was a -2% decrease for the FTP but as the tests included more wide open throttle operation the decrease became less, -1%, on the Unified test and became a small increase, +0.2%, on the REPO5.

Table 23
CO, HC and NOx baseline emissions and percent changes for the LEV

LEV	CO (g/mi)		HC (g/mi)		NOx (g/mi)	
	NonOxy	% Δ	NonOxy	% Δ	NonOxy	% Δ
FTP c	0.75	23.8	0.129	-6.9	0.122	11.3
FTP 1	2.42	15.4	0.532	-8.2	0.526	-1.9
FTP 2	0.31	23.3	0.022	-1.1	0.002	371.4
FTP 3	0.33	73.0	0.025	6.4	0.043	93.4
Unified 1	0.80	-11.7	0.026	-2.6	0.042	11.1
Unified 2	2.38	-42.3	0.036	-4.6	0.040	95.0
Unified 3	0.61	32.8	0.017	52.0	0.047	99.3
REPO5	6.44	-39.8	0.039	-13.7	0.024	37.0

Table 24
Particulate and Fuel Economy baseline emissions and percent changes for the LEV

LEV	PM (mg/mi)		MPG	
	NonOxy	% Δ	NonOxy	% Δ
FTP c	5.98	-18.0	24.3	-2.35
FTP 1	13.99	8.8	21.1	-2.75
FTP 2	1.51	31.8	24.6	-2.82
FTP 3	8.39	-68.7	26.9	-0.96
Unified 1	1.04	-28.7	18.8	-3.27
Unified 2			25.4	-0.88
Unified 3			18.9	-1.35
REPO5	2.80	41.7	26.5	0.21

11. Conclusions

This study was designed to expand the database of information regarding the effects of oxygenated fuel on exhaust emissions, especially with regard to low temperature tests and newer technology vehicles as well as to simply add more tests to the available data. Data from this study should also provide additional information on tests conducted at high altitude, on a 48” diameter dynamometer, on high emitting vehicles identified by an I/M 240 program, on a Low Emitting Vehicle, on tests using alternative driving cycles and on particulate emissions.

Thirty-one vehicles were tested in an effort to obtain as large and as statistically meaningful a database as possible. However, when the test results were analyzed to see if the responses from different subsets of vehicles varied, the sample sizes decreased to 12, 8 and even 4 vehicles. This together with a high degree of vehicle to vehicle variability made finding statistically significant changes within these subsets difficult. As a result some subsets were recombined in order to have a large enough sample that statistically significant results could be observed. One other important aspect of statistical significance and sample size should be reiterated at this point. In many cases the confidence limits were so close to the dividing line between significance and lack of significance that small changes such as including or excluding one value or one similar group of vehicles could determine whether or not a change was statistically significant. For this reason two levels of significance, α = 0.05 (95% confidence) and α = 0.10 (90% confidence), were calculated. If the difference between non-oxygenated and oxygenated emissions is significant at the 95% confidence level then oxygenated fuel can be considered to have had a real effect upon that group of vehicles. Likewise, if the difference is not significant at the 90% confidence level, then oxygenated fuel can be considered to have had little effect or an inconsistent effect upon the group. Effects which are significant only at the 90% confidence level should not be considered to be conclusive. In this summary significant will mean statistically significant at the 95% confidence level and not significant will mean not statistically significant at the 90% confidence level.

As the various subsets of vehicles were examined it was discovered that emissions changes attributable to oxygenated fuel were in many cases proportional to baseline emission levels. Baseline levels in turn seemed to be related to certification level which also implies vehicle age and mileage. In some cases baseline levels seemed to be related as well to vehicle type, i.e. LDV or LDT. Emissions changes were also dependent upon the nature of the driving cycle used in the different tests. Driving cycles which included higher acceleration rates and higher speeds often had different results than the traditional FTP with the UDDS driving cycle.

There was considerable variation in emissions and fuel economy results between certification Tiers, between LDVs and LDTs and among tests and their phases. Because of this and the fact that this group of vehicles only represents the <u>current</u> status of the Denver area fleet, blanket statements about the observed effects of oxygenated fuel or predictions of its effects on other fleets should not be made solely on the basis of this study. Keeping that caveat in mind, based upon this particular combined set of 24 Tier 0 and Tier 1 LDVs and LDTs and using the composite value of the FTP, the 10% oxygenated fuel at an ambient temperature of 35° F reduced CO emissions by about -11%, reduced HC and

PM emissions by about -16% and -36% respectively, had no significant effect upon NOx and decreased fuel economy by about -1.4%. An accurate assessment of the effects of oxygenated fuel cannot be made however without considering the variations in effects among vehicle groups and test conditions.

The primary focus of this study was on carbon monoxide or CO emissions. The largest group of comparable vehicles consisted of twenty-four Tier 0 and Tier 1 LDVs and LDTs without the designated high emitters or the LEV. On the traditional FTP test this group showed an overall reduction in CO of approximately -11% which was statistically significant at the 95% confidence level. As this group was subdivided, certain subsets also showed statistically significant effects from the use of oxygenated fuel. The sixteen LDVs had a -11% reduction and the eight Tier 1 LDVs had a -16% reduction. For the FTP, the effects of oxygenated fuel on CO emissions were not significant for Tier 0 vehicles either as a whole or as LDVs or LDTs. There was also no significant effect on LDTs either as a combined group or within each Tier. On the Unified test the only significant changes were for phase 3 LDVs and phase 3 LDVs plus LDTs in Tier 0 and the combined Tiers plus phases 2 and 3 of the combined Tier 1 set. There were no significant changes for LDTs nor for phases 1 and 2 with the exception of the Tier 1 set in phase 2 and possibly in phase 1. The REPO5 test only resulted in significant CO reductions for all twenty-four vehicles combined. There were no significant changes indicated for Tier 1 nor for LDVs in either Tier or in the combination of Tiers.

The only statistically significant change in FTP CO emissions for the six high emitting vehicles was a -14.1% reduction during phase 3. On the Unified cycle, phases 2 and 3 had CO reductions of -9.5% and -26.5% respectively. There was also a statistically significant CO reduction of -15.1% on the REPO5 test. Since only one LEV was tested, no statistical significance could be calculated for that vehicle.

Table 25
Effects of Oxygenated Fuel on CO Emissions

		FTP				Unified			REPO5
	#	Comp	Ph 1	Ph 2	Ph 3	Ph 1	Ph 2	Ph 3	
Tier 0									
LDT	4	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	?
LDV	8	NoSD	NoSD	?	NoSD	NoSD	NoSD	-32.6	NoSD
All	12	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	-27.4	?
Tier 1									
LDT	4	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD
LDV	8	-15.8	?	NoSD	-31.3	NoSD	NoSD	?	NoSD
All	12	?	NoSD	NoSD	-30.4	?	-22.6	-21.2	NoSD
Both									
LDT	8	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	?
LDV	16	-10.8	?	-14.8	-18.3	NoSD	NoSD	-28.7	NoSD
All	24	-11.1	?	-10.9	NoSD	NoSD	NoSD	-26.0	-12.5
HiEms	6	?	NoSD	?	-14.1	NoSD	-9.5	-26.5	-15.1

##.# = Statistically significant change at the 95% confidence level expressed in terms of percent
? = Change which is only statistically significant at the 90% confidence level
NoSD = Change which is not statistically significant at the 90% confidence level

Hydrocarbon (HC) and particulate (PM) emissions were also of interest and the groups of vehicles whose HC and PM emissions were significantly affected by oxygenated fuel were very similar. In the composite and cold start (phase 1) FTP emissions there were significant HC reductions of -12% to -17% and significant PM reductions of -25% to -43% for the LDVs and LDVs combined with LDTs for each Tier separately as well as in combination. Also, in phase 3 of the FTP, LDVs had HC reductions of -16% and -14% for Tier 1 and the combination of Tiers. in both Tiers for LDTs there were no significant changes in either pollutant on any test with one definite exception and two possible exceptions. In phase 2 of the FTP, Tier 0 LDTs had a -45% reduction in PM and the eight LDTs combined had questionable (significant only at 90%) reductions in HC in phase 1 of the FTP and questionable reductions in PM in phase 1 and the composite of the FTP. In phases 2 and 3 of the FTP for both HC and PM, except for the three cases mentioned above, there were no other significant changes. In the Unified and REPO5 tests there were no significant effects on PM emissions nor on either HC or PM for any groups of LDTs. There were also no significant effects on phase 1 Unified HC emissions nor on phase 2 Unified HC for Tier 0 vehicles. The only significant Unified or REPO5 reductions were for HC. There was a significant REPO5 HC reduction for the sixteen LDVs combined. The rest of the reductions were in the Unified test and they occurred during phase 3 for the Tier 0 set, during phase 2 for the Tier 1 set and during phases 2 and 3 for the 16 combined LDVs and the 24 vehicle group.

As was the case for CO, the only statistically significant change in FTP HC emissions for the six high emitting vehicles was a -20.5% reduction during phase 3. On the Unified cycle only phase 2 had a statistically significant HC reduction of -14.0%. There was also a statistically significant HC reduction of -19.2% on the REPO5 test. There were no statistically significant changes in PM emissions on any test cycles for the high emitting vehicles. Again, since only one LEV was tested no statistical significance could be calculated for that vehicle.

Table 26
Effects of Oxygenated Fuel on HC Emissions

		FTP				Unified			REPO5
	#	Comp	Ph 1	Ph 2	Ph 3	Ph 1	Ph 2	Ph 3	
Tier 0									
LDT	4	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD
LDV	8	-15.9	-16.2	?	NoSD		NoSD	?	NoSD
All	12	-17.3	-13.8	NoSD	NoSD	NoSD	NoSD	-24.1	?
Tier 1									
LDT	4	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD
LDV	8	-13.8	-15.0	NoSD	-15.7	NoSD	?	?	?
All	12	-11.6	-13.2	NoSD	NoSD	NoSD	-17.9	?	NoSD
Both									
LDT	8	NoSD	?	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD
LDV	16	-15.2	-15.8	NoSD	-13.8	NoSD	-12.4	-30.7	-12.3
All	24	-15.7	-13.6	NoSD	NoSD	NoSD	-10.3	-24.7	?
HiEms	6	?	NoSD	NoSD	-20.5	NoSD	-14.0	NoSD	-19.2

##.# = Statistically significant change at the 95% confidence level expressed in terms of percent
? = Change which is only statistically significant at the 90% confidence level
NoSD = Change which is not statistically significant at the 90% confidence level

Table 27
Effects of Oxygenated Fuel on PM Emissions

		FTP				Unified	REPO5
	#	Comp	Ph 1	Ph 2	Ph 3		
Tier 0							
LDT	4	NoSD	NoSD	-45.0	NoSD	NoSD	NoSD
LDV	8	-32.1	-42.4	NoSD	NoSD	NoSD	NoSD
All	12	-39.7	-42.6	NoSD	NoSD	NoSD	NoSD
Tier 1							
LDT	4	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD
LDV	8	-25.3	-29.9	NoSD	NoSD	NoSD	NoSD
All	12	-26.6	-26.6	NoSD	NoSD	NoSD	NoSD
Both							
LDT	8	?	?	NoSD	NoSD	NoSD	NoSD
LDV	16	-30.1	-38.7	NoSD	NoSD	NoSD	NoSD
All	24	-36.0	-39.0	NoSD	NoSD	NoSD	NoSD
HiEms	6	NoSD	NoSD	NoSD	NoSD	NoSD	?

##.# = Statistically significant change at the 95% confidence level expressed in terms of percent
? = Change which is only statistically significant at the 90% confidence level
NoSD = Change which is not statistically significant at the 90% confidence level

NOx emissions on the FTP were significantly increased only for Tier 1 LDVs on all 3 phases plus the composite and for combined LDVs during phase 3 and the composite and finally, phase 3 for all twenty-four vehicles. These NOx changes ranged from +15% to +31% (+19% composite) for the Tier 1 LDVs by themselves. Again there were no significant changes for LDTs and, except for borderline phase 3 Tier 0 LDVs (with or without the LDTs), no significant Tier 0 NOx changes. On the Unified test only the sixteen combined LDVs in phases 2 and 3 and the full 24 vehicle group in phase 2 had significant increases. On the REPO5 test only the Tier 0 LDVs with or without the Tier 0 LDTs and with or without Tier 1 vehicles had significant increases. There were no significant changes for LDTs on either test and no significant changes for any group or set during phase 1 and none for Tier 0 during any phase of the Unified test. NOx emissions from the high emitting vehicles were not significantly affected on any test cycle.

Table 28
Effects of Oxygenated Fuel on NOx Emissions

	#	FTP				Unified			REPO5
		Comp	Ph 1	Ph 2	Ph 3	Ph 1	Ph 2	Ph 3	
Tier 0									
LDT	4	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD
LDV	8	NoSD	NoSD	NoSD	?	NoSD	NoSD	NoSD	+10.3
All	12	NoSD	NoSD	NoSD	?	NoSD	NoSD	NoSD	+6.2
Tier 1									
LDT	4	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD
LDV	8	+19.2	+16.0	+30.5	+15.1	NoSD	?	NoSD	?
All	12	?	?	?	NoSD	NoSD	?	?	?
Both									
LDT	8	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD
LDV	16	+7.1	NoSD	?	+8.7	NoSD	+10.4	+9.2	+11.7
All	24	NoSD	NoSD	?	+6.6	NoSD	+6.9	?	+9.7
HiEms	6	NoSD	?	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD

##.# = Statistically significant change at the 95% confidence level expressed in terms of percent
? = Change which is only statistically significant at the 90% confidence level
NoSD = Change which is not statistically significant at the 90% confidence level

Fuel economy was affected less on a percentage basis than any measured pollutant but the changes were more consistent so there were considerably more statistically significant changes. On all phases of the FTP all Tier 1 groups except Tier 1 LDTs in phase 3 and all combined Tiers except phase 3 LDTs were significantly affected. For Tier 0 LDVs the composite as well as phases 2 and 3 were affected and for Tier 0 LDTs only phase 2 was affected. For all Tier 0s, the composite and phase 2 were significantly affected and phase 3 was marginally affected. All of the significant changes were decreases in fuel economy and they ranged from -0.9% to -2.4%. On the Unified and REPO5 tests all Tier 1 groups were significantly affected except the LDVs in phase 1 and the LDTs in phase 3 of the Unified which were questionable. All of the combined Tier groups except the eight LDTs in phases 1 and 3 of the Unified and in the REPO5 were also significantly affected. On the Unified test, like the FTP, no Tier 0 groups were significantly affected in phase 1 but there were also no significant Tier 0 effects in phase 3. Also, the Tier 0 LDTs in the REPO5 were not significantly affected. The only significant Tier 0 effects were on the LDVs in phase 2 of the Unified and on the REPO5 along with the LDVs and LDTs combined in phase 2 of the Unified test. Fuel economy for the high emitting vehicles was not significantly affected on any test cycle.

Table 29
Effects of Oxygenated Fuel on Fuel Economy

		FTP				Unified			REPO5
	#	Comp	Ph 1	Ph 2	Ph 3	Ph 1	Ph 2	Ph 3	
Tier 0									
LDT	4	NoSD	NoSD	-1.3	NoSD	NoSD	?	NoSD	NoSD
LDV	8	-2.0	NoSD	-2.1	-2.4	NoSD	-2.5	NoSD	-1.9
All	12	-1.7	NoSD	-1.9	?	NoSD	-2.1	NoSD	?
Tier 1									
LDT	4	-1.8	-1.7	-1.7	-2.1	-2.3	-2.5	?	-2.3
LDV	8	-1.0	-0.9	-1.2	NoSD	?	-1.7	-5.1	-2.4
All	12	-1.2	-1.1	-1.4	-1.0	-1.5	-1.9	-4.9	-2.4
Both									
LDT	8	-1.3	-1.4	-1.5	NoSD	NoSD	-1.7	NoSD	NoSD
LDV	16	-1.5	?	-1.7	-1.5	-1.3	-2.1	-2.5	-2.2
All	24	-1.4	-1.1	-1.6	-1.3	-1.2	-2.0	-2.2	-1.9
HiEms	6	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD	NoSD

##.# = Statistically significant change at the 95% confidence level expressed in terms of percent
? = Change which is only statistically significant at the 90% confidence level
NoSD = Change which is not statistically significant at the 90% confidence level

Acknowledgments

The Mobile Sources Section of the Air Pollution Control Division thanks all of the members of the oxygenated fuel design committee. Their contribution allowed the Division to conduct an efficient testing protocol and build a data base which will be valuable for additional analyses.

The Mobile Sources Section acknowledges the following people for their assistance in making this study possible: Dennis Creamer and Conoco for supplying the test fuel; Bev Lynn from the CDPHE Information Technology Section for her work with the State's Motor Vehicle Registration database that ultimately provided the mailing list data base; and Jim Sidebottom, CDPHE, Mobile Sources Section, for providing daily updates on "high emitters" identified from the Enhanced I/M data base. Special thanks to the following AETC staff: Dawn Mirabile for taking on the additional task of vehicle procurement; Steve Sargent, Thad Pyzdrowski and Michael Waida for their continued and conscientious efforts in conducting the actual vehicle testing; and Jerry Lyons for preparing vehicles for testing and de-prepping them for return to the owners. We would also like to express a particular note of appreciation to Dr. Tom Obremski of the University of Denver for his invaluable guidance and assistance in the statistical analysis of the data.

Limitations and Disclaimer

It is acknowledged that this report may not reflect all of the concerns and comments by individual members and their participation does not constitute a consensus. The Division encourages and welcomes further analysis of the data by all interested parties.

Fuels

We recognize that the observed effects are not strictly due to the addition of an ethanol oxygenate. Rather, the study was designed to compare emissions from a fuel sold in Denver during the mandatory oxygenated fuel period to a fuel typical of the fuels which would most likely be sold during the same period in Denver if there were not a mandatory program in effect. Because these two fuels would not be created from the same blendstocks, other factors such as distillation curves could also affect emission levels, especially during cold starts.

Analyses

There are other factors and methods of analysis which, if time and resources had permitted, we would like to have explored further. Among these are more detailed analyses of the possible correlations between emissions and vehicle mileage and/or testing sequences. We recognized that there was a difference in oxygenated fuel effects between Tier 0 and Tier 1 vehicles and that the Tier 0 vehicles were generally older and had higher odometer readings but we were not able to analyze the data to determine if accumulated mileage had an independent effect upon emissions. It is also possible that relationships might exist between testing sequence (i.e. cold FTP, hot Unified then hot REPO5) and/or elevation in fuel tank temperature and/or emissions levels. It would also have been interesting to compare results from additional methods of data analysis such as assuming log normal rather than normal distributions of emission levels, using medians to represent central tendencies, and utilizing other statistical tools such as “Analysis of Variance” to look more critically for effects due to factors or inter-relationships among factors such as base fuel emissions level for HC, PM or other components as well as for CO.

References

V. R. Burns, et al. “Description of Auto/Oil Quality Improvement Research Program,” Society of Automotive Engineers Publication, SAE 912320, 1991

S. C. Cadle, et al. “ Dynamometer Study of Off-Cycle Exhaust Emissions - The Auto/Oil Air Quality Improvement Research Program, ” Society of Automotive Engineers Publication, SAE 971655, 1997

Code of Federal Regulations, Title 40, Part 86, Subparts B and C, July 1, 1997

J. Doyon, K. Mitchell, T. Mayhew, “ The Effect of Gasoline Composition on Vehicle Tailpipe Emissions at Low Ambient Temperature,” Society of Automotive Engineers Publication, SAE 932669, 1993

R. T. Gammarielo, J. R. Long, “An Emissions Comparison Between the Unified Cycle and the Federal Test Procedure” Presented at The Emissions Inventory: Perception and Reality, Pasadena, California, October 18-20, 1993

J. Hood, R. Farina, “Emissions from Light Duty Vehicles Operating on Oxygenated Fuels at Low Ambient Temperatures: A Review of Published Studies,” Society of Automotive Engineers Publication, SAE 952403, 1995

K. T. Knapp, C. B. Prakash, “MTBE Effect on Vehicle Emissions at Cold Temperatures.” *Proceedings of the XIth International Symposium on Alcohol Fuels (ISAF XI),* Sun City, South Africa, April 1996.

K. T. Knapp, F. D. Stump, S. B. Tejada, “The Effect of Ethanol Fuel on the Emissions of Vehicles Over a Wide Range Of Temperatures,” Journal of Air & Waste Management, 48: 646-653, July 1998.

D. Lax, “The Effects of Fuel RVP and Fuel Blends on Emissions at Non-FTP Temperatures,” American Petroleum Institute, Health and Environmental Sciences Department, Vol. 1, Summary Report, API Publication 4533

D. M. Levine, M. L. Berenson, D. Stephan, *Statistics for Managers Using Microsoft Excel*, Prentice Hall, Inc. 1998.

W. J. Most, “ Coordinating Research Council Study of Winter Exhaust Emissions With Gasoline/Oxygenate Blends, “ Society of Automotive Engineers Publication SAE 892091, 1989

P. A. Mulawa, S. H. Cadle, K. T. Knapp, R. Zweidinger, R. Lucas, and J. Goldbach, *Effect of Ambient Temperature and E-10 Fuel on PM Emissions from Light Duty Vehicles*. Environmental Science & Technology, **31**, 1302-1307, 1997

National Research Council, "Toxicological and Performance Aspects of Oxygenated Motor Fuels" National Academy Press, Washington, DC 1996

National Science and Technology Council, "Interagency Assessment of Oxygenated Fuels" June 1997

K. Nelson, R. Ragazzi, G. Gallagher, "The Effect of Fuel Oxygen Concentration on Automotive Carbon Monoxide Emissions at High Altitude," Society of Automotive Engineers Publication, SAE 902128, 1990

L. J. Painter, J. A. Rutherford. "Statistical Design and Analysis Methods for the Auto/Oil Air Quality Research Program," Society of Automotive Engineers Publication, SAE 920319, 1992

APPENDIX A

OXYGENATED FUELS

ASSESSMENT DESIGN COMMITTEE

OXYGENATED FUELS ASSESSMENT DESIGN COMMITTEE MEMBERS

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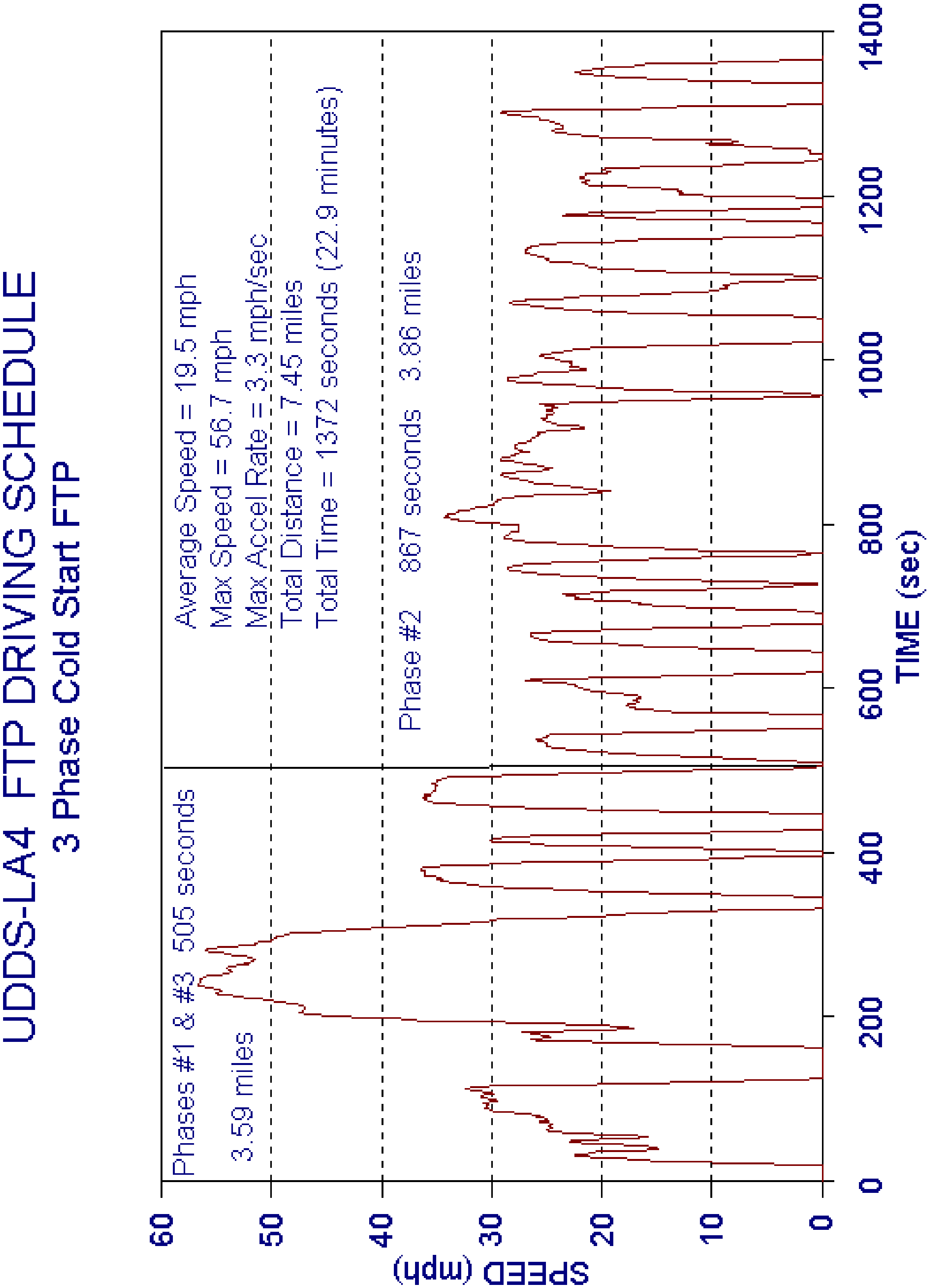
APPENDIX B

OXYGENATED FUELS EVALUATION

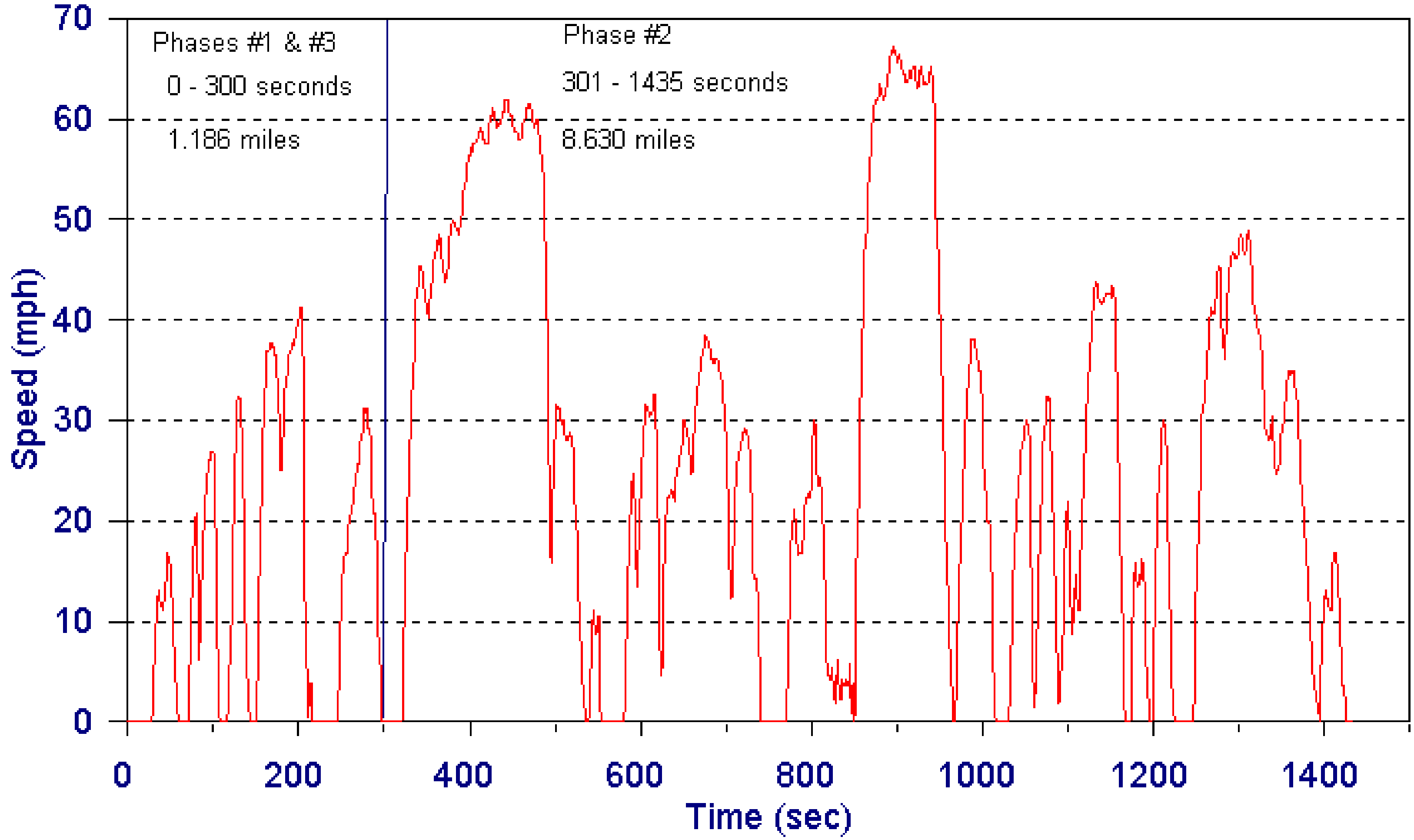
DRIVING SCHEDULES

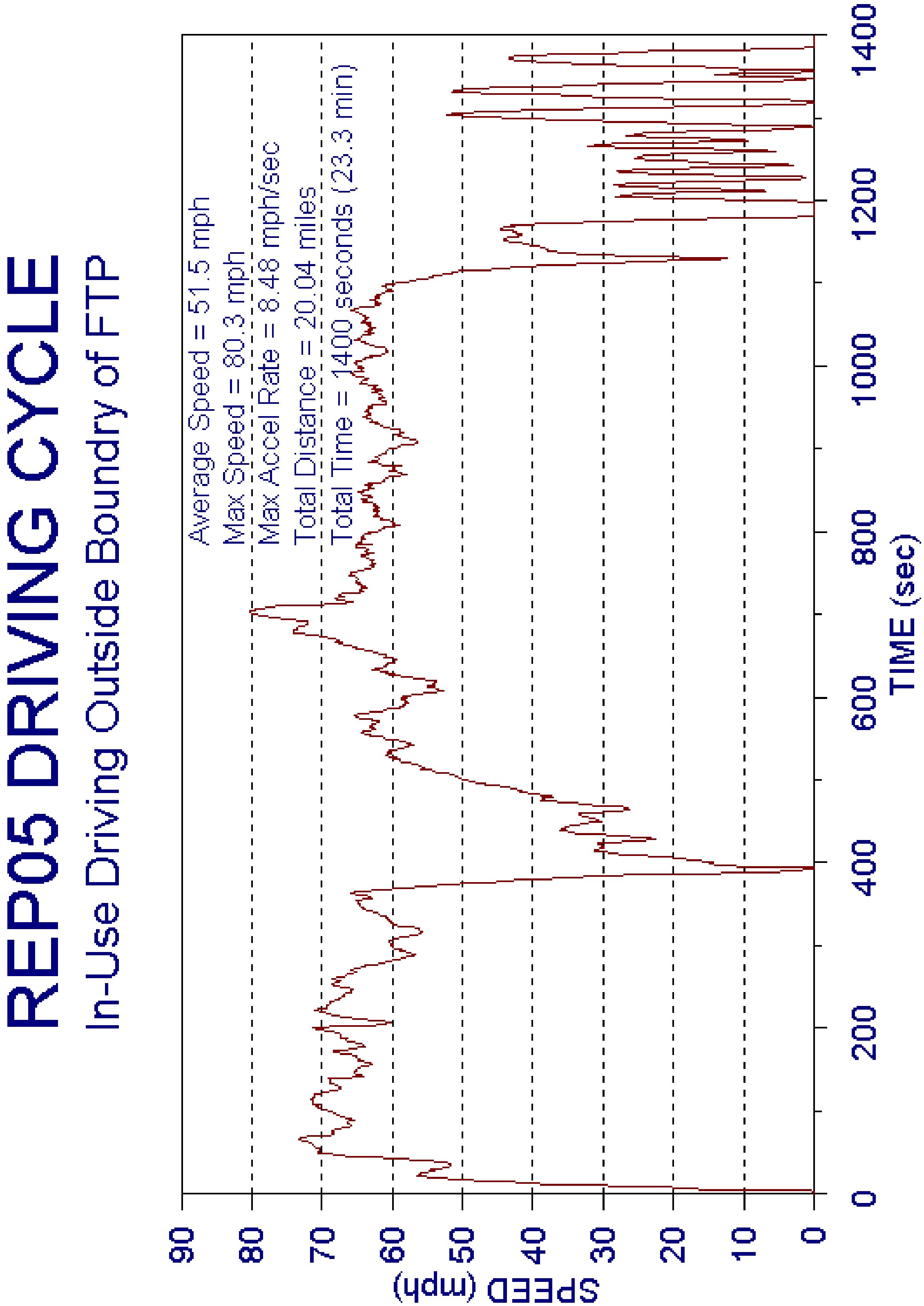


UDDS-LA4 FTP DRIVING SCHEDULE
3 Phase Cold Start FTP
Phases #1 & #3 505 seconds
3.59 miles
Average Speed = 19.5 mph
Max Speed = 56.7 mph
Max Accel Rate = 3.3 mph/sec
Total Distance = 7.45 miles
Total Time = 1372 seconds (22.9 minutes)
Phase #2 867 seconds 3.86 miles
SPEED (mph)
TIME (sec)
0
10
20
30
40
50
60
0
200
400
600
800
1000
1200
1400

UNIFIED DRIVING CYCLE

Three Phase - Cold Start Test





REP05 DRIVING CYCLE
In-Use Driving Outside Boundry of FTP
Average Speed = 51.5 mph
Max Speed = 80.3 mph
Max Accel Rate = 8.48 mph/sec
Total Distance = 20.04 miles
Total Time = 1400 seconds (23.3 min)
SPEED (mph)
0
10
20
30
40
50
60
70
80
90
TIME (sec)
0
200
400
600
800
1000
1200
1400

APPENDIX C

OXYGENATED FUELS EVALUATION

CALCULATIONS FOR FUEL ECONOMY ADJUSTMENTS

Explanation of Calculations used for the Adjustment of Fuel Economy

Fuel economy is not measured directly. Instead it is calculated indirectly from measured HC, CO and CO2 emissions. There are several methods and formulas available for this calculation but for the most part they reduce to the following ratio: the number of grams of carbon per gallon of fuel divided by the total mass of carbon in the exhaust in units of grams per mile. The procedures for determining the exhaust emission rates are well established and relatively independent of the type of fuel. However, because carbon content is inherently dependent upon fuel composition, there is not a simple, well established method for determining the exact number of grams of carbon per gallon of a specific fuel.
In studies where the same fuel is used to compare vehicles to each other or to themselves under differing conditions, changes in fuel economy are not substantially affected by small inaccuracies in establishing the number of grams of carbon per gallon of fuel. In studies such as this where fuels and their effects are compared however, precise calculation of fuel economy becomes important. This is especially true when the effects are small but they apply to a significant portion of the vehicle population.

For any fuel, strictly theoretical calculations of gmC/gal (grams carbon per gallon) based upon chemical composition are desirable but quite impractical because of the difficulty in determining the exact proportion and composition of not only the various different hydro-carbon compounds in the fuel blend but also the proportions and compositions of the additives and impurities. For this reason empirical methods have been developed for determining carbon content. These empirical methods typically rely on deriving the "net heating value" of a fuel from laboratory measurements of it's volatility and "Aromatic fraction" and then, using tables established by the ASTM, relating that value to a gmc/gal number. For typical non-oxygenated gasolines a nominal value of 2421 gmC/gal has been established. While this value may not be exactly correct for every non-oxygenated gasoline, it has been close enough to be used by the EPA and the industry for in-use vehicle testing purposes. For oxygenated fuels however, because the compounds used to add oxygen can vary in both their composition and their concentration, there is not a single corresponding nominal value for grams carbon per gallon of oxygenated fuel.

Obviously, if one method were known absolutely to be more accurate than the others and if that method could be applied practically to both oxygenated and non-oxygenated fuels, that method should be used. In the absence of that capability and not having sufficient reasons to favor one method over another, we have chosen to derive a composite value. We decided to combine the nominal value, the theoretical value for a pure fuel and the empirically based value for each fuel into a single value with equal weighting given to each method. In other words we have decided to use, for each fuel, the numerical averages of the three values which are equivalent to grams carbon per gallon.

For non-oxygenated fuel a purely theoretical value for gmC/gal is 2426.8. The typical value used by EPA which is probably representative of many empirical measurements is

2421. From analyses of the specific fuel used in this study and based upon net heating value calculations, the gmC/gal equivalent number is 2421.5. The average of these three values is 2423.0 gmC/gal. For the oxygenated fuel used in this study; the theoretical value, the value based upon published nominal values, and the empirically derived gmC/gal equivalent from net heating value are 2364.4, 2340, and 2314.6 respectively. The average of the three oxygenated values is 2339.6.

Testing was already underway using previously accepted values for both non-oxygenated and oxygenated gmC/gal when the discrepancy between those values and the values above were discovered. For reasons of consistency and clarity we decided to continue to use the old values and make an after test correction to all fuel economy results. The correction factors were simply the ratios of the composite gmC/gal values above to the values already in place. Those correction factors are 1.006 for non-oxygenated fuel and 1.021 for oxygenated fuel.

APPENDIX D

OXYGENATED FUELS EVALUATION

TEST VEHICLE PROCUREMENT PACKAGE

Dear Vehicle Owner:

The Colorado Department of Public Health and Environment is conducting a study to determine the effectiveness of oxygenated fuels when used by newer vehicles. Your vehicle has been randomly selected for possible participation in this research program.

The study is being conducted to test the reaction of the more sophisticated and durable emission control systems on newer vehicles when fueled with oxygenated gasolines. Ultimately, we want to assess the level of continuing effectiveness of oxygenated fuels, which have been mandated for use during winter months along Colorado's Front Range since 1988.

Past studies have shown the use of oxygenated fuels resulted in significant reductions of carbon monoxide emissions. However, it is important that we determine whether the same results are being obtained from newly manufactured vehicles.

We are attempting to locate several of these newer vehicles, which are owned and driven along the Front Range, for testing as part of our study. We ask that you return the enclosed post card letting us know if you will allow you vehicle to be tested at the State Health Department's Vehicle Emissions Technical Center, 15608 E. 18th Ave, in Aurora. Vehicles will be selected from those belonging to respondents willing to participate in this study.

If your vehicle is chosen, my staff will contact you to schedule the test at your convenience. The following is a list of incentives offered for participation.

1. You will receive $25.00 for each work day your vehicle is being tested, up to a maximum of $375. If you prefer, we will provide you with a late model loaner vehicle. If you elect to take the loaner vehicle, you will be reimbursed $5 per work day for the use of your vehicle, up to a maximum of $75. Payment will be by check and sent to your address.

   Please note that the use of a loaner car is dependent on your insurance company extending its coverage to the use of this vehicle. The insurance provided by the loaner car company serves as secondary coverage.

2. Your vehicle will receive an oil and oil filter change prior to being tested.

Oxygenated Fuels Study

3. Your vehicle will be returned to you with a full tank of fuel.

No unusual operations will be performed on your vehicle. The testing will simulate city and highway conditions and will be conducted inside the laboratory. We will need your vehicle up to two full weeks because multiple tests must be conducted from a cold start condition.

Less than 450 miles will be added to your car's odometer during the test. Should your vehicle be damaged while in our possession, it will repaired at no cost to you.

A list of the questions most commonly asked about this type of testing program is enclosed. If you have additional questions or would like further information, please check the appropriate box and/or call 364-5334. If you are interested, we also will be happy to show you our laboratory and how the testing is conducted.

We ask that you complete and return the enclosed postcard at your earliest convenience because your response is critical to the statistical accuracy of this study. Also, the prompt return of your response will eliminate the need for follow-up reminders.

Thank you for your cooperation. Your willingness to participate is important to the accuracy of our study. We are looking forward to your reply.

Sincerely,

Gerald Gallagher, Ph.D
Program Manager
Mobile Sources Section
Air Pollution Control Division

COLORADO DEPARTMENT of PUBLIC HEALTH & ENVIRONMENT
AIR POLLUTION CONTROL DIVISION
Mobile Sources Section

IN-USE EMISSION TESTING PROGRAMS
Questions and Answers

1. MUST I PARTICIPATE IN THIS PROGRAM?

No. Your cooperation in this program is completely voluntary. However, in order to maintain the statistical validity for the program it is necessary that we receive an answer from you. Please take a moment and mark the postcard indicating whether or not you would like to participate. If you do not return the postcard, you may be contacted again in the next few weeks.

2. WHY SHOULD I PARTICIPATE?

In addition to the gasoline and a check, your participation will benefit you indirectly by helping the Colorado Department of Public Health & Environment (CDPHE) understand and improve the quality of the air in and around your city.

3. WHAT DETERMINES WHETHER OR NOT MY VEHICLE WILL BE ULTIMATELY SELECTED?

Your vehicle has been initially identified by a statistically random sampling procedure. In order to obtain a cross section of the population of vehicles on the road, certain other criteria such as make, model, model year, and odometer reading must be met. We are examining a limited number of vehicles that meet these particular specifications. The final decision on whether your vehicle is selected will be based on these criteria.

4. WILL MY VEHICLE BE MISTREATED IN ANY WAY?

No, every aspect of our evaluation has been designed to duplicate typical everyday operation.

5. EXACTLY WHAT WILL BE DONE TO MY VEHICLE?

Once the vehicle is parked in the laboratory long enough to cool to room temperature, it will be pushed onto a dynamometer. Although the vehicle does not actually move during the examination, the dynamometer is a type of treadmill which simulates conditions which would normally be encountered on the road. A hose is connected to the exhaust pipe to collect the exhaust. A specially trained technician then starts the vehicle and drives it through a cycle which represents typical operation in urban, suburban, and rural areas. Throughout this time, a portion of the exhaust gases are collected for subsequent analysis. This analysis allows us to calculate the quantity of exhaust emissions emitted by your vehicle. Values for fuel economy are also calculated.*

* The above test will be repeated four or more times.

6. HOW LONG WILL THE EXAMINATION TAKE?

The actual test sequence takes about four hours. The vehicle must be completely cooled to room temperature (35 F) before each test sequence can begin. This requires that the vehicle not be started for 12 to 36 hours to simulate overnight parking. Your vehicle will be tested four to six times using this procedure. Thus, we will need it for approximately fourteen days. You will be contacted once the evaluation is complete so that arrangements can be made to return your vehicle.

7. HOW MANY MILES WILL BE DRIVEN DURING THE PROGRAM?

Your vehicle will probably accumulate less than 450 miles during the entire test program. These miles will be accumulated indoors on the dynamometer.

8. WHAT HAPPENS TO THE INFORMATION OBTAINED FROM MY VEHICLE?

The information collected as a result of this program is used to assess the effectiveness of current pollution control regulations and to determine if any improvements in these regulations are necessary. The data from individual vehicles are combined in order to obtain a statistically valid sample and are not used by themselves. The fact that your vehicle may or may not meet the emission standards will not affect your participation nor will you be required to perform any maintenance on your vehicle.

9. HOW WILL MY VEHICLE BE PROTECTED WHILE IN THE COLORADO DEPARTMENT OF
HEALTH'S POSSESSION?

Your vehicle will be stored indoors while the examination is being conducted. If required to be parked outside, your vehicle will be located in a secure area. Should any damage occur to your vehicle while in our possession, it will be repaired at no cost to you.

APPENDIX E

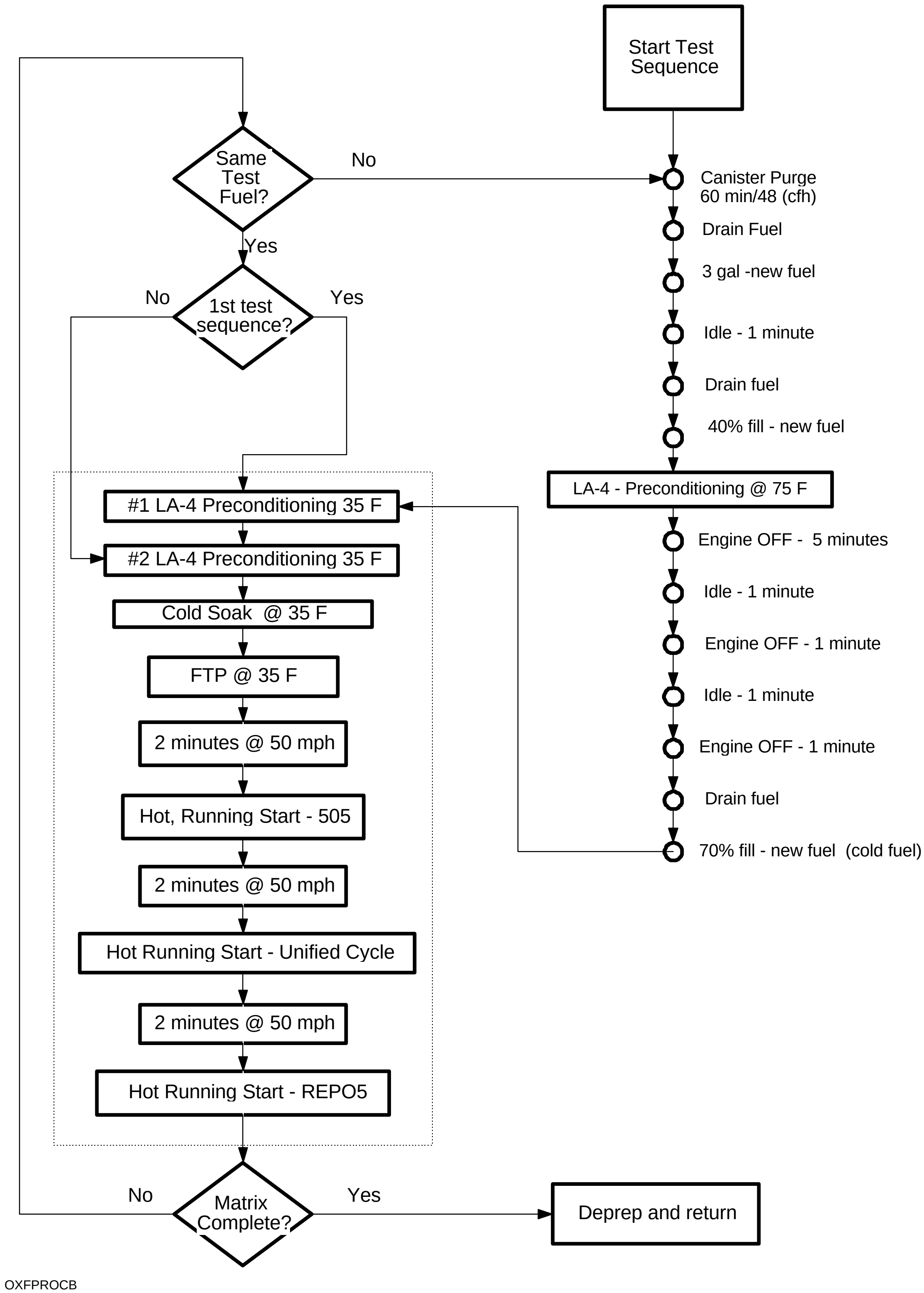
OXYGENATED FUELS TEST VEHICLE

PREPARATION AND TEST PROCEDURE

FLOW CHART

CDPHE Oxygenated Fuels

Vehicle Testing Procedure



APPENDIX F

TEST RESULTS for the

FEDERAL TEST PROCEDURE, UNIFIED CYCLE,

and the REPO5

FTP TEST RESULTS for TIER 0 VEHICLES
1998 OXY FUEL EVAL @ 35 F

Veh #	Year	Make	Model	Cyl	Disp	Odom	F-Del	Type	EC	Trans	Grp/Tier	FTP#	FT-HC	HC-Ph1	HC-Ph2	HC-Ph3
OF098V1	1993	TOYOTA	CORROLA	4	1.8	20163	PI	Oxy	TWC	AUTO	LDV0	8042	0.668	2.891	0.030	0.195
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20192	PI	Oxy	TWC	AUTO	LDV0	8047	0.605	2.657	0.040	0.122
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20301	PI	NonOxy	TWC	AUTO	LDV0	8052	0.619	2.620	0.067	0.146
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20341	PI	NonOxy	TWC	AUTO	LDV0	8064	0.676	2.889	0.068	0.139
OF098V2	1990	HONDA	ACCORD	4	2.2	92586	PI	NonOxy	TWC	M5	LDV0	8055	0.793	3.017	0.223	0.206
OF098V2	1990	HONDA	ACCORD	4	2.2	92649	PI	NonOxy	TWC	M5	LDV0	8060	0.613	2.070	0.269	0.156
OF098V2	1990	HONDA	ACCORD	4	2.2	92688	PI	Oxy	TWC	M5	LDV0	8071	0.595	1.986	0.236	0.219
OF098V2	1990	HONDA	ACCORD	4	2.2	92886	PI	Oxy	TWC	M5	LDV0	8085	0.541	1.852	0.186	0.223
OF098V3	1991	FORD	ESCORT	4	1.8	109295	PI	Oxy	TWC	M5	LDV0	8103	0.654	2.541	0.141	0.194
OF098V3	1991	FORD	ESCORT	4	1.8	109351	PI	Oxy	TWC	M5	LDV0	8113	0.713	2.709	0.182	0.212
OF098V3	1991	FORD	ESCORT	4	1.8	109424	PI	NonOxy	TWC	M5	LDV0	8128	0.920	3.749	0.154	0.238
OF098V3	1991	FORD	ESCORT	4	1.8	109460	PI	NonOxy	TWC	M5	LDV0	8139	0.956	3.510	0.267	0.332
OF098V4	1991	HONDA	CIVIC	4	1.5	110927	TBI	NonOxy	TWC	M4	LDV0	8094	1.147	2.579	0.679	0.956
OF098V4	1991	HONDA	CIVIC	4	1.5	110984	TBI	NonOxy	TWC	M4	LDV0	8108	1.465	3.450	0.916	1.014
OF098V4	1991	HONDA	CIVIC	4	1.5	111030	TBI	Oxy	TWC	M4	LDV0	8117	1.262	3.151	0.715	0.874
OF098V4	1991	HONDA	CIVIC	4	1.5	111118	TBI	Oxy	TWC	M4	LDV0	8124	1.066	2.419	0.625	0.887
OF098V7	1993	FORD	TAURUS	6	3.8	79183	PI	NonOxy	TWC	AUTO	LDV0	8194	0.452	1.996	0.019	0.102
OF098V7	1993	FORD	TAURUS	6	3.8	79241	PI	NonOxy	TWC	AUTO	LDV0	8199	0.442	1.982	0.016	0.075
OF098V7	1993	FORD	TAURUS	6	3.8	79280	PI	Oxy	TWC	AUTO	LDV0	8213	0.416	1.765	0.041	0.101
OF098V7	1993	FORD	TAURUS	6	3.8	79343	PI	Oxy	TWC	AUTO	LDV0	8218	0.409	1.758	0.030	0.102
OF098V20	1992	TOYOTA	CAMRY	4	2.2	88112	PI	Oxy	TWC	AUTO	LDV0	8473	0.359	1.600	0.022	0.059
OF098V20	1992	TOYOTA	CAMRY	4	2.2	88182	PI	Oxy	TWC	AUTO	LDV0	8482	0.341	1.498	0.030	0.055
OF098V20	1992	TOYOTA	CAMRY	4	2.2	88246	PI	NonOxy	TWC	AUTO	LDV0	8499	0.330	1.450	0.022	0.068
OF098V20	1992	TOYOTA	CAMRY	4	2.2	88290	PI	NonOxy	TWC	AUTO	LDV0	8508	0.358	1.594	0.018	0.065
OF098V23	1994	CHEVY	CAVALIER	6	3.1	46994	PI	Oxy	TWC	AUTO	LDV0	8553	0.661	2.519	0.075	0.358
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47104	PI	Oxy	TWC	AUTO	LDV0	8567	0.720	2.960	0.039	0.297
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47207	PI	NonOxy	TWC	AUTO	LDV0	8577	0.887	3.441	0.086	0.469
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47285	PI	NonOxy	TWC	AUTO	LDV0	8591	0.958	3.828	0.071	0.456
OF098V26	1993	SATURN	SC2	4	1.9	34578	PI	Oxy	TWC	AUTO	LDV0	8615	0.348	1.520	0.035	0.049
OF098V26	1993	SATURN	SC2	4	1.9	34635	PI	Oxy	TWC	AUTO	LDV0	8620	0.348	1.507	0.029	0.076
OF098V26	1993	SATURN	SC2	4	1.9	34710	PI	NonOxy	TWC	AUTO	LDV0	8632	0.487	2.126	0.033	0.109
OF098V26	1993	SATURN	SC2	4	1.9	34771	PI	NonOxy	TWC	AUTO	LDV0	8641	0.438	1.870	0.046	0.093

Italicized & underlined data not used in calculating averages

TIER 0 LDTs

Veh #	Year	Make	Model	Cyl	Disp	Odom	F-Del	Type	EC	Trans	Tier	FTP#	FT-HC	HC-Ph1	HC-Ph2	HC-Ph3
OF098T11	*1993*	*FORD*	*EXPLORER*	*6*	*4.0*	*44112*	*PI*	*Oxy*	*TWC*	*AUTO*	*LDT0*	*8284*	*1.519*	*7.246*	*0.005*	*0.190*
OF098T11	1993	FORD	EXPLORER	6	4.0	44161	PI	Oxy	TWC	AUTO	LDT0	8291	0.504	2.112	0.035	0.180
OF098T11	1993	FORD	EXPLORER	6	4.0	44219	PI	Oxy	TWC	AUTO	LDT0	8305	0.525	2.209	0.042	0.168
OF098T11	1993	FORD	EXPLORER	6	4.0	44293	PI	NonOxy	TWC	AUTO	LDT0	8313	0.501	2.042	0.038	0.197
OF098T11	1993	FORD	EXPLORER	6	4.0	44340	PI	NonOxy	TWC	AUTO	LDT0	8323	0.490	2.067	0.018	0.183
OF098T12	1991	CHEVY	BLAZER	6	4.3	122759	TBI	NonOxy	TWC	AUTO	LDT0	8296	1.690	4.019	0.317	2.519
OF098T12	1991	CHEVY	BLAZER	6	4.3	122816	TBI	NonOxy	TWC	AUTO	LDT0	8301	1.901	4.751	0.248	2.848
OF098T12	1991	CHEVY	BLAZER	6	4.3	122887	TBI	Oxy	TWC	AUTO	LDT0	8318	1.102	3.760	0.219	0.762
OF098T12	1991	CHEVY	BLAZER	6	4.3	122941	TBI	Oxy	TWC	AUTO	LDT0	8327	0.972	3.075	0.258	0.719
OF098T15	1993	JEEP	CHEROKEE	6	4.0	36929	PI	NonOxy	TWC	AUTO	LDT0	8339	0.525	2.122	0.041	0.211
OF098T15	1993	JEEP	CHEROKEE	6	4.0	36988	PI	NonOxy	TWC	AUTO	LDT0	8348	0.502	2.109	0.027	0.179
OF098T15	1993	JEEP	CHEROKEE	6	4.0	37061	PI	Oxy	TWC	AUTO	LDT0	8360	0.496	2.041	0.042	0.174
OF098T15	1993	JEEP	CHEROKEE	6	4.0	37122	PI	Oxy	TWC	AUTO	LDT0	8366	0.476	1.934	0.037	0.197
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63119	TBI	NonOxy	TWC	AUTO	LDT0	8670	1.244	3.700	0.542	0.702
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63179	TBI	NonOxy	TWC	AUTO	LDT0	8675	1.289	3.956	0.541	0.684
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63253	TBI	Oxy	TWC	AUTO	LDT0	8681	1.329	3.987	0.576	0.738
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63290	TBI	Oxy	TWC	AUTO	LDT0	8686	1.159	3.257	0.547	0.729

Italicized & underlined data not used in calculating averages

FTP TEST RESULTS for TIER 0 VEHICLES

Veh #	FT-CO	CO-Ph1	CO-Ph2	CO-Ph3	NOx-FTP	NO-Ph1	NO-Ph2	NO-Ph3	FT-CO2	CO2-Ph1	CO2-Ph2	CO2-Ph3
OF098V1	7.769	33.156	0.174	2.928	0.199	0.393	0.083	0.273	339.46	369.06	335.93	323.77
OF098V1	6.285	28.862	0.228	0.688	0.200	0.356	0.073	0.320	334.42	370.86	335.68	304.52
OF098V1	6.545	29.320	0.389	0.949	0.218	0.466	0.074	0.301	327.09	366.14	325.85	299.95
OF098V1	6.939	30.333	0.532	1.224	0.202	0.441	0.077	0.257	327.01	361.28	328.83	297.65
OF098V2	20.941	76.727	6.108	7.175	0.694	0.972	0.633	0.603	332.55	308.86	353.86	310.20
OF098V2	17.964	62.245	7.181	4.753	0.684	1.046	0.636	0.503	335.75	324.33	356.64	305.27
OF098V2	15.731	53.674	6.519	4.410	0.728	1.106	0.608	0.670	331.96	321.99	351.12	303.46
OF098V2	15.768	51.563	6.079	7.011	0.752	1.111	0.602	0.766	333.62	322.82	356.08	299.46
OF098V3	8.085	30.006	2.449	2.127	1.121	1.148	1.063	1.211	357.98	336.91	386.97	319.46
OF098V3	8.395	31.023	2.534	2.430	1.060	1.051	0.998	1.185	359.13	341.03	388.17	317.93
OF098V3	10.399	39.495	2.973	2.547	1.107	0.972	1.093	1.238	380.82	358.23	412.99	336.73
OF098V3	11.439	38.077	4.474	4.506	1.097	1.122	1.014	1.237	365.30	345.91	392.00	329.44
OF098V4	14.896	37.598	9.505	8.019	2.507	2.317	2.280	3.087	231.63	238.76	234.27	221.19
OF098V4	16.491	40.028	11.337	8.575	2.450	2.295	2.242	2.959	233.58	237.24	237.83	222.78
OF098V4	17.223	43.443	11.246	8.789	2.357	1.969	2.122	3.094	226.80	228.06	229.29	221.12
OF098V4	15.915	45.470	8.273	8.213	2.404	2.081	2.176	3.080	227.02	228.74	230.14	219.78
OF098V7	7.305	29.926	1.079	1.942	0.756	1.091	0.540	0.908	443.08	468.05	459.90	392.57
OF098V7	7.826	33.943	0.958	0.940	0.635	0.961	0.437	0.759	447.12	462.99	466.68	398.56
OF098V7	7.915	31.524	1.744	1.620	0.857	1.168	0.645	1.017	447.53	461.70	466.79	400.88
OF098V7	8.584	37.326	0.709	1.661	0.757	0.994	0.577	0.917	445.24	458.41	466.17	395.99
OF098V20	3.066	12.661	0.614	0.468	1.054	1.931	0.740	0.987	376.98	427.23	382.38	328.81
OF098V20	3.085	13.386	0.375	0.433	0.981	1.960	0.650	0.868	353.31	394.19	358.77	312.16
OF098V20	2.414	9.885	0.401	0.582	1.020	2.066	0.610	1.006	357.27	405.90	360.74	313.93
OF098V20	2.264	9.197	0.362	0.622	1.002	2.193	0.588	0.884	363.59	403.71	367.55	325.85
OF098V23	17.551	65.754	4.228	6.207	1.287	1.652	0.918	1.703	383.06	396.17	401.53	338.51
OF098V23	15.319	62.139	2.046	4.729	1.141	1.349	0.799	1.623	384.84	398.67	403.99	338.53
OF098V23	18.202	68.129	3.977	7.284	1.096	1.551	0.721	1.458	382.59	395.27	401.18	338.03
OF098V23	19.733	76.751	3.535	7.095	0.956	1.256	0.569	1.455	387.85	395.48	408.10	344.03
OF098V26	6.958	29.008	1.158	1.171	0.245	0.513	0.096	0.320	309.59	338.24	320.73	266.97
OF098V26	7.599	32.945	0.743	1.433	0.216	0.493	0.060	0.301	308.25	330.10	321.02	267.57
OF098V26	9.020	38.291	1.041	2.033	0.294	0.712	0.126	0.299	315.54	335.67	330.33	272.25
OF098V26	8.556	35.661	1.236	1.874	0.275	0.724	0.073	0.319	317.37	338.91	331.87	273.76

Italicized & underlined data not used in calculating averages

TIER 0 LDTs

Veh #	FT-CO	CO-Ph1	CO-Ph2	CO-Ph3	NOx-FTP	NO-Ph1	NO-Ph2	NO-Ph3	FT-CO2	CO2-Ph1	CO2-Ph2	CO2-Ph3
OF098T11	*12.947*	*56.716*	*1.457*	*2.653*	*0.733*	*1.456*	*0.404*	*0.825*	*503.81*	*551.68*	*505.14*	*466.40*
OF098T11	10.105	39.715	1.870	3.355	0.623	0.915	0.397	0.834	506.52	535.16	507.33	483.17
OF098T11	9.598	40.317	1.487	1.756	0.562	0.904	0.318	0.765	493.77	526.73	495.81	465.00
OF098T11	10.010	39.847	1.585	3.145	0.630	1.155	0.315	0.820	506.24	543.07	509.02	473.09
OF098T11	10.665	41.935	1.920	3.452	0.653	1.076	0.372	0.860	509.03	542.28	513.06	476.54
OF098T12	29.518	80.798	7.036	33.179	1.246	2.112	0.793	1.447	506.69	516.99	528.30	458.13
OF098T12	31.421	87.409	6.140	36.557	1.171	2.177	0.763	1.177	531.56	543.97	563.64	462.03
OF098T12	20.029	66.243	5.041	13.401	1.281	2.477	0.766	1.349	509.02	525.26	532.73	451.94
OF098T12	21.029	68.615	6.669	11.921	1.221	2.041	0.753	1.477	508.79	521.27	530.99	457.87
OF098T15	7.222	27.310	1.046	3.454	0.707	1.088	0.459	0.880	572.05	579.25	595.36	523.03
OF098T15	6.356	26.296	0.540	2.205	0.789	1.238	0.594	0.817	567.12	588.98	588.50	510.23
OF098T15	6.981	28.869	0.720	2.086	0.767	1.040	0.553	0.961	562.23	579.58	585.05	506.39
OF098T15	6.195	26.481	0.396	1.717	0.761	1.165	0.523	0.902	554.49	574.79	577.30	496.12
OF098T28	24.513	84.157	8.526	9.365	2.730	4.631	1.866	2.910	647.28	673.32	658.48	606.64
OF098T28	26.006	97.319	6.420	9.093	2.456	4.267	1.656	2.598	640.51	676.48	646.41	602.18
OF098T28	26.895	96.029	8.464	9.321	2.411	4.019	1.618	2.687	632.12	669.36	641.47	586.39
OF098T28	24.560	85.473	8.103	9.593	2.476	4.148	1.703	2.669	629.00	676.12	631.69	588.39

Italicized & underlined data not used in calculating averages

FTP TEST RESULTS for TIER 0 VEHICLES

							PM = mg/mi		
Veh #	FT-FE	FE-Ph1	FE-Ph2	FE-Ph3	Avg T-Temp	FT-PM	PM-Ph1	PM-Ph2	PM-Ph3
OF098V1	25.46	20.93	26.78	27.38	34.1	10.997	36.022	3.406	6.418
OF098V1	24.77	20.21	25.50	28.02	33.1	6.354	27.661	0.000	2.274
OF098V1	26.15	21.10	27.17	29.40	36.9	8.813	32.645	2.973	1.826
OF098V1	26.10	21.23	26.90	29.58	36.2	8.093	34.684	1.294	0.696
OF098V2	24.12	20.22	24.37	27.55	36.5	14.291	60.794	1.486	3.638
OF098V2	24.25	20.70	24.07	28.33	37.0	ND	ND	ND	ND
OF098V2	23.91	20.79	23.68	27.56	36.0	6.895	9.594	7.042	4.582
OF098V2	23.81	20.94	23.41	27.55	36.3	3.519	9.471	2.885	0.221
OF098V3	23.00	21.88	21.91	26.51	34.4	5.498	19.474	1.638	2.200
OF098V3	22.89	21.54	21.83	26.59	34.4	6.672	23.503	0.816	5.060
OF098V3	22.18	20.54	21.22	25.99	35.8	9.117	42.677	0.000	1.108
OF098V3	22.97	21.29	22.19	26.29	35.9	8.424	28.346	4.335	1.120
OF098V4	34.31	29.00	35.31	37.47	34.0	18.941	73.230	3.645	7.082
OF098V4	33.60	28.53	34.33	37.06	37.0	16.875	68.749	2.271	5.573
OF098V4	33.27	28.02	34.41	36.08	34.3	15.918	47.634	5.346	12.057
OF098V4	33.58	27.87	34.99	36.42	34.4	11.993	40.870	3.639	6.156
OF098V7	19.46	17.02	19.22	22.41	37.8	6.369	26.300	0.208	2.913
OF098V7	19.26	16.98	18.95	22.17	36.6	6.326	23.900	1.660	1.776
OF098V7	18.59	16.60	18.25	21.23	36.5	3.503	13.052	1.042	0.890
OF098V7	18.64	16.41	18.34	21.49	37.2	2.524	12.140	0.000	0.000
OF098V20	22.39	18.97	22.36	26.00	34.2	7.468	35.132	0.384	0.000
OF098V20	23.87	20.42	23.85	27.39	37.2	4.988	24.087	0.000	0.000
OF098V20	24.51	20.83	24.55	28.17	37.1	8.424	34.992	1.936	0.632
OF098V20	24.10	20.97	24.11	27.14	36.2	5.683	27.148	0.000	0.208
OF098V23	20.78	16.90	20.99	24.54	36.3	10.538	31.006	5.043	5.419
OF098V23	20.85	16.97	21.05	24.72	35.7	5.124	21.156	1.379	0.000
OF098V23	21.44	17.29	21.77	25.29	36.0	11.575	52.286	0.390	1.892
OF098V23	21.04	16.80	21.44	24.89	36.3	10.222	40.692	1.958	2.734
OF098V26	26.66	22.07	26.57	31.88	34.4	5.396	25.923	0.000	0.000
OF098V26	26.69	22.18	26.60	31.75	36.3	4.893	17.872	1.533	1.450
OF098V26	26.79	22.04	26.73	32.18	33.2	9.890	44.990	0.572	1.039
OF098V26	26.72	22.14	26.58	32.04	36.4	8.142	32.940	1.535	1.863

Italicized & underlined data not used in calculating averages

TIER 0 LDTs

Veh #	FT-FE	FE-Ph1	FE-Ph2	FE-Ph3	T-Temp	FT-PM	PM-Ph1	PM-Ph2	PM-Ph3
OF098T11	*16.21*	*12.93*	*16.89*	*18.20*	*37.3*	*20.669*	*82.430*	*5.466*	*4.242*
OF098T11	16.36	14.19	16.80	17.53	39.4	11.867	46.598	0.000	8.180
OF098T11	16.80	14.36	17.20	18.31	36.2	7.559	32.648	0.000	2.926
OF098T11	16.95	14.50	17.35	18.54	34.2	11.232	36.918	2.511	8.076
OF098T11	16.83	14.44	17.19	18.39	34.1	8.473	35.403	0.000	4.015
OF098T12	15.89	13.51	16.42	17.13	38.4	38.872	121.424	2.891	44.378
OF098T12	15.12	12.74	15.46	16.79	39.2	33.607	117.083	2.494	28.927
OF098T12	15.76	13.38	15.84	18.04	35.3	14.537	66.214	0.000	2.923
OF098T12	15.74	13.43	15.81	17.91	35.4	8.652	38.861	0.000	2.004
OF098T15	15.17	14.11	14.86	16.77	34.9	19.319	59.503	6.953	11.804
OF098T15	15.34	13.93	15.06	17.26	36.6	16.289	54.783	4.248	9.807
OF098T15	14.92	13.58	14.62	16.80	36.8	12.032	33.411	5.083	8.808
OF098T15	15.16	13.78	14.83	17.17	34.8	10.394	31.463	3.303	7.755
OF098T28	12.87	10.86	13.18	14.23	36.4	12.722	45.400	4.657	3.123
OF098T28	12.95	10.54	13.48	14.35	35.3	12.647	53.290	3.078	0.000
OF098T28	12.64	10.30	13.06	14.21	35.2	8.264	30.586	2.487	2.267
OF098T28	12.77	10.45	13.27	14.15	35.5	6.505	18.844	4.032	1.853

Italicized & underlined data not used in calculating averages

FTP TEST RESULTS for TIER 1 VEHICLES

TIER 1 LDVs

Veh #	Year	Make	Model	Cyl	Disp	Odom	F-Del	Type	EC	Trans	Tier	FTP#	FT-HC	HC-Ph1	HC-Ph2	HC-Ph3
OF198V5	1996	FORD	TAURUS	6	3.0	38267	PI	Oxy	TWC	AUTO	LDV1	8156	0.268	1.075	0.015	0.136
OF198V5	1996	FORD	TAURUS	6	3.0	38340	PI	Oxy	TWC	AUTO	LDV1	8165	0.232	0.932	0.016	0.108
OF198V5	1996	FORD	TAURUS	6	3.0	38397	PI	Oxy	TWC	AUTO	LDV1	8170	0.233	0.892	0.012	0.153
OF198V5	1996	FORD	TAURUS	6	3.0	38440	PI	NonOxy	TWC	AUTO	LDV1	8174	0.258	1.079	0.000	0.124
OF198V5	1996	FORD	TAURUS	6	3.0	38480	PI	NonOxy	TWC	AUTO	LDV1	8178	0.308	1.237	0.005	0.177
OF198V6	1996	SATURN	LS2	4	1.9	11978	PI	NonOxy	TWC	M5	LDV1	8183	0.422	1.577	0.093	0.167
OF198V6	1996	SATURN	LS2	4	1.9	12020	PI	NonOxy	TWC	M5	LDV1	8189	0.484	1.986	0.046	0.184
OF198V6	1996	SATURN	LS2	4	1.9	12090	PI	NonOxy	TWC	M5	LDV1	8203	0.345	1.261	0.100	0.111
OF198V6	1996	SATURN	LS2	4	1.9	12179	PI	Oxy	TWC	M5	LDV1	8209	0.278	1.004	0.067	0.126
OF198V6	1996	SATURN	LS2	4	1.9	12239	PI	Oxy	TWC	M5	LDV1	8222	0.340	1.243	0.078	0.154
OF198V9	*1995*	*HONDA*	*CIVIC*	*4*	*1.5*	*52636*	*PI*	*NonOxy*	*TWC*	*M5*	*LDV1*	*8238*	*0.032*	*0.000*	*0.033*	*0.052*
OF198V9	1995	HONDA	CIVIC	4	1.5	52696	PI	NonOxy	TWC	M5	LDV1	8248	0.181	0.782	0.014	0.042
OF198V9	1995	HONDA	CIVIC	4	1.5	52760	PI	NonOxy	TWC	M5	LDV1	8255	0.188	0.795	0.016	0.052
OF198V9	1995	HONDA	CIVIC	4	1.5	52837	PI	Oxy	TWC	M5	LDV1	8264	0.155	0.637	0.020	0.044
OF198V9	1995	HONDA	CIVIC	4	1.5	52884	PI	Oxy	TWC	M5	LDV1	8278	0.148	0.620	0.013	0.043
OF198V19	1997	CHEVROLET	CAVALIER	4	2.4	22286	PI	Oxy	TWC	AUTO	LDV1	8446	0.314	1.430	0.012	0.037
OF198V19	1997	CHEVROLET	CAVALIER	4	2.4	22344	PI	Oxy	TWC	AUTO	LDV1	8455	0.430	1.991	0.000	0.054
OF198V19	1997	CHEVROLET	CAVALIER	4	2.4	22390	PI	Oxy	TWC	AUTO	LDV1	8460	0.397	1.782	0.007	0.077
OF198V19	1997	CHEVROLET	CAVALIER	4	2.4	22467	PI	NonOxy	TWC	AUTO	LDV1	8466	0.429	1.892	0.001	0.118
OF198V19	1997	CHEVROLET	CAVALIER	4	2.4	22526	PI	NonOxy	TWC	AUTO	LDV1	8477	0.373	1.681	0.009	0.070
OF198V19	1997	CHEVROLET	CAVALIER	4	2.4	22950	PI	NonOxy	TWC	AUTO	LDV1	8486	0.536	2.390	0.019	0.102
OF198V21	1997	TOYOTA	CAMRY	4	2.2	23045	PI	Oxy	TWC	M5	LDV1	8494	0.382	1.325	0.116	0.173
OF198V21	1997	TOYOTA	CAMRY	4	2.2	23104	PI	Oxy	TWC	M5	LDV1	8504	0.325	1.278	0.055	0.112
OF198V21	1997	TOYOTA	CAMRY	4	2.2	23165	PI	NonOxy	TWC	M5	LDV1	8514	0.366	1.401	0.049	0.177
OF198V21	1997	TOYOTA	CAMRY	4	2.2	23209	PI	NonOxy	TWC	M5	LDV1	8526	0.371	1.405	0.048	0.200
OF198V22	1996	HONDA	ACCORD	4	2.2	29885	PI	NonOxy	TWC	M5	LDV1	8521	0.238	1.021	0.014	0.072
OF198V22	1996	HONDA	ACCORD	4	2.2	29930	PI	NonOxy	TWC	M5	LDV1	8530	0.240	1.055	0.012	0.053
OF198V22	1996	HONDA	ACCORD	4	2.2	29988	PI	Oxy	TWC	M5	LDV1	8536	0.191	0.798	0.016	0.062
OF198V22	1996	HONDA	ACCORD	4	2.2	30115	PI	Oxy	TWC	M5	LDV1	8541	0.184	0.805	0.007	0.049
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43817	PI	NonOxy	TWC	AUTO	LDV1	8558	0.254	0.887	0.076	0.113
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43877	PI	NonOxy	TWC	AUTO	LDV1	8563	0.265	0.973	0.060	0.117
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43936	PI	Oxy	TWC	AUTO	LDV1	8582	0.192	0.660	0.064	0.082
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43995	PI	Oxy	TWC	AUTO	LDV1	8587	0.220	0.814	0.055	0.080
OF198V25	1996	SUBARU	LEGACY	4	2.2	19389	PI	Oxy	TWC	AUTO	LDV1	8597	0.473	1.976	0.000	0.235
OF198V25	1996	SUBARU	LEGACY	4	2.2	19446	PI	Oxy	TWC	AUTO	LDV1	8602	0.436	2.005	0.000	0.073
OF198V25	1996	SUBARU	LEGACY	4	2.2	19521	PI	NonOxy	TWC	AUTO	LDV1	8610	0.539	2.499	0.000	0.073
OF198V25	1996	SUBARU	LEGACY	4	2.2	19580	PI	NonOxy	TWC	AUTO	LDV1	8625	0.274	1.112	0.005	0.150
OF198V25	1996	SUBARU	LEGACY	4	2.2	19638	PI	NonOxy	TWC	AUTO	LDV1	8637	0.554	2.408	0.000	0.198

Italicized & underlined data not used in calculating averages

TIER 1 LDTs

Veh #	Year	Make	Model	Cyl	Disp	Odom	F-Del	Type	EC	Trans	Tier	FTP#	FT-HC	HC-Ph1	HC-Ph2	HC-Ph3
OF198T0	1997	DODGE	CARAVAN	6	3.0	7863	PI	Oxy	TWC	AUTO	LDT1	8089	0.635	2.858	0.027	0.115
OF198T0	1997	DODGE	CARAVAN	6	3.0	7899	PI	Oxy	TWC	AUTO	LDT1	8099	0.493	2.184	0.018	0.106
OF198T0	1997	DODGE	CARAVAN	6	3.0	7995	PI	Oxy	TWC	AUTO	LDT1	8135	0.545	2.416	0.031	0.107
OF198T0	1997	DODGE	CARAVAN	6	3.0	8040	PI	NonOxy	TWC	AUTO	LDT1	8145	0.549	2.557	0.000	0.072
OF198T0	1997	DODGE	CARAVAN	6	3.0	8079	PI	NonOxy	TWC	AUTO	LDT1	8150	0.652	3.011	0.005	0.098
OF198T0	1997	DODGE	CARAVAN	6	3.0	8184	PI	NonOxy	TWC	AUTO	LDT1	8160	0.533	2.450	0.009	0.072
OF198T18	1996	FORD	EXPLORER	6	4.0	33724	PI	Oxy	TWC	AUTO	LDT1	8397	0.148	0.522	0.046	0.059
OF198T18	1996	FORD	EXPLORER	6	4.0	33765	PI	Oxy	TWC	AUTO	LDT1	8407	0.144	0.533	0.032	0.062
OF198T18	1996	FORD	EXPLORER	6	4.0	33840	PI	Oxy	TWC	AUTO	LDT1	8417	0.145	0.555	0.026	0.061
OF198T18	1996	FORD	EXPLORER	6	4.0	33912	PI	NonOxy	TWC	AUTO	LDT1	8434	0.255	1.054	0.070	0.000
OF198T18	1996	FORD	EXPLORER	6	4.0	33965	PI	NonOxy	TWC	AUTO	LDT1	8439	0.150	0.592	0.018	0.066
OF198T18	1996	FORD	EXPLORER	6	4.0	34023	PI	NonOxy	TWC	AUTO	LDT1	8451	0.158	0.668	0.010	0.053
OF198T27	1996	CHEVY	BLAZER	6	4.3	42610	PI	Oxy	TWC	AUTO	LDT1	8648	0.308	1.249	0.022	0.134
OF198T27	1996	CHEVY	BLAZER	6	4.3	42675	PI	Oxy	TWC	AUTO	LDT1	8653	0.309	1.268	0.016	0.134
OF198T27	1996	CHEVY	BLAZER	6	4.3	42738	PI	NonOxy	TWC	AUTO	LDT1	8659	0.363	1.527	0.009	0.150
OF198T27	1996	CHEVY	BLAZER	6	4.3	42790	PI	NonOxy	TWC	AUTO	LDT1	8664	0.346	1.452	0.011	0.135
OF198T29	*1997*	*FORD*	*EXPEDITION*	*8*	*5.4*	*14013*	*PI*	*NonOxy*	*2TWC*	*AUTO*	*LDT1*	*8692*	*0.239*	*1.106*	*0.007*	*0.022*
OF198T29	1997	FORD	EXPEDITION	8	5.4	14076	PI	NonOxy	2TWC	AUTO	LDT1	8698	0.194	0.908	0.001	0.017
OF198T29	1997	FORD	EXPEDITION	8	5.4	14133	PI	NonOxy	2TWC	AUTO	LDT1	8702	0.210	0.977	0.003	0.020
OF198T29	1997	FORD	EXPEDITION	8	5.4	14181	PI	Oxy	2TWC	AUTO	LDT1	8709	0.211	0.996	0.000	0.014
OF198T29	1997	FORD	EXPEDITION	8	5.4	14258	PI	Oxy	2TWC	AUTO	LDT1	8714	0.221	1.029	0.005	0.018
OF198T29	1997	FORD	EXPEDITION	8	5.4	14314	PI	Oxy	2TWC	AUTO	LDT1	8719	0.220	1.004	0.013	0.017

Italicized & underlined data not used in calculating averages

FTP TEST RESULTS for TIER 1 VEHICLES

TIER 1 LDVs

Veh #	FT-CO	CO-Ph1	CO-Ph2	CO-Ph3	NOx-FTP	NO-Ph1	NO-Ph2	NO-Ph3	FT-CO2	CO2-Ph1	CO2-Ph2	CO2-Ph3
OF198V5	5.401	17.589	0.116	6.152	0.453	0.728	0.323	0.491	427.82	481.11	434.56	374.77
OF198V5	4.282	18.624	0.132	1.207	0.363	0.697	0.166	0.478	433.45	490.66	437.66	382.39
OF198V5	5.000	16.473	0.106	5.550	0.315	0.678	0.139	0.374	428.81	488.04	434.78	372.86
OF198V5	4.652	17.352	0.145	3.523	0.356	0.808	0.128	0.444	434.54	491.05	440.15	381.38
OF198V5	5.777	16.505	0.105	8.327	0.326	0.712	0.139	0.386	437.70	491.91	444.66	383.81
OF198V6	4.436	14.855	1.793	1.535	0.280	0.526	0.199	0.245	322.58	318.98	343.77	285.51
OF198V6	3.371	10.366	1.521	1.621	0.182	0.276	0.114	0.241	332.64	357.96	346.04	288.45
OF198V6	4.103	12.406	2.225	1.353	0.210	0.435	0.129	0.193	331.71	329.05	347.18	304.71
OF198V6	3.482	11.994	1.226	1.311	0.276	0.609	0.166	0.231	319.98	322.97	339.51	281.01
OF198V6	4.051	13.990	1.549	1.286	0.224	0.463	0.151	0.181	321.05	327.48	339.71	281.08
OF198V9	*3.087*	*12.633*	*0.465*	*0.809*	*0.178*	*0.001*	*0.200*	*0.269*	*240.48*	*255.94*	*243.44*	*223.22*
OF198V9	2.787	12.476	0.178	0.388	0.231	0.529	0.125	0.208	248.65	263.63	253.58	228.03
OF198V9	2.632	11.618	0.138	0.532	0.225	0.533	0.109	0.209	251.91	263.57	256.24	234.98
OF198V9	2.079	9.193	0.131	0.370	0.273	0.552	0.158	0.277	247.00	260.75	252.01	227.21
OF198V9	2.072	9.251	0.107	0.327	0.217	0.490	0.130	0.172	247.72	265.66	250.93	228.12
OF198V19	3.585	13.765	0.967	0.816	0.367	0.785	0.188	0.388	353.48	397.05	360.57	307.23
OF198V19	4.738	17.332	1.420	1.428	0.207	0.488	0.097	0.199	356.73	405.97	363.05	307.66
OF198V19	4.701	16.428	1.342	2.100	0.230	0.551	0.083	0.261	356.83	402.52	362.30	312.10
OF198V19	5.631	17.882	2.173	2.798	0.173	0.425	0.062	0.188	365.35	410.63	371.57	319.58
OF198V19	4.461	15.008	1.350	2.352	0.127	0.310	0.031	0.169	368.85	413.73	376.98	319.68
OF198V19	5.436	18.044	1.888	2.552	0.160	0.413	0.038	0.197	364.06	404.38	373.68	315.75
OF198V21	4.865	17.266	1.823	1.224	0.209	0.492	0.087	0.225	330.57	345.76	345.92	290.40
OF198V21	4.324	18.083	0.657	0.841	0.190	0.559	0.053	0.169	331.81	350.33	342.21	298.41
OF198V21	4.225	16.704	0.786	1.257	0.194	0.528	0.066	0.183	338.90	354.55	349.23	307.74
OF198V21	4.772	16.706	1.102	2.703	0.190	0.548	0.046	0.190	339.32	356.83	350.76	304.61
OF198V22	4.684	17.572	0.811	2.278	0.214	0.615	0.078	0.168	324.12	342.15	331.33	296.91
OF198V22	3.680	14.498	0.533	1.436	0.268	0.621	0.145	0.234	329.61	347.89	338.74	298.61
OF198V22	3.096	11.163	0.602	1.708	0.294	0.852	0.100	0.239	322.05	342.03	331.49	289.18
OF198V22	2.993	10.757	0.710	1.433	0.279	0.737	0.098	0.275	323.29	343.83	332.62	290.23
OF198V24	7.182	13.564	6.178	4.267	1.147	2.284	0.684	1.163	456.39	498.35	473.35	392.74
OF198V24	7.291	17.552	4.357	5.085	1.092	2.072	0.500	1.467	456.35	490.58	474.79	396.08
OF198V24	4.518	10.420	3.223	2.497	1.222	2.301	0.629	1.524	438.23	479.85	451.90	380.88
OF198V24	5.951	16.429	3.454	2.702	1.187	2.375	0.638	1.317	440.12	478.47	452.57	387.80
OF198V25	3.570	15.377	0.149	1.130	0.659	1.243	0.349	0.804	371.66	449.43	356.16	342.33
OF198V25	3.542	15.375	0.101	1.082	0.557	0.849	0.262	0.892	375.77	453.85	360.25	345.99
OF198V25	4.823	21.935	0.090	0.791	0.358	0.521	0.146	0.631	380.26	455.49	365.77	350.65
OF198V25	4.651	20.782	0.119	1.069	0.411	0.734	0.125	0.705	386.75	474.85	372.02	348.30
OF198V25	3.846	16.874	0.088	1.089	0.385	0.765	0.132	0.575	381.33	464.01	367.77	344.46

Italicized & underlined data not used in calculating averages

TIER 1 LDTs

Veh #	FT-CO	CO-Ph1	CO-Ph2	CO-Ph3	NOx-FTP	NO-Ph1	NO-Ph2	NO-Ph3	FT-CO2	CO2-Ph1	CO2-Ph2	CO2-Ph3
OF198T0	4.348	20.509	0.000	0.430	0.421	0.662	0.365	0.345	448.36	485.70	456.76	404.07
OF198T0	3.195	14.954	0.000	0.305	0.471	0.897	0.306	0.459	443.93	482.91	448.47	405.91
OF198T0	3.935	18.414	0.011	0.433	0.397	0.651	0.297	0.393	446.35	483.96	454.91	401.83
OF198T0	3.204	14.993	0.012	0.334	0.454	0.914	0.323	0.353	450.96	489.54	457.35	409.82
OF198T0	3.602	16.894	0.010	0.375	0.416	0.856	0.253	0.393	460.70	501.63	468.23	415.39
OF198T0	2.696	12.507	0.028	0.316	0.452	0.965	0.258	0.430	458.14	500.27	464.40	414.41
OF198T18	1.017	4.235	0.064	0.391	1.145	2.298	0.957	0.630	553.45	633.52	556.05	488.11
OF198T18	1.221	5.201	0.061	0.402	0.865	2.025	0.520	0.638	549.35	628.98	552.10	483.98
OF198T18	1.394	5.655	0.159	0.507	0.852	2.094	0.468	0.640	546.64	626.78	548.63	482.39
OF198T18	1.815	6.520	0.311	1.093	0.449	1.359	0.162	0.304	559.85	629.86	570.90	486.15
OF198T18	1.444	5.328	0.171	0.923	0.497	1.222	0.315	0.297	557.46	643.11	561.81	484.66
OF198T18	1.268	4.680	0.160	0.782	0.594	1.744	0.244	0.387	554.33	645.18	554.58	485.28
OF198T27	2.721	10.981	0.264	1.093	0.505	1.380	0.216	0.387	520.91	588.46	516.98	477.23
OF198T27	2.879	11.703	0.166	1.300	0.532	1.469	0.184	0.478	521.37	599.43	512.08	479.86
OF198T27	3.099	12.840	0.168	1.265	0.535	1.285	0.210	0.580	531.31	609.39	526.51	481.46
OF198T27	3.165	12.646	0.246	1.463	0.519	1.341	0.205	0.484	527.39	600.50	518.99	487.85
OF198T29	*1.947*	*8.894*	*0.078*	*0.222*	*0.359*	*0.985*	*0.145*	*0.288*	*663.35*	*716.00*	*673.19*	*605.07*
OF198T29	1.515	6.952	0.105	0.065	0.300	0.776	0.117	0.286	664.99	712.53	685.87	590.05
OF198T29	1.623	7.122	0.111	0.306	0.388	0.980	0.233	0.230	668.96	721.64	688.80	591.88
OF198T29	2.179	10.068	0.105	0.096	0.349	0.944	0.163	0.247	660.60	707.04	683.70	582.05
OF198T29	2.182	9.905	0.104	0.262	0.269	0.827	0.135	0.101	660.41	711.03	680.48	584.54
OF198T29	2.260	10.748	0.043	0.027	0.278	0.752	0.082	0.290	652.70	695.34	671.69	584.71

Italicized & underlined data not used in calculating averages

TEST RESULTS for TIER 1 VEHICLES

TIER 1 LDVs

Veh #	FT-FE	FE-Ph1	FE-Ph2	FE-Ph3	T-Temp	FT-PM	PM-Ph1	PM-Ph2	PM-Ph3
OF198V5	19.61	16.74	19.72	22.28	35.0	5.763	16.747	2.276	4.032
OF198V5	19.44	16.40	19.58	22.29	36.0	4.530	15.760	1.259	2.164
OF198V5	19.60	16.59	19.71	22.44	35.0	3.851	12.016	1.669	1.795
OF198V5	20.05	17.01	20.15	22.91	35.5	5.796	26.486	0.208	0.668
OF198V5	19.82	17.01	19.95	22.33	35.5	4.104	19.765	0.000	0.000
OF198V6	26.82	25.55	25.58	30.77	36.3	6.537	31.159	0.000	0.223
OF198V6	26.14	23.32	25.46	30.44	35.7	8.090	38.076	0.000	0.888
OF198V6	26.16	25.17	25.28	28.89	36.0	5.199	24.989	0.000	0.000
OF198V6	26.27	24.86	25.09	30.25	36.3	2.918	14.074	0.000	0.000
OF198V6	26.10	24.27	25.04	30.23	35.7	4.209	17.249	1.235	0.000
OF198V9	*36.16*	*32.18*	*36.33*	*39.50*	*37.2*	*1.655*	*4.701*	*0.000*	*2.470*
OF198V9	34.99	31.06	34.95	38.79	36.6	2.674	5.515	2.366	1.110
OF198V9	34.58	31.21	34.60	37.61	36.8	3.154	7.956	2.075	1.553
OF198V9	34.19	30.94	33.98	37.61	36.0	1.310	4.184	0.618	0.442
OF198V9	34.10	30.39	34.14	37.47	35.4	0.228	1.094	0.000	0.000
OF198V19	23.81	20.27	23.67	27.78	37.3	5.209	23.670	0.000	1.058
OF198V19	23.46	19.52	23.47	27.65	36.2	7.745	34.761	0.972	0.000
OF198V19	23.46	19.76	23.52	27.16	36.6	11.302	44.715	2.142	3.124
OF198V19	23.63	19.96	23.67	27.36	36.1	10.661	45.195	1.565	1.460
OF198V19	23.54	20.05	23.41	27.43	36.6	7.317	34.763	0.195	0.000
OF198V19	23.71	20.16	23.56	27.73	36.1	ND	ND	ND	ND
OF198V21	25.26	22.74	24.56	29.28	37.2	3.274	13.554	0.000	1.666
OF198V21	25.25	22.40	24.96	28.57	35.0	3.511	11.831	0.388	3.098
OF198V21	25.60	23.04	25.31	28.60	35.0	3.662	15.215	0.966	0.000
OF198V21	25.50	22.90	25.17	28.68	36.1	3.652	13.361	0.388	2.491
OF198V22	26.71	23.79	26.68	29.51	36.0	2.099	10.138	0.000	0.000
OF198V22	26.40	23.73	26.13	29.48	36.2	3.541	7.451	0.772	5.805
OF198V22	26.18	23.68	25.79	29.35	36.5	2.155	6.611	0.964	1.036
OF198V22	26.09	23.61	25.69	29.30	36.0	2.239	7.426	0.578	1.453
OF198V24	18.94	16.99	18.36	22.20	36.4	3.856	10.339	1.546	3.329
OF198V24	18.94	17.03	18.42	21.94	36.2	2.267	7.804	0.588	1.257
OF198V24	19.23	17.21	18.75	22.26	36.7	0.870	3.706	0.193	0.000
OF198V24	19.04	16.92	18.71	21.85	36.2	1.134	4.957	0.195	0.000
OF198V25	22.64	17.87	24.05	24.86	36.3	3.620	13.612	0.000	2.925
OF198V25	22.40	17.71	23.79	24.64	36.2	2.675	8.469	0.773	1.879
OF198V25	22.78	17.83	24.25	25.20	34.1	2.310	9.729	0.000	1.045
OF198V25	22.59	17.46	23.97	25.46	37.2	4.376	18.381	0.000	2.099
OF198V25	22.81	17.82	24.12	25.59	37.0	2.299	10.802	0.000	0.210

Italicized & underlined data not used in calculating averages

TIER 1 LDTs

Veh #	FT-FE	FE-Ph1	FE-Ph2	FE-Ph3	T-Temp	FT-PM	PM-Ph1	PM-Ph2	PM-Ph3
OF198T0	18.75	16.28	18.77	21.16	34.2	10.899	52.829	0.000	0.000
OF198T0	19.03	16.71	19.11	21.08	35.5	9.479	45.557	0.000	0.000
OF198T0	18.88	16.48	18.84	21.28	34.2	10.479	48.072	1.024	0.000
OF198T0	19.39	17.03	19.40	21.62	35.9	13.791	63.365	0.818	0.883
OF198T0	18.95	16.50	18.95	21.32	34.7	16.874	79.523	0.000	1.559
OF198T0	19.12	16.82	19.11	21.38	34.4	14.416	64.911	0.413	2.678
OF198T18	15.43	13.36	15.41	17.54	37.3	2.578	8.084	1.743	0.000
OF198T18	15.54	13.42	15.52	17.68	35.2	1.324	6.382	0.000	0.000
OF198T18	15.61	13.45	15.62	17.74	35.4	0.000	0.000	0.000	0.000
OF198T18	15.75	13.79	15.53	18.19	36.1	1.760	4.961	0.194	2.295
OF198T18	15.84	13.58	15.79	18.25	36.2	0.687	3.323	0.000	0.000
OF198T18	15.94	13.56	15.99	18.24	35.4	2.214	8.473	0.771	0.209
OF198T27	16.29	14.07	16.57	17.88	36.5	4.430	11.861	1.930	3.511
OF198T27	16.27	13.79	16.73	17.77	35.7	5.520	18.918	0.969	3.930
OF198T27	16.52	13.99	16.85	18.34	36.0	5.706	22.080	0.192	3.727
OF198T27	16.64	14.20	17.09	18.09	35.4	5.352	18.879	0.767	3.712
OF198T29	*13.30*	*12.10*	*13.18*	*14.66*	*35.5*	*5.789*	*24.089*	*0.000*	*2.879*
OF198T29	13.29	12.22	12.94	15.04	35.7	3.701	14.140	1.154	0.616
OF198T29	13.20	12.06	12.88	14.98	36.4	4.839	22.310	0.382	0.000
OF198T29	12.90	11.81	12.54	14.72	35.9	3.356	9.316	1.531	2.266
OF198T29	12.90	11.75	12.60	14.65	35.9	2.266	10.091	0.000	0.621
OF198T29	13.05	11.99	12.76	14.66	36.9	1.395	6.722	0.000	0.000

HC, CO, NOx & CO2 are reported in grams/mile

Italicized & underlined data not used in calculati: PM is reported in milligr

UNIFIED CYCLE TEST RESULTS for TIER 0 VEHICLES
No cold start assessment - Conducted as a hot start 3 phase test.

TIER 0 LDVs

VEH #	0	Make	Model	Cyl	Disp	Odom	Fuel	Type	EC	Trans	Grp/Tier	UNF#	HC-UNF	HC-Ph1	HC-Ph2	HC-Ph3
OF098V1	1993	TOYOTA	CORROLA	4	4.0	20163	PI	Oxy	TWC	AUTO	LDV0	8044	0.107	0.104	0.104	0.145
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20192	PI	Oxy	TWC	AUTO	LDV0	8049	0.094	0.092	0.092	0.134
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20301	PI	NonOxy	TWC	AUTO	LDV0	8054	0.106	0.097	0.102	0.156
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20341	PI	NonOxy	TWC	AUTO	LDV0	8066	0.121	0.109	0.112	0.244
OF098V2	1990	HONDA	ACCORD	4	2.2	92586	PI	NonOxy	TWC	M5	LDV0	8058	0.240	0.300	0.227	0.357
OF098V2	1990	HONDA	ACCORD	4	2.2	92649	PI	NonOxy	TWC	M5	LDV0	8062	0.288	0.632	0.262	0.357
OF098V2	1990	HONDA	ACCORD	4	2.2	92688	PI	Oxy	TWC	M5	LDV0	8073	0.268	0.748	0.236	0.314
OF098V2	1990	HONDA	ACCORD	4	2.2	92886	PI	Oxy	TWC	M5	LDV0	8087	0.244	0.250	0.241	0.273
OF098V3	1991	FORD	ESCORT	4	1.8	109295	PI	Oxy	TWC	M5	LDV0	8105	0.233	0.320	0.213	0.415
OF098V3	1991	FORD	ESCORT	4	1.8	109351	PI	Oxy	TWC	M5	LDV0	8115	0.192	0.409	0.167	0.357
OF098V3	1991	FORD	ESCORT	4	1.8	109424	PI	NonOxy	TWC	M5	LDV0	8130	0.273	0.436	0.243	0.527
OF098V3	1991	FORD	ESCORT	4	1.8	109460	PI	NonOxy	TWC	M5	LDV0	8141	0.291	0.482	0.256	0.590
OF098V4	1991	HONDA	CIVIC	4	1.5	110927	TBI	NonOxy	TWC	M4	LDV0	8096	0.583	0.969	0.484	1.568
OF098V4	1991	HONDA	CIVIC	4	1.5	110984	TBI	NonOxy	TWC	M4	LDV0	8110	0.766	1.591	0.593	2.334
OF098V4	1991	HONDA	CIVIC	4	1.5	111030	TBI	Oxy	TWC	M4	LDV0	8119	0.535	0.888	0.456	1.280
OF098V4	1991	HONDA	CIVIC	4	1.5	111118	TBI	Oxy	TWC	M4	LDV0	8126	0.552	0.882	0.461	1.448
OF098V7	1993	FORD	TAURUS	6	3.8	79183	PI	NonOxy	TWC	AUTO	LDV0	8196	0.118	0.089	0.116	0.170
OF098V7	1993	FORD	TAURUS	6	3.8	79241	PI	NonOxy	TWC	AUTO	LDV0	8201	0.067	0.079	0.062	0.130
OF098V7	1993	FORD	TAURUS	6	3.8	79280	PI	Oxy	TWC	AUTO	LDV0	8215	0.107	0.169	0.094	0.227
OF098V7	1993	FORD	TAURUS	6	3.8	79343	PI	Oxy	TWC	AUTO	LDV0	8220	0.089	0.075	0.079	0.225
OF098V20	1992	TOYO	CAM	4	2.2	88112	PI	Oxy	TWC	AUTO	LDV0	8475	0.036	0.050	0.031	0.088
OF098V20	1992	TOYO	CAM	4	2.2	88182	PI	Oxy	TWC	AUTO	LDV0	8484	0.033	0.049	0.029	0.079
OF098V20	1992	TOYO	CAM	4	2.2	88246	PI	NonOxy	TWC	AUTO	LDV0	8501	0.040	0.049	0.034	0.106
OF098V20	1992	TOYO	CAM	4	2.2	88290	PI	NonOxy	TWC	AUTO	LDV0	8510	0.034	0.048	0.029	0.087
OF098V23	1994	CHEVY	CAVALIER	6	3.1	46994	PI	Oxy	TWC	AUTO	LDV0	8555	0.127	0.303	0.072	0.686
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47104	PI	Oxy	TWC	AUTO	LDV0	8569	0.159	1.042	0.082	0.479
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47207	PI	NonOxy	TWC	AUTO	LDV0	8579	0.138	0.174	0.059	1.117
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47285	PI	NonOxy	TWC	AUTO	LDV0	8593	0.121	0.197	0.048	0.990
OF098V26	1993	SATURN	SC2	4	1.9	34578	PI	Oxy	TWC	AUTO	LDV0	8617	0.078	0.077	0.077	0.082
OF098V26	1993	SATURN	SC2	4	1.9	34635	PI	Oxy	TWC	AUTO	LDV0	8622	0.064	0.081	0.063	0.074
OF098V26	1993	SATURN	SC2	4	1.9	34710	PI	NonOxy	TWC	AUTO	LDV0	8634	0.080	0.128	0.065	0.240
OF098V26	1993	SATURN	SC2	4	1.9	34771	PI	NonOxy	TWC	AUTO	LDV0	8643	0.078	0.167	0.067	0.139

Italicized & underlined data not used in calculating averages

TIER 0 LDTs

VEH #	Year	Make	Model	Cyl	Disp	Odom	Fuel	Type	EC	Trans	Grp/Tier	UNF#	HC-UNF	HC-Ph1	HC-Ph2	HC-Ph3
OF098T11	1993	FORD	EXPLORER	6	4.0	44112	PI	Oxy	TWC	AUTO	LDT0	8286	0.153	0.118	0.140	0.360
OF098T11	1993	FORD	EXPLORER	6	4.0	44161	PI	Oxy	TWC	AUTO	LDT0	8293	0.098	0.083	0.086	0.252
OF098T11	1993	FORD	EXPLORER	6	4.0	44219	PI	Oxy	TWC	AUTO	LDT0	8307	0.084	0.082	0.072	0.234
OF098T11	1993	FORD	EXPLORER	6	4.0	44293	PI	NonOxy	TWC	AUTO	LDT0	8315	0.070	0.079	0.051	0.299
OF098T11	1993	FORD	EXPLORER	6	4.0	44340	PI	NonOxy	TWC	AUTO	LDT0	8325	0.065	0.070	0.058	0.146
OF098T12	1991	CHEVY	BLAZER	6	4.3	122759	TBI	NonOxy	TWC	AUTO	LDT0	8298	0.356	0.508	0.237	1.706
OF098T12	1991	CHEVY	BLAZER	6	4.3	122816	TBI	NonOxy	TWC	AUTO	LDT0	8303	0.523	0.368	0.437	1.744
OF098T12	1991	CHEVY	BLAZER	6	4.3	122887	TBI	Oxy	TWC	AUTO	LDT0	8320	0.388	0.406	0.319	1.256
OF098T12	1991	CHEVY	BLAZER	6	4.3	122941	TBI	Oxy	TWC	AUTO	LDT0	8329	0.422	0.314	0.362	1.257
OF098T15	1993	JEEP	CHEROKEE	6	4.0	36929	PI	NonOxy	TWC	AUTO	LDT0	8341	0.102	0.129	0.085	0.300
OF098T15	1993	JEEP	CHEROKEE	6	4.0	36988	PI	NonOxy	TWC	AUTO	LDT0	8350	0.086	0.109	0.072	0.256
OF098T15	1993	JEEP	CHEROKEE	6	4.0	37061	PI	Oxy	TWC	AUTO	LDT0	8362	0.096	0.105	0.084	0.239
OF098T15	1993	JEEP	CHEROKEE	6	4.0	37122	PI	Oxy	TWC	AUTO	LDT0	8368	0.088	0.120	0.072	0.274
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63119	TBI	NonOxy	TWC	AUTO	LDT0	8672	0.733	0.943	0.704	0.933
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63179	TBI	NonOxy	TWC	AUTO	LDT0	8677	0.682	0.997	0.649	0.861
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63253	TBI	Oxy	TWC	AUTO	LDT0	8683	0.585	0.811	0.550	0.864
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63290	TBI	Oxy	TWC	AUTO	LDT0	8688	0.639	0.837	0.607	0.892

Italicized & underlined data not used in calculating averages

HC, CO, NOx & CO2 are reported i
PM is reported in milligrams/mil

UNIFIED CYCLE TEST RESULTS forTIER 0 VEHICLES

No cold start assessment - Conducted as a hot start 3 phase test.

TIER 0 LDVs

VEH #	CO-UNF	CO-Ph1	CO-Ph2	CO-Ph3	NO-UNF	NO-Ph1	NO-Ph2	NO-Ph3	CO2UNF	CO2Ph1	CO2Ph2	CO2Ph3
OF098V1	1.105	0.452	1.187	0.550	0.227	0.234	0.189	0.700	337.75	423.62	328.93	385.52
OF098V1	1.199	0.459	1.281	0.720	0.212	0.297	0.168	0.710	327.59	427.25	315.45	406.61
OF098V1	1.810	0.692	1.952	0.835	0.211	0.136	0.171	0.791	330.88	422.44	318.82	416.10
OF098V1	1.732	0.190	1.865	1.188	0.224	0.316	0.184	0.677	326.96	423.49	314.13	418.23
OF098V2	8.884	10.703	8.650	10.466	0.694	0.921	0.656	0.999	334.57	431.20	320.70	437.19
OF098V2	12.125	13.240	12.231	9.914	0.708	1.299	0.641	1.112	325.23	496.40	304.76	455.44
OF098V2	9.938	22.377	9.285	8.800	0.738	1.060	0.699	1.000	338.12	464.35	324.30	418.31
OF098V2	11.529	8.885	11.847	9.462	0.670	1.025	0.639	0.798	338.47	453.00	323.82	439.60
OF098V3	4.695	4.118	4.801	3.778	1.465	1.838	1.414	1.839	353.41	497.63	335.89	468.17
OF098V3	3.460	6.220	3.142	5.445	1.475	2.008	1.413	1.867	359.01	498.45	341.32	479.98
OF098V3	5.069	7.227	4.849	6.259	1.503	1.913	1.447	1.902	368.03	517.38	349.28	494.89
OF098V3	4.998	6.020	4.810	6.619	1.506	1.958	1.452	1.857	367.72	520.07	349.57	483.80
OF098V4	11.971	13.624	11.629	15.091	3.162	3.710	3.067	3.959	252.15	317.57	244.11	305.43
OF098V4	12.874	18.000	12.362	15.462	3.119	3.587	3.037	3.793	248.38	307.49	241.32	292.91
OF098V4	9.840	13.497	9.510	11.271	3.135	3.290	3.060	3.977	244.57	292.09	238.22	289.40
OF098V4	11.261	14.662	10.968	12.427	3.131	3.463	3.043	4.000	245.28	302.39	237.93	295.61
OF098V7	6.666	3.629	7.158	2.658	0.920	0.873	0.899	1.227	431.04	590.43	408.91	594.13
OF098V7	2.899	2.688	2.916	2.845	0.838	0.944	0.809	1.131	442.52	620.35	419.03	609.33
OF098V7	4.418	7.938	4.463	1.241	1.115	1.445	1.068	1.470	441.26	615.39	418.19	606.08
OF098V7	3.217	1.575	3.407	2.014	0.974	0.994	0.947	1.306	439.39	602.25	416.23	614.32
OF098V20	0.798	0.484	0.824	0.696	1.082	1.410	1.027	1.537	368.71	501.12	352.67	473.74
OF098V20	0.469	0.562	0.451	0.628	1.114	1.306	1.083	1.372	357.13	473.73	342.05	462.08
OF098V20	1.092	0.593	1.134	0.939	0.992	1.265	0.944	1.396	362.45	480.98	346.98	468.90
OF098V20	0.648	0.570	0.624	1.014	0.988	1.376	0.941	1.297	365.73	492.52	350.10	469.06
OF098V23	3.836	8.492	3.168	8.796	1.477	1.970	1.395	2.153	385.74	516.39	368.39	507.44
OF098V23	5.352	10.207	4.915	7.282	1.475	2.547	1.346	2.301	383.80	504.74	367.71	497.81
OF098V23	2.824	5.624	1.707	14.862	1.204	1.714	1.103	2.099	384.38	517.81	367.22	500.90
OF098V23	2.515	4.977	1.446	14.199	1.138	1.250	1.064	1.992	387.94	524.81	371.21	497.33
OF098V26	2.839	1.909	2.988	1.660	0.296	0.182	0.304	0.281	294.87	393.43	282.30	380.11
OF098V26	2.808	2.527	2.925	1.525	0.233	0.156	0.229	0.343	297.56	396.26	284.99	383.90
OF098V26	2.798	3.515	2.403	7.352	0.252	0.226	0.264	0.114	305.32	399.95	292.29	401.70
OF098V26	2.919	4.001	2.807	3.525	0.238	0.372	0.236	0.163	304.02	402.85	291.22	392.26

Italicized & underlined data not used in calculating averages

TIER 0 LDTs

VEH #	CO-UNF	CO-Ph1	CO-Ph2	CO-Ph3	NO-UNF	NO-Ph1	NO-Ph2	NO-Ph3	CO2UNF	CO2Ph1	CO2Ph2	CO2Ph3
OF098T11	7.171	4.056	7.609	3.884	0.863	1.221	0.812	1.257	488.16	670.45	464.82	650.92
OF098T11	5.216	3.126	5.494	3.224	0.728	0.706	0.702	1.067	502.71	663.95	482.54	639.54
OF098T11	2.819	2.753	2.855	2.406	0.812	1.251	0.770	1.026	492.41	685.66	469.43	640.44
OF098T11	2.590	2.637	2.447	4.377	0.751	1.041	0.715	0.994	504.02	683.16	481.06	661.31
OF098T11	2.552	1.780	2.498	3.822	0.711	0.835	0.666	1.183	518.82	701.09	495.90	674.07
OF098T12	10.603	13.055	8.816	30.780	1.641	1.754	1.620	1.809	494.41	686.42	473.11	617.15
OF098T12	22.949	11.442	22.454	38.117	1.796	2.310	1.735	2.186	506.08	675.82	485.41	643.36
OF098T12	17.019	12.589	16.822	22.904	1.563	1.783	1.522	1.919	477.52	645.19	457.38	607.74
OF098T12	18.142	12.007	17.724	28.056	1.405	1.614	1.414	1.140	472.45	619.01	459.81	522.17
OF098T15	2.586	3.144	2.395	4.591	0.802	1.181	0.705	1.750	566.45	733.96	544.51	718.79
OF098T15	1.560	1.949	1.326	4.280	0.798	1.208	0.717	1.536	570.70	759.21	546.93	735.61
OF098T15	1.726	1.446	1.649	2.930	0.727	1.489	0.620	1.527	555.17	731.60	531.43	726.02
OF098T15	1.701	2.454	1.538	3.218	0.988	1.402	0.877	2.101	561.00	740.72	539.36	701.25
OF098T28	18.533	14.612	19.268	12.128	3.078	4.144	2.962	3.752	671.19	880.46	643.14	870.28
OF098T28	19.767	18.054	20.262	14.755	2.968	3.673	2.867	3.729	670.09	895.41	640.74	873.53
OF098T28	10.685	12.282	10.456	12.432	3.170	3.603	3.111	3.596	666.87	856.79	641.62	848.55
OF098T28	16.456	12.474	17.040	12.015	2.888	3.623	2.770	3.848	661.20	854.58	633.90	863.20

Italicized & underlined data not used in calcul HC, CO, NOx & CO2 are reported in grams/mile

PM is reported in milligrams/mile

UNIFIED CYCLE TEST RESULTS forTIER 0 VEHICLES
No cold start assessment - Conducted as a hot

TIER 0 LDVs

VEH #	FE-UNF	FE-Ph1	FE-Ph2	FE-Ph3	T-Temp	PM-UNF
OF098V1	26.51	21.21	27.20	23.28	34.4	3.712
OF098V1	26.00	20.02	26.98	21.01	35.8	1.987
OF098V1	26.57	20.94	27.54	21.24	36.5	2.723
OF098V1	26.89	20.92	27.96	21.09	36.4	1.052
OF098V2	25.41	19.77	26.49	19.52	35.8	4.314
OF098V2	25.71	17.09	27.32	18.80	36.9	ND
OF098V2	24.18	17.09	25.24	19.80	36.4	4.473
OF098V2	23.99	18.33	24.98	18.83	37.9	1.295
OF098V3	23.72	16.97	24.92	18.03	36.4	4.753
OF098V3	23.49	16.83	24.72	17.51	36.0	3.075
OF098V3	23.55	16.74	24.81	17.53	35.7	2.955
OF098V3	23.57	16.71	24.79	17.89	36.0	2.034
OF098V4	32.53	25.95	33.63	26.56	34.8	23.765
OF098V4	32.74	26.04	33.79	27.34	35.4	10.738
OF098V4	32.76	27.13	33.68	27.57	34.1	8.825
OF098V4	32.39	26.13	33.41	26.83	33.7	10.625
OF098V7	20.08	14.88	21.10	14.82	35.7	1.311
OF098V7	19.84	14.20	20.94	14.45	37.5	0.726
OF098V7	19.11	13.64	20.15	14.08	37.4	0.798
OF098V7	19.28	14.17	20.32	13.87	36.9	0.436
OF098V20	23.17	17.08	24.21	18.05	34.2	0.814
OF098V20	23.95	18.06	25.01	18.50	38.8	0.674
OF098V20	24.36	18.41	25.44	18.85	36.0	0.551
OF098V20	24.19	17.98	25.27	18.85	33.8	1.151
OF098V23	21.86	16.16	22.95	16.38	36.2	32.409
OF098V23	21.83	16.36	22.82	16.79	36.3	5.142
OF098V23	22.80	16.83	23.98	16.82	36.7	4.442
OF098V23	22.62	16.64	23.75	16.98	40.5	1.922
OF098V26	28.62	21.61	29.85	22.39	35.5	2.740
OF098V26	28.37	21.41	29.58	22.18	36.5	1.436
OF098V26	28.63	21.87	29.96	21.44	35.3	1.019
OF098V26	28.74	21.66	30.00	22.28	36.5	1.494

Italicized & underlined data not used in calculating a

TIER 0 LDTs

VEH #	FE-UNF	FE-Ph1	FE-Ph2	FE-Ph3	T-Temp	PM-UNF
OF098T11	17.15	12.66	17.97	13.03	36.2	16.151
OF098T11	16.77	12.81	17.44	13.28	40.7	4.656
OF098T11	17.25	12.42	18.08	13.29	39.5	1.739
OF098T11	17.46	12.91	18.30	13.26	35.2	1.016
OF098T11	16.97	12.60	17.75	13.04	33.7	0.724
OF098T12	17.33	12.53	18.20	13.23	39.8	2.207
OF098T12	16.32	12.77	17.00	12.52	41.9	3.751
OF098T12	16.96	12.87	17.68	13.24	34.7	2.823
OF098T12	17.07	13.42	17.54	15.04	35.8	2.096
OF098T15	15.55	12.00	16.18	12.21	35.1	17.603
OF098T15	15.48	11.64	16.16	11.94	37.5	13.050
OF098T15	15.36	11.68	16.05	11.72	36.3	8.770
OF098T15	15.20	11.51	15.82	12.12	35.3	8.695
OF098T28	12.63	9.79	13.14	9.95	37.1	12.910
OF098T28	12.62	9.57	13.16	9.87	36.3	4.507
OF098T28	12.51	9.76	13.00	9.85	36.6	3.211
OF098T28	12.44	9.78	12.94	9.69	37.0	3.684

Italicized & HC, CO, NOx & CO2 are reported in grams/mile
PM is reported in milligrams/mile

UNIFIED CYCLE TEST RESULTS for TIER 1 VEHICLES

TIER 1 LDVs

VEH #	Year	Make	Model	Cyl	Disp	Odom	Fuel	Type	EC	Trans	Grp	UNF#	HC-UNF	HC-Ph1	HC-Ph2	HC-Ph3
OF198V5	1996	FORD	TAURUS	6	3.0	38267	PI	Oxy	TWC	AUTO	LDV1	8158	0.083	0.050	0.070	0.266
OF198V5	1996	FORD	TAURUS	6	3.0	38340	PI	Oxy	TWC	AUTO	LDV1	8167	0.091	0.051	0.078	0.283
OF198V5	1996	FORD	TAURUS	6	3.0	38397	PI	Oxy	TWC	AUTO	LDV1	8172	0.061	0.036	0.057	0.137
OF198V5	1996	FORD	TAURUS	6	3.0	38440	PI	NonOxy	TWC	AUTO	LDV1	8176	0.080	0.044	0.066	0.282
OF198V5	1996	FORD	TAURUS	6	3.0	38480	PI	NonOxy	TWC	AUTO	LDV1	8180	0.070	0.105	0.060	0.166
OF198V6	1996	SATURN	LS2	4	1.9	11978	PI	NonOxy	TWC	M5	LDV1	8185	0.218	0.424	0.177	0.581
OF198V6	1996	SATURN	LS2	4	1.9	12020	PI	NonOxy	TWC	M5	LDV1	8191	0.183	0.389	0.158	0.342
OF198V6	1996	SATURN	LS2	4	1.9	12090	PI	NonOxy	TWC	M5	LDV1	8205	0.196	0.384	0.166	0.435
OF198V6	1996	SATURN	LS2	4	1.9	12179	PI	Oxy	TWC	M5	LDV1	8211	0.118	0.317	0.097	0.232
OF198V6	1996	SATURN	LS2	4	1.9	12239	PI	Oxy	TWC	M5	LDV1	8224	0.112	0.305	0.088	0.269
OF198V9	1995	HONDA	CIVIC	4	1.5	52636	PI	NonOxy	TWC	M5	LDV1	8240	0.058	0.048	0.056	0.086
OF198V9	1995	HONDA	CIVIC	4	1.5	52696	PI	NonOxy	TWC	M5	LDV1	8250	0.067	0.063	0.066	0.083
OF198V9	1995	HONDA	CIVIC	4	1.5	52760	PI	NonOxy	TWC	M5	LDV1	8257	0.055	0.036	0.055	0.072
OF198V9	1995	HONDA	CIVIC	4	1.5	52837	PI	Oxy	TWC	M5	LDV1	8266	0.036	0.037	0.034	0.060
OF198V9	1995	HONDA	CIVIC	4	1.5	52884	PI	Oxy	TWC	M5	LDV1	8280	0.050	0.053	0.049	0.068
OF198V19	1997	CHEV	CAV	4	2.4	22286	PI	Oxy	TWC	AUTO	LDV1	8448	0.039	0.046	0.037	0.057
OF198V19	1997	CHEV	CAV	4	2.4	22344	PI	Oxy	TWC	AUTO	LDV1	8457	0.042	0.038	0.033	0.161
OF198V19	1997	CHEV	CAV	4	2.4	22390	PI	Oxy	TWC	AUTO	LDV1	8462	0.046	0.043	0.047	0.029
OF198V19	1997	CHEV	CAV	4	2.4	22467	PI	NonOxy	TWC	AUTO	LDV1	8468	0.078	0.081	0.079	0.063
OF198V19	1997	CHEV	CAV	4	2.4	22526	PI	NonOxy	TWC	AUTO	LDV1	8479	0.068	0.056	0.065	0.115
OF198V19	1997	CHEV	CAV	4	2.4	22950	PI	NonOxy	TWC	AUTO	LDV1	8488	0.063	0.079	0.056	0.142
OF198V21	1997	TOYO	CAMRY	4	2.2	23045	PI	Oxy	TWC	M5	LDV1	8496	0.164	0.311	0.147	0.264
OF198V21	1997	TOYO	CAMRY	4	2.2	23104	PI	Oxy	TWC	M5	LDV1	8506	0.136	0.151	0.130	0.197
OF198V21	1997	TOYO	CAMRY	4	2.2	23165	PI	NonOxy	TWC	M5	LDV1	8516	0.155	0.112	0.146	0.308
OF198V21	1997	TOYO	CAMRY	4	2.2	23209	PI	NonOxy	TWC	M5	LDV1	8528	0.152	0.151	0.143	0.271
OF198V22	1996	HONDA	ACCORD	4	2.2	29885	PI	NonOxy	TWC	M5	LDV1	8523	0.068	0.055	0.067	0.091
OF198V22	1996	HONDA	ACCORD	4	2.2	29930	PI	NonOxy	TWC	M5	LDV1	8532	0.053	0.038	0.053	0.058
OF198V22	1996	HONDA	ACCORD	4	2.2	29988	PI	Oxy	TWC	M5	LDV1	8538	0.047	0.045	0.046	0.069
OF198V22	1996	HONDA	ACCORD	4	2.2	30115	PI	Oxy	TWC	M5	LDV1	8543	0.071	0.116	0.064	0.129
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43817	PI	NonOxy	TWC	AUTO	LDV1	8560	0.074	0.137	0.059	0.212
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43877	PI	NonOxy	TWC	AUTO	LDV1	8565	0.084	0.140	0.071	0.213
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43936	PI	Oxy	TWC	AUTO	LDV1	8584	0.063	0.117	0.051	0.174
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43995	PI	Oxy	TWC	AUTO	LDV1	8589	0.073	0.114	0.063	0.167
OF198V25	1996	SUBARU	LEGACY	4	2.2	19389	PI	Oxy	TWC	AUTO	LDV1	8599	0.196	0.046	0.189	0.392
OF198V25	1996	SUBARU	LEGACY	4	2.2	19446	PI	Oxy	TWC	AUTO	LDV1	8604	0.171	0.052	0.178	0.176
OF198V25	1996	SUBARU	LEGACY	4	2.2	19521	PI	NonOxy	TWC	AUTO	LDV1	8612	0.201	0.051	0.180	0.574
OF198V25	1996	SUBARU	LEGACY	4	2.2	19580	PI	NonOxy	TWC	AUTO	LDV1	8627	0.225	0.093	0.205	0.581
OF198V25	1996	SUBARU	LEGACY	4	2.2	19638	PI	NonOxy	TWC	AUTO	LDV1	8639	0.213	0.049	0.192	0.603

Italicized & underlined data not used in calculating averages

TIER 1 LDTs

VEH #	Year	Make	Model	Cyl	Disp	Odom	Fuel	Type	EC	Trans	Grp	UNF#	HC-UNF	HC-Ph1	HC-Ph2	HC-Ph3
Caravan	1997	DODGE	CARAVAN	6	3.0	7863	PI	Oxy	TWC	AUTO	LDT1	8091	0.109	0.073	0.104	0.190
Caravan	1997	DODGE	CARAVAN	6	3.0	7899	PI	Oxy	TWC	AUTO	LDT1	8101	0.099	0.058	0.101	0.103
Caravan	1997	DODGE	CARAVAN	6	3.0	7995	PI	Oxy	TWC	AUTO	LDT1	8137/36	0.086	0.073	0.086	0.102
Caravan	1997	DODGE	CARAVAN	6	3.0	8040	PI	NonOxy	TWC	AUTO	LDT1	8147/40	0.095	0.063	0.096	0.107
Caravan	1997	DODGE	CARAVAN	6	3.0	8079	PI	NonOxy	TWC	AUTO	LDT1	8152	0.092	0.067	0.088	0.162
Caravan	1997	DODGE	CARAVAN	6	3.0	8184	PI	NonOxy	TWC	AUTO	LDT1	8162	0.103	0.063	0.107	0.089
OF198T18	1996	FORD	EXPLORER	6	4.0	33724	PI	Oxy	TWC	AUTO	LDT1	8399	0.032	0.055	0.025	0.110
OF198T18	1996	FORD	EXPLORER	6	4.0	33765	PI	Oxy	TWC	AUTO	LDT1	8409	0.027	0.046	0.027	0.021
OF198T18	1996	FORD	EXPLORER	6	4.0	33840	PI	Oxy	TWC	AUTO	LDT1	8419	0.044	0.052	0.040	0.087
OF198T18	1996	FORD	EXPLORER	6	4.0	33912	PI	NonOxy	TWC	AUTO	LDT1	8436	0.069	0.100	0.063	0.115
OF198T18	1996	FORD	EXPLORER	6	4.0	33965	PI	NonOxy	TWC	AUTO	LDT1	8441	0.070	0.047	0.066	0.097
OF198T18	1996	FORD	EXPLORER	6	4.0	34023	PI	NonOxy	TWC	AUTO	LDT1	8453	0.070	0.037	0.071	0.083
OF198T27	1996	CHEVY	BLAZER	6	4.3	42610	PI	Oxy	TWC	AUTO	LDT1	8650	0.053	0.045	0.044	0.167
OF198T27	1996	CHEVY	BLAZER	6	4.3	42675	PI	Oxy	TWC	AUTO	LDT1	8655	0.054	0.039	0.049	0.137
OF198T27	1996	CHEVY	BLAZER	6	4.3	42738	PI	NonOxy	TWC	AUTO	LDT1	8661	0.064	0.074	0.056	0.158
OF198T27	1996	CHEVY	BLAZER	6	4.3	42790	PI	NonOxy	TWC	AUTO	LDT1	8666	0.070	0.061	0.061	0.190
OF198T29	*1997*	*FORD*	*EXPEDITION*	*8*	*5.4*	*14013*	*PI*	*NonOxy*	*2TWC*	*AUTO*	*LDT1*	*8694*	*0.013*	*0.012*	*0.012*	*0.027*
OF198T29	1997	FORD	EXPEDITION	8	5.4	14076	PI	NonOxy	2TWC	AUTO	LDT1	8700	0.009	0.010	0.009	0.017
OF198T29	1997	FORD	EXPEDITION	8	5.4	14133	PI	NonOxy	2TWC	AUTO	LDT1	8705	0.008	0.012	0.007	0.017
OF198T29	1997	FORD	EXPEDITION	8	5.4	14181	PI	Oxy	2TWC	AUTO	LDT1	8711	0.009	0.008	0.009	0.013
OF198T29	1997	FORD	EXPEDITION	8	5.4	14258	PI	Oxy	2TWC	AUTO	LDT1	8716	0.010	0.012	0.010	0.020
OF198T29	1997	FORD	EXPEDITION	8	5.4	14314	PI	Oxy	2TWC	AUTO	LDT1	8721	0.015	0.023	0.013	0.034

Italicized & underlined data not used in calculating averages

HC, CO, NOx & CO2 are reported i
PM is reported in milligrams/mil

UNIFIED CYCLE TEST RESULTS for TIER 1 VEHICLES

TIER 1 LDVs

VEH #	CO-UNF	CO-Ph1	CO-Ph2	CO-Ph3	NO-UNF	NO-Ph1	NO-Ph2	NO-Ph3	CO2UNF	CO2Ph1	CO2Ph2	CO2Ph3
OF198V5	4.790	0.657	5.117	3.733	0.400	0.657	0.333	1.061	409.60	572.33	388.68	554.82
OF198V5	5.872	0.470	6.336	4.034	0.387	0.578	0.314	1.174	409.34	557.92	388.84	558.30
OF198V5	3.362	0.357	3.616	2.410	0.357	0.459	0.306	0.922	412.91	560.26	393.21	551.70
OF198V5	4.270	0.474	4.498	4.235	0.397	0.708	0.334	0.958	423.89	577.00	403.33	570.69
OF198V5	2.842	0.374	3.045	2.118	0.386	0.556	0.327	1.009	425.24	596.91	404.45	561.50
OF198V6	2.603	5.176	2.466	2.417	0.356	0.502	0.354	0.268	315.78	421.59	301.28	421.82
OF198V6	2.963	4.740	2.831	3.312	0.293	0.191	0.297	0.319	316.04	415.47	302.75	411.42
OF198V6	2.201	4.277	2.072	2.293	0.224	0.176	0.237	0.088	318.00	425.72	304.17	413.84
OF198V6	1.522	3.489	1.402	1.576	0.300	0.288	0.299	0.330	315.14	429.44	300.47	415.26
OF198V6	1.531	3.458	1.369	2.139	0.309	0.227	0.322	0.211	315.14	420.84	300.65	420.17
OF198V9	0.949	1.415	0.855	1.812	0.193	0.372	0.161	0.474	240.11	310.58	232.18	289.79
OF198V9	0.998	0.707	0.968	1.601	0.155	0.431	0.120	0.388	244.38	320.20	235.17	304.70
OF198V9	0.946	0.706	0.939	1.218	0.137	0.328	0.121	0.193	245.52	319.79	236.18	309.29
OF198V9	0.659	0.469	0.623	1.273	0.139	0.277	0.112	0.376	241.59	316.13	231.92	308.87
OF198V9	0.596	0.913	0.552	0.924	0.132	0.230	0.116	0.267	246.22	307.00	237.67	309.87
OF198V19	1.753	2.085	1.756	1.468	0.340	0.412	0.316	0.589	341.77	447.41	326.92	452.99
OF198V19	1.321	1.338	1.311	1.435	0.345	0.203	0.344	0.464	347.26	454.83	331.76	463.38
OF198V19	2.154	2.211	2.231	1.135	0.203	0.179	0.191	0.365	354.66	475.00	339.73	452.96
OF198V19	4.732	4.237	4.974	2.038	0.155	0.197	0.133	0.403	360.22	475.62	343.95	479.37
OF198V19	3.135	2.450	3.271	1.931	0.130	0.134	0.114	0.326	356.68	459.81	342.13	463.99
OF198V19	1.516	1.991	1.422	2.337	0.141	0.134	0.116	0.456	353.15	466.22	338.18	457.42
OF198V21	2.377	1.785	2.542	0.728	0.237	0.118	0.241	0.273	333.12	433.10	319.20	434.29
OF198V21	2.842	1.775	3.056	0.895	0.173	0.131	0.166	0.289	338.16	485.41	319.19	469.87
OF198V21	3.461	0.965	3.780	1.291	0.202	0.160	0.192	0.359	346.00	469.26	328.54	474.63
OF198V21	3.027	0.993	3.337	0.643	0.207	0.239	0.189	0.413	351.26	469.86	339.75	407.12
OF198V22	3.504	2.304	3.720	1.663	0.159	0.183	0.149	0.266	318.65	436.24	306.99	377.37
OF198V22	3.008	1.528	3.215	1.514	0.143	0.185	0.133	0.236	322.70	444.37	306.46	435.66
OF198V22	1.810	1.323	1.834	1.874	0.199	0.375	0.183	0.272	318.86	412.61	305.77	412.67
OF198V22	1.361	1.151	1.324	1.984	0.200	0.291	0.171	0.498	330.74	435.23	316.41	432.76
OF198V24	5.267	9.377	4.632	10.270	2.113	1.945	2.161	1.627	437.60	591.60	417.18	582.39
OF198V24	6.109	9.850	5.567	10.193	2.528	2.508	2.563	2.084	437.13	594.05	416.76	578.27
OF198V24	3.939	7.376	3.481	7.136	2.668	2.549	2.709	2.240	428.71	569.86	408.99	571.52
OF198V24	4.685	5.947	4.362	7.832	2.679	2.414	2.741	2.094	430.35	583.49	409.90	574.16
OF198V25	8.136	0.405	8.962	3.488	0.739	1.186	0.709	0.770	372.42	488.06	357.80	470.69
OF198V25	7.433	0.188	8.148	3.903	0.635	0.891	0.594	0.958	373.72	476.76	359.26	477.63
OF198V25	7.017	0.152	7.592	4.883	0.509	0.505	0.530	0.244	370.60	493.27	360.30	409.16
OF198V25	7.541	0.335	8.119	5.601	0.509	0.626	0.499	0.546	376.36	488.29	362.21	472.78
OF198V25	7.505	0.506	8.166	4.425	0.384	0.746	0.369	0.295	370.64	488.68	360.14	414.32

Italicized & underlined data not used in calculating averages

TIER 1 LDTs

VEH #	CO-UNF	CO-Ph1	CO-Ph2	CO-Ph3	NO-UNF	NO-Ph1	NO-Ph2	NO-Ph3	CO2UNF	CO2Ph1	CO2Ph2	CO2Ph3
Caravan	3.003	0.055	3.332	1.043	0.279	0.459	0.228	0.794	447.52	596.62	428.40	578.11
Caravan	3.355	0.022	3.754	0.808	0.301	0.392	0.247	0.925	448.15	585.31	429.69	578.51
Caravan	2.140	0.093	2.364	0.839	0.283	0.356	0.227	0.930	448.99	599.63	430.29	572.40
Caravan	3.024	0.057	3.379	0.749	0.320	0.369	0.262	1.017	451.46	581.77	432.74	591.54
Caravan	2.051	0.054	2.267	0.815	0.290	0.384	0.241	0.829	456.70	609.24	437.04	590.71
Caravan	4.257	0.041	4.795	0.546	0.323	0.523	0.270	0.843	450.46	599.24	431.17	585.35
OF198T18	0.200	0.141	0.173	0.582	0.509	0.503	0.462	1.117	541.69	723.44	516.82	723.52
OF198T18	0.421	0.111	0.449	0.306	0.382	0.434	0.349	0.757	535.58	718.52	512.78	689.37
OF198T18	1.072	0.222	1.184	0.287	0.592	0.327	0.595	0.765	528.67	693.21	505.63	697.82
OF198T18	1.414	0.915	1.436	1.509	0.227	0.238	0.206	0.479	549.90	727.38	525.69	718.16
OF198T18	3.420	0.450	3.768	1.158	0.150	0.038	0.149	0.271	526.50	721.79	509.22	600.03
OF198T18	4.277	0.362	4.768	1.004	0.257	0.186	0.249	0.411	531.82	717.21	507.14	705.09
OF198T27	0.571	0.348	0.531	1.260	0.440	0.568	0.390	0.992	527.40	685.49	505.95	680.66
OF198T27	0.662	0.386	0.623	1.369	0.415	0.454	0.338	1.374	532.74	696.38	511.40	682.96
OF198T27	1.344	0.650	1.381	1.393	0.507	0.502	0.446	1.289	533.13	704.99	511.88	677.40
OF198T27	1.565	0.767	1.599	1.730	0.584	0.355	0.544	1.264	528.31	700.94	507.37	667.79
OF198T29	*0.151*	*0.119*	*0.143*	*0.289*	*0.530*	*0.309*	*0.522*	*0.802*	*650.92*	*870.30*	*621.55*	*863.74*
OF198T29	0.133	0.101	0.112	0.417	0.326	0.241	0.327	0.390	636.42	867.19	606.43	842.93
OF198T29	0.132	0.109	0.116	0.358	0.406	0.804	0.373	0.528	644.07	889.46	613.24	851.75
OF198T29	0.104	0.107	0.100	0.149	0.361	0.303	0.356	0.467	631.71	874.56	601.12	838.64
OF198T29	0.120	0.200	0.114	0.139	0.366	0.460	0.349	0.520	633.49	869.09	602.97	846.01
OF198T29	0.237	0.078	0.215	0.629	0.457	0.403	0.437	0.752	638.44	866.34	607.95	856.20

Italicized & underlined data not used in calculating averages

HC, CO, NOx & CO2 are reported in grams/mile
PM is reported in milligrams/mile

UNIFIED CYCLE TEST RESULTS for TIER 1

TIER 1 LDVs

VEH #	FE-UNF	FE-Ph1	FE-Ph2	FE-Ph3	T-Temp	PM-UNF
OF198V5	20.54	14.95	21.60	15.27	36.1	0.508
OF198V5	20.47	15.34	21.48	15.16	37.0	1.312
OF198V5	20.49	15.28	21.48	15.42	35.5	0.802
OF198V5	20.60	15.36	21.61	15.35	37.3	0.000
OF198V5	20.64	14.85	21.68	15.70	37.2	1.384
OF198V6	27.69	20.59	29.03	20.76	38.0	2.106
OF198V6	27.62	20.92	28.84	21.25	37.1	1.230
OF198V6	27.56	20.47	28.82	21.19	38.8	0.797
OF198V6	26.97	19.67	28.30	20.49	37.1	1.004
OF198V6	26.97	20.07	28.29	20.20	35.3	0.717
OF198V9	36.71	28.36	37.98	30.30	36.8	2.288
OF198V9	36.05	27.60	37.46	28.86	37.3	1.302
OF198V9	35.91	27.65	37.32	28.50	37.2	1.589
OF198V9	35.32	27.05	36.79	27.56	36.5	0.434
OF198V9	34.66	27.78	35.92	27.52	35.4	0.939
OF198V19	24.88	19.02	26.00	18.82	36.1	2.331
OF198V19	24.53	18.76	25.67	18.39	36.4	1.565
OF198V19	23.93	17.91	24.97	18.85	36.1	1.357
OF198V19	24.12	18.39	25.21	18.38	34.8	1.087
OF198V19	24.53	19.13	25.54	18.99	36.5	1.159
OF198V19	24.95	18.90	26.06	19.23	35.9	0.824
OF198V21	25.41	19.62	26.49	19.65	36.7	2.856
OF198V21	24.99	17.54	26.43	18.17	35.5	1.225
OF198V21	25.22	18.84	26.50	18.58	36.0	0.809
OF198V21	24.89	18.81	25.69	21.70	36.0	2.107
OF198V22	27.36	20.17	28.35	23.34	35.9	0.947
OF198V22	27.09	19.86	28.47	20.25	36.4	0.676
OF198V22	26.64	20.67	27.76	20.62	36.4	0.537
OF198V22	25.74	19.60	26.90	19.65	36.1	0.742
OF198V24	19.89	14.63	20.90	14.81	36.2	7.229
OF198V24	19.85	14.55	20.85	14.92	36.7	3.600
OF198V24	19.70	14.74	20.68	14.70	36.7	1.642
OF198V24	19.58	14.45	20.56	14.61	35.5	0.748
OF198V25	22.22	17.54	23.02	17.96	36.4	1.968
OF198V25	22.21	17.96	23.01	17.70	37.3	1.505
OF198V25	23.22	17.98	23.81	21.20	36.2	1.771
OF198V25	22.82	18.15	23.63	18.36	36.8	1.641
OF198V25	23.17	18.13	23.76	20.97	36.8	0.749

Italicized & underlined data not used in calcul

TIER 1 LDTs

VEH #	FE-UNF	FE-Ph1	FE-Ph2	FE-Ph3	T-Temp	PM-UNF
Caravan	18.94	14.36	19.76	14.77	37.3	1.355
Caravan	18.89	14.64	19.67	14.78	36.6	4.593
Caravan	18.94	14.29	19.74	14.94	37.2	3.375
Caravan	19.44	15.25	20.25	14.96	38.6	1.868
Caravan	19.28	14.56	20.13	14.98	38.2	1.225
Caravan	19.40	14.80	20.21	15.13	33.0	5.845
OF198T18	15.81	11.84	16.58	11.83	40.7	1.632
OF198T18	15.98	11.93	16.69	12.43	36.1	0.000
OF198T18	16.16	12.36	16.89	12.27	36.0	0.000
OF198T18	16.07	12.17	16.80	12.31	36.7	0.000
OF198T18	17.10	12.28	17.22	14.74	36.8	0.660
OF198T18	16.47	12.36	17.24	12.55	35.8	1.222
OF198T27	16.22	12.49	16.91	12.55	36.7	8.769
OF198T27	16.06	12.30	16.73	12.51	36.2	4.043
OF198T27	16.57	12.57	17.26	13.05	37.1	4.508
OF198T27	16.71	12.64	17.40	13.22	36.2	6.843
OF198T29	*13.63*	*10.19*	*14.27*	*10.27*	*36.3*	*3.127*
OF198T29	13.94	10.23	14.63	10.52	36.4	1.265
OF198T29	13.77	9.98	14.47	10.41	36.8	0.601
OF198T29	13.57	9.80	14.26	10.22	36.8	0.000
OF198T29	13.53	9.86	14.21	10.13	37.4	0.803
OF198T29	13.42	9.89	14.09	10.00	38.5	2.602

Italicized & underlined data not used in calcul

HC, CO, NOx & CO2 are reported in gra

PM is reported in milligrams/mile

REPOS TEST RESULTS for TIER 0 VEHICLES

TIER 0 LDVs

Veh #	Year	Make	Model	Cyl	Disp	Odom	Fuel	Type	EC	Trans	Grp/Tier	Run#	HC-REP	CO-REP	NO-REP	CO2-REP	FE-REP	Temp	PM-REP
OF098V1	1993	TOYOTA	CORROLA	4	1.8	20163	PI	Oxy	TWC	AUTO	LDV0	8045	0.252	16.870	0.176	302.94	27.27	34.1	16.492
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20192	PI	Oxy	TWC	AUTO	LDV0	8050	0.169	9.518	0.194	309.43	26.39	33.4	10.514
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20301	PI	NonOxy	TWC	AUTO	LDV0	8055	0.163	8.188	0.183	308.95	27.53	35.1	9.378
OF098V1	1993	TOYOTA	COROLLA	4	1.8	20341	PI	NonOxy	TWC	AUTO	LDV0	8068	0.177	7.811	0.216	304.74	27.95	36.8	4.578
OF098V2	1990	HONDA	ACCORD	4	2.2	92586	PI	NonOxy	TWC	M5	LDV0	8059	0.233	12.229	0.577	301.92	27.57	36.1	15.570
OF098V2	1990	HONDA	ACCORD	4	2.2	92649	PI	NonOxy	TWC	M5	LDV0	8063	0.248	14.387	0.561	280.37	29.22	37.1	ND
OF098V2	1990	HONDA	ACCORD	4	2.2	92688	PI	Oxy	TWC	M5	LDV0	8074	0.262	13.543	0.622	296.70	26.89	37.8	5.108
OF098V2	1990	HONDA	ACCORD	4	2.2	92886	PI	Oxy	TWC	M5	LDV0	8088	0.263	13.604	0.682	294.01	27.11	38.8	4.852
OF098V3	1991	FORD	ESCORT	4	1.8	109295	PI	Oxy	TWC	M5	LDV0	8106	0.153	3.561	1.446	301.42	27.88	40.1	14.277
OF098V3	1991	FORD	ESCORT	4	1.8	109351	PI	Oxy	TWC	M5	LDV0	8116	0.166	4.518	1.559	301.89	27.70	39.1	8.961
OF098V3	1991	FORD	ESCORT	4	1.8	109424	PI	NonOxy	TWC	M5	LDV0	8131	0.221	6.624	1.385	305.14	28.06	38.8	12.191
OF098V3	1991	FORD	ESCORT	4	1.8	109460	PI	NonOxy	TWC	M5	LDV0	8142	0.221	6.521	1.390	307.68	27.85	33.8	8.338
OF098V4	1991	HONDA	CIVIC	4	1.5	110927	TBI	NonOxy	TWC	M4	LDV0	8097	0.444	14.399	3.173	248.60	32.55	38.4	48.497
OF098V4	1991	HONDA	CIVIC	4	1.5	110984	TBI	NonOxy	TWC	M4	LDV0	8111	0.355	11.805	3.005	246.36	33.36	33.8	31.838
OF098V4	1991	HONDA	CIVIC	4	1.5	111030	TBI	Oxy	TWC	M4	LDV0	8120	0.259	9.236	3.101	244.33	33.02	38.1	25.352
OF098V4	1991	HONDA	CIVIC	4	1.5	111118	TBI	Oxy	TWC	M4	LDV0	8127	0.338	12.645	3.122	244.94	32.25	37.1	28.314
OF098V7	1993	FORD	TAURUS	6	3.8	79183	PI	NonOxy	TWC	AUTO	LDV0	8197	0.145	11.243	0.798	353.83	23.86	36.4	2.617
OF098V7	1993	FORD	TAURUS	6	3.8	79241	PI	NonOxy	TWC	AUTO	LDV0	8202	0.146	11.991	0.764	358.53	23.49	38.8	3.116
OF098V7	1993	FORD	TAURUS	6	3.8	79280	PI	Oxy	TWC	AUTO	LDV0	8216	0.124	9.001	1.054	357.12	23.07	38.1	2.871
OF098V7	1993	FORD	TAURUS	6	3.8	79343	PI	Oxy	TWC	AUTO	LDV0	8221	0.124	9.108	1.022	357.01	23.06	43.1	2.880
OF098V20	1992	TOYOTA	CAMRY	4	2.2	88112	PI	Oxy	TWC	AUTO	LDV0	8476	0.060	4.920	0.716	313.38	26.68	36.4	5.474
OF098V20	1992	TOYOTA	CAMRY	4	2.2	88182	PI	Oxy	TWC	AUTO	LDV0	8485	0.053	4.309	0.743	308.40	27.19	36.1	3.825
OF098V20	1992	TOYOTA	CAMRY	4	2.2	88246	PI	NonOxy	TWC	AUTO	LDV0	8502	0.044	2.914	0.698	313.89	27.86	35.8	4.105
OF098V20	1992	TOYOTA	CAMRY	4	2.2	88290	PI	NonOxy	TWC	AUTO	LDV0	8511	0.067	5.917	0.654	313.21	27.50	34.1	3.779
OF098V23	1994	CHEVY	CAVALIER	6	3.1	46994	PI	Oxy	TWC	AUTO	LDV0	8556	0.141	11.586	0.901	321.59	25.20	36.8	61.701
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47104	PI	Oxy	TWC	AUTO	LDV0	8570	0.101	9.183	0.903	320.67	25.56	38.1	27.660
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47207	PI	NonOxy	TWC	AUTO	LDV0	8580	0.166	11.300	0.809	324.57	25.89	37.4	28.094
OF098V23	1994	CHEVY	CAVALIER	6	3.1	47285	PI	NonOxy	TWC	AUTO	LDV0	8594	0.182	13.664	0.654	326.69	25.45	37.1	12.563
OF098V26	1993	SATURN	SC2	4	1.9	34578	PI	Oxy	TWC	AUTO	LDV0	8618	0.075	4.632	0.310	268.15	31.10	37.4	15.424
OF098V26	1993	SATURN	SC2	4	1.9	34635	PI	Oxy	TWC	AUTO	LDV0	8623	0.078	4.938	0.388	268.37	31.02	37.1	10.708
OF098V26	1993	SATURN	SC2	4	1.9	34710	PI	NonOxy	TWC	AUTO	LDV0	8635	0.108	7.419	0.227	274.81	30.94	37.1	16.092
OF098V26	1993	SATURN	SC2	4	1.9	34771	PI	NonOxy	TWC	AUTO	LDV0	8644	0.130	8.696	0.263	274.59	30.74	36.8	19.546

TIER 0 LDVs

Veh #	Year	Make	Model	Cyl	Disp	Odom	Fuel	Type	EC	Trans	Grp/Tier	Run#	HC-REP	CO-REP	NO-REP	CO2-REP	FE-REP	Temp	PM-REP
OF098T11	1993	FORD	EXPLORER	6	4.0	44112	PI	Oxy	TWC	AUTO	LDT0	8287	0.044	2.617	0.604	446.04	19.04	37.1	11.521
OF098T11	1993	FORD	EXPLORER	6	4.0	44161	PI	Oxy	TWC	AUTO	LDT0	8294	0.044	3.196	0.548	451.60	18.77	42.7	9.746
OF098T11	1993	FORD	EXPLORER	6	4.0	44219	PI	Oxy	TWC	AUTO	LDT0	8308	0.038	2.203	0.520	448.92	18.95	38.8	6.859
OF098T11	1993	FORD	EXPLORER	6	4.0	44293	PI	NonOxy	TWC	AUTO	LDT0	8316	0.055	4.716	0.399	454.80	19.19	36.4	7.907
OF098T11	1993	FORD	EXPLORER	6	4.0	44340	PI	NonOxy	TWC	AUTO	LDT0	8326	0.080	7.482	0.461	458.13	18.88	36.1	9.047
OF098T12	1991	CHEVY	BLAZER	6	4.3	122759	TBI	NonOxy	TWC	AUTO	LDT0	8299	1.182	36.927	1.514	437.82	17.76	41.1	27.441
OF098T12	1991	CHEVY	BLAZER	6	4.3	122816	TBI	NonOxy	TWC	AUTO	LDT0	8304	0.649	33.304	1.662	450.65	17.57	45.7	24.522
OF098T12	1991	CHEVY	BLAZER	6	4.3	122887	TBI	Oxy	TWC	AUTO	LDT0	8321	0.478	25.391	1.508	425.07	18.38	36.4	13.752
OF098T12	1991	CHEVY	BLAZER	6	4.3	122941	TBI	Oxy	TWC	AUTO	LDT0	8330	0.532	25.837	1.336	427.20	18.26	36.4	15.609
OF098T15	1993	JEEP	CHEROKEE	6	4.0	36929	PI	NonOxy	TWC	AUTO	LDT0	8342	0.152	5.456	0.463	514.66	16.95	36.8	53.922
OF098T15	1993	JEEP	CHEROKEE	6	4.0	36988	PI	NonOxy	TWC	AUTO	LDT0	8351	0.145	4.986	0.440	506.45	17.24	39.8	57.083
OF098T15	1993	JEEP	CHEROKEE	6	4.0	37061	PI	Oxy	TWC	AUTO	LDT0	8363	0.118	4.270	0.492	ND	ND	40.1	43.111
OF098T15	1993	JEEP	CHEROKEE	6	4.0	37122	PI	Oxy	TWC	AUTO	LDT0	8369	0.104	4.026	0.505	490.37	17.25	41.4	43.688
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63119	TBI	NonOxy	TWC	AUTO	LDT0	8673	0.668	31.736	2.795	583.64	13.96	37.8	13.166
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63179	TBI	NonOxy	TWC	AUTO	LDT0	8678	0.647	31.709	2.662	580.23	14.04	37.8	9.021
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63253	TBI	Oxy	TWC	AUTO	LDT0	8684	0.622	30.038	2.617	575.56	13.72	42.4	7.337
OF098T28	1992	CHEVY	SUBURBAN	8	5.7	63290	TBI	Oxy	TWC	AUTO	LDT0	8689	0.595	25.889	2.849	584.00	13.68	38.1	8.534

% underlined data not used in calculating averages

HC, CO, NOx, CO2 are in grams/mile
PM is reported in milligrams/mile

REPOS Test Results for Tier 1 Vehicles

TIER 1 LDVs

Veh #	Year	Make	Model	Cyl	Disp	Odom	Fuel	Type	EC	Trans	Grp/Tier	Run#	HC-REP	CO-REP	NO-REP	CO2-REP	FE-REP	Temp	PM-REP
OF198V5	1996	FORD	TAURUS	6	3.0	38267	PI	Oxy	TWC	AUTO	LDV1	8159	0.121	11.520	0.297	359.25	22.70	39.1	4.086
OF198V5	1996	FORD	TAURUS	6	3.0	38340	PI	Oxy	TWC	AUTO	LDV1	8168	0.115	11.306	0.273	348.88	23.36	33.1	3.773
OF198V5	1996	FORD	TAURUS	6	3.0	38397	PI	Oxy	TWC	AUTO	LDV1	8173	0.093	8.932	0.287	346.50	23.76	36.4	2.969
OF198V5	1996	FORD	TAURUS	6	3.0	38440	PI	NonOxy	TWC	AUTO	LDV1	8177	0.130	14.056	0.271	354.19	23.56	35.8	2.977
OF198V5	1996	FORD	TAURUS	6	3.0	38480	PI	NonOxy	TWC	AUTO	LDV1	8181	0.110	11.622	0.309	351.66	23.97	35.4	3.174
OF198V6	1996	SATURN	LS2	4	1.9	11978	PI	NonOxy	TWC	M5	LDV1	8186	0.129	3.807	0.229	267.43	32.41	40.4	6.568
OF198V6	1996	SATURN	LS2	4	1.9	12020	PI	NonOxy	TWC	M5	LDV1	8192	0.103	3.296	0.257	272.40	31.93	37.4	3.779
OF198V6	1996	SATURN	LS2	4	1.9	12090	PI	NonOxy	TWC	M5	LDV1	8206	0.121	4.140	0.230	272.23	31.80	35.4	3.051
OF198V6	1996	SATURN	LS2	4	1.9	12179	PI	Oxy	TWC	M5	LDV1	8212	0.073	2.904	0.319	267.78	31.45	39.1	2.836
OF198V6	1996	SATURN	LS2	4	1.9	12239	PI	Oxy	TWC	M5	LDV1	8225	0.099	3.610	0.288	269.56	31.11	37.4	2.710
OF198V9	1995	HONDA	CIVIC	4	1.5	52636	PI	NonOxy	TWC	M5	LDV1	8241	0.147	4.939	0.171	230.57	37.16	38.1	5.792
OF198V9	1995	HONDA	CIVIC	4	1.5	52696	PI	NonOxy	TWC	M5	LDV1	8251	0.115	4.099	0.182	232.17	37.14	37.8	6.517
OF198V9	1995	HONDA	CIVIC	4	1.5	52760	PI	NonOxy	TWC	M5	LDV1	8258	0.138	5.041	0.163	232.92	36.78	36.4	3.523
OF198V9	1995	HONDA	CIVIC	4	1.5	52837	PI	Oxy	TWC	M5	LDV1	8267	0.115	3.805	0.164	231.74	36.01	37.4	3.336
OF198V9	1995	HONDA	CIVIC	4	1.5	52884	PI	Oxy	TWC	M5	LDV1	8281	0.116	3.518	0.192	231.15	36.17	36.8	2.193
OF198V19	1997	CHEVY	CAVALIER	4	2.4	22286	PI	Oxy	TWC	AUTO	LDV1	8449	0.038	2.264	0.301	303.29	27.93	40.8	6.087
OF198V19	1997	CHEVY	CAVALIER	4	2.4	22344	PI	Oxy	TWC	AUTO	LDV1	8458	0.039	2.412	0.419	308.14	27.47	36.1	5.282
OF198V19	1997	CHEVY	CAVALIER	4	2.4	22390	PI	Oxy	TWC	AUTO	LDV1	8463	0.048	3.034	0.272	312.88	26.98	37.4	5.791
OF198V19	1997	CHEVY	CAVALIER	4	2.4	22467	PI	NonOxy	TWC	AUTO	LDV1	8469	0.053	4.444	0.096	313.52	27.68	36.4	3.349
OF198V19	1997	CHEVY	CAVALIER	4	2.4	22526	PI	NonOxy	TWC	AUTO	LDV1	8480	0.063	4.925	0.092	311.78	27.76	37.1	2.893
OF198V19	1997	CHEVY	CAVALIER	4	2.4	22950	PI	NonOxy	TWC	AUTO	LDV1	8489	0.066	4.444	0.127	304.95	28.43	37.8	3.779
OF198V21	1997	TOYOTA	CAMRY	4	2.2	23045	PI	Oxy	TWC	M5	LDV1	8497	0.153	5.333	0.196	290.50	28.64	37.4	4.793
OF198V21	1997	TOYOTA	CAMRY	4	2.2	23104	PI	Oxy	TWC	M5	LDV1	8507	0.123	5.508	0.200	294.20	28.27	35.4	2.890
OF198V21	1997	TOYOTA	CAMRY	4	2.2	23165	PI	NonOxy	TWC	M5	LDV1	8517	0.130	5.192	0.224	302.18	28.56	36.8	3.302
OF198V21	1997	TOYOTA	CAMRY	4	2.2	23209	PI	NonOxy	TWC	M5	LDV1	8529	0.137	6.266	0.204	295.89	28.99	36.8	3.530
OF198V22	1996	HONDA	ACCORD	4	2.2	29885	PI	NonOxy	TWC	M5	LDV1	8524	0.069	4.153	0.071	293.01	29.61	37.1	4.767
OF198V22	1996	HONDA	ACCORD	4	2.2	29930	PI	NonOxy	TWC	M5	LDV1	8533	0.065	4.603	0.084	293.61	29.48	36.8	3.882
OF198V22	1996	HONDA	ACCORD	4	2.2	29988	PI	Oxy	TWC	M5	LDV1	8539	0.065	4.166	0.125	290.61	28.83	37.1	4.865
OF198V22	1996	HONDA	ACCORD	4	2.2	30115	PI	Oxy	TWC	M5	LDV1	8544	0.103	7.929	0.000	304.73	27.00	36.8	7.976
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43817	PI	NonOxy	TWC	AUTO	LDV1	8561	0.106	3.354	2.516	369.75	23.64	34.1	24.038
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43877	PI	NonOxy	TWC	AUTO	LDV1	8566	0.040	2.976	2.769	372.48	23.52	38.4	22.807
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43936	PI	Oxy	TWC	AUTO	LDV1	8585	0.044	2.739	2.789	357.19	23.71	38.8	5.207
OF198V24	1995	PONTIAC	BONNEVILLE	6	3.8	43995	PI	Oxy	TWC	AUTO	LDV1	8590	0.048	3.401	2.993	365.29	23.12	38.1	7.077
OF198V25	1996	SUBARU	LEGACY	4	2.2	19389	PI	Oxy	TWC	AUTO	LDV1	8600	0.277	18.424	0.401	347.70	22.71	36.8	20.827
OF198V25	1996	SUBARU	LEGACY	4	2.2	19446	PI	Oxy	TWC	AUTO	LDV1	8605	0.248	18.276	0.318	346.54	22.80	37.1	16.464
OF198V25	1996	SUBARU	LEGACY	4	2.2	19521	PI	NonOxy	TWC	AUTO	LDV1	8613	0.278	18.184	0.228	350.21	23.38	37.4	10.641
OF198V25	1996	SUBARU	LEGACY	4	2.2	19580	PI	NonOxy	TWC	AUTO	LDV1	8628	0.275	15.200	0.325	351.09	23.61	36.4	14.767
OF198V25	1996	SUBARU	LEGACY	4	2.2	19638	PI	NonOxy	TWC	AUTO	LDV1	8640	0.258	17.212	0.324	352.75	23.32	37.1	11.801

TIER 1 LDTs

Veh #	Year	Make	Model	Cyl	Disp	Odom	Fuel	Type	EC	Trans	Grp/Tier	Run#	HC-REP	CO-REP	NO-REP	CO2-REP	FE-REP	Temp	PM-REP
OF198T0	1997	DODGE	CARAVAN	6	3.0	7863	PI	Oxy	TWC	AUTO	LDT1	8092	0.212	12.871	0.130	398.04	20.46	44.4	10.765
OF198T0	1997	DODGE	CARAVAN	6	3.0	7899	PI	Oxy	TWC	AUTO	LDT1	8102	0.170	8.493	0.215	397.44	20.84	36.4	7.662
OF198T0	1997	DODGE	CARAVAN	6	3.0	7995	PI	Oxy	TWC	AUTO	LDT1	8138	0.217	10.378	0.130	395.58	20.78	38.1	11.816
OF198T0	1997	DODGE	CARAVAN	6	3.0	8040	PI	NonOxy	TWC	AUTO	LDT1	8148	0.231	13.209	0.135	402.04	20.95	42.7	9.802
OF198T0	1997	DODGE	CARAVAN	6	3.0	8079	PI	NonOxy	TWC	AUTO	LDT1	8153	0.177	7.996	0.169	401.62	21.40	42.4	5.727
OF198T0	1997	DODGE	CARAVAN	6	3.0	8184	PI	NonOxy	TWC	AUTO	LDT1	8163	0.224	13.569	0.189	400.22	20.01	39.1	8.745
OF198T18	1996	FORD	EXPLORER	6	4.0	33724	PI	Oxy	TWC	AUTO	LDT1	8400	0.048	2.931	0.701	469.25	18.09	36.8	14.719
OF198T18	1996	FORD	EXPLORER	6	4.0	33765	PI	Oxy	TWC	AUTO	LDT1	8410	0.042	2.222	0.538	465.81	18.26	36.8	7.662
OF198T18	1996	FORD	EXPLORER	6	4.0	33840	PI	Oxy	TWC	AUTO	LDT1	8420	0.032	1.853	0.798	469.35	18.15	39.1	8.473
OF198T18	1996	FORD	EXPLORER	6	4.0	33912	PI	NonOxy	TWC	AUTO	LDT1	8437	0.060	4.964	0.459	478.14	18.26	38.8	12.553
OF198T18	1996	FORD	EXPLORER	6	4.0	33965	PI	NonOxy	TWC	AUTO	LDT1	8442	0.037	2.673	0.206	472.14	18.63	40.4	5.733
OF198T18	1996	FORD	EXPLORER	6	4.0	34023	PI	NonOxy	TWC	AUTO	LDT1	8454	0.030	2.202	0.277	470.75	18.71	41.4	9.299
OF198T27	1996	CHEVY	BLAZER	6	4.3	42610	PI	Oxy	TWC	AUTO	LDT1	*8651*	*0.103*	*5.117*	*0.372*	*474.06*	*17.74*	*36.4*	*132.170*
OF198T27	1996	CHEVY	BLAZER	6	4.3	42675	PI	Oxy	TWC	AUTO	LDT1	8656	0.121	6.340	0.449	477.45	17.58	38.8	29.377
OF198T27	1996	CHEVY	BLAZER	6	4.3	42738	PI	NonOxy	TWC	AUTO	LDT1	8662	0.118	7.058	0.451	478.36	18.12	38.4	29.220
OF198T27	1996	CHEVY	BLAZER	6	4.3	42790	PI	NonOxy	TWC	AUTO	LDT1	8667	0.088	4.097	0.313	469.52	18.64	38.4	17.590
OF198T29	*1997*	*FORD*	*EXPEDITION*	*8*	*5.4*	*14013*	*PI*	*NonOxy*	*2TWC*	*AUTO*	*LDT1*	*8695*	*0.019*	*1.352*	*0.540*	*594.07*	*14.89*	*36.4*	*17.344*
OF198T29	1997	FORD	EXPEDITION	8	5.4	14076	PI	NonOxy	2TWC	AUTO	LDT1	8701	0.021	1.901	0.458	552.39	15.98	37.4	4.870
OF198T29	1997	FORD	EXPEDITION	8	5.4	14133	PI	NonOxy	2TWC	AUTO	LDT1	8706	0.015	1.348	0.435	551.33	16.03	37.4	5.419
OF198T29	1997	FORD	EXPEDITION	8	5.4	14181	PI	Oxy	2TWC	AUTO	LDT1	8712	0.025	2.550	0.471	546.96	15.56	37.1	5.927
OF198T29	1997	FORD	EXPEDITION	8	5.4	14258	PI	Oxy	2TWC	AUTO	LDT1	8717	0.020	1.908	0.376	549.11	15.53	37.1	6.460
OF198T29	1997	FORD	EXPEDITION	8	5.4	14314	PI	Oxy	2TWC	AUTO	LDT1	8722	0.022	1.775	0.477	552.98	15.42	37.1	6.953

Italicized & underlined data not used in calculating averages

HC, CO, NOx, CO2 are in grams/mile
PM is reported in milligrams/mile

APPENDIX G

TEST STATISTICS for the

FEDERAL TEST PROCEDURE, UNIFIED CYCLE,

and REPO5

HC STATISTICS

Tier 0 Vehicles		FTPHC	Phase1HC	Phase2HC	Phase3HC	UNIFPh1HC	UNIFPh2HC	UNIFPh3HC	RepHC
Cars(8)	NonOxyMean:	0.721	2.636	0.185	0.289	0.347	0.173	0.570	0.191
	OxyMean:	0.607	2.208	0.154	0.251	0.346	0.156	0.394	0.164
	%Change:	-15.8%	-16.2%	-16.8%	-13.1%	-0.3%	-9.8%	-30.9%	-14.1%
	95% CI:	**-0.196,-0.033**	**-0.757,-0.098**	-0.069,0.007	-0.091,0.016	-0.204,0.203	-0.046,0.013	-0.370,0.019	-0.066,0.013
	90% CI:	**-0.180,-0.050**	**-0.690,-0.164**	**-0.061,-0.001**	-0.080,0.005	-0.163,0.162	-0.040,0.007	**-0.331,-0.020**	-0.058,0.005
Trucks(4)	NonOxyMean:	1.018	3.096	0.222	0.940	0.401	0.287	0.781	0.448
	OxyMean:	0.82	2.797	0.22	0.458	0.348	0.274	0.669	0.365
	%Change:	-19.4%	-9.7%	-0.9%	-51.3%	-13.2%	-4.5%	-14.3%	-18.5%
	95% CI:	-0.793,0.398	-1.221,2.258	-0.048,0.044	-2.031,1.067	-0.171,0.066	-0.109,0.083	-0.494,0.270	-0.428,0.166
	90% CI:	-0.638,0.243	-1.029,1.065	-0.036,0.032	-1.628,0.664	-0.140,0.035	-0.084,0.058	-0.395,0.170	-0.351,0.088
Total(12)	NonOxyMean:	0.820	2.789	0.197	0.506	0.365	0.211	0.640	0.277
	OxyMean:	0.678	2.405	0.176	0.32	0.347	0.196	0.486	0.215
	%Change:	-17.3%	-13.8%	-10.7%	-36.8%	-4.9%	-7.1%	-24.1%	-22.4%
	95% CI:	**-0.280,-0.005**	**-0.641,-0.128**	-0.048,0.005	-0.542,0.170	-0.145,0.109	-0.042,0.012	**-0.299,-0.010**	-0.136,0.013
	90% CI:	**-0.253,-0.031**	**-0.593,-0.176**	**-0.043,-0.000**	-0.474,0.103	-0.121,0.085	-0.037,0.007	**-0.0271,-0.037**	**-0.122,-0.001**
Tier 1 Vehicles									
Cars(8)	NonOxyMean:	0.332	1.365	0.03	0.119	0.122	0.102	0.254	0.122
	OxyMean:	0.286	1.160	0.033	0.101	0.115	0.085	0.176	0.11
	%Change:	-13.9%	-15.0%	10.0%	-15.1%	-5.7%	-16.7%	-30.7%	-9.8%
	95% CI:	**-0.073,-0.018**	**-0.319,-0.090**	-0.009,0.016	**-0.036,-0.002**	-0.053,0.039	-0.038,0.003	-0.173,0.019	-0.025,0.002
	90% CI:	**-0.068,-0.024**	**-0.296,-0.113**	-0.007,0.014	**-0.032,-0.005**	-0.044,0.030	**-0.034,-0.001**	**-0.154,-0.001**	**-0.022,-0.001**
Trucks(4)	NonOxyMean:	0.331	1.469	0.012	0.071	0.051	0.058	0.102	0.094
	OxyMean:	0.307	1.323	0.021	0.080	0.044	0.047	0.095	0.094
	%Change:	-7.3%	-9.9%	75.0%	12.7%	-13.7%	-19.0%	-6.9%	0.0%
	95% CI:	-0.068,0.021	-0.375,0.082	-0.004,0.022	-0.019,0.038	-0.030,0.015	-0.039,0.017	-0.038,0.023	-0.014,0.014
	90% CI:	-0.056,0.010	-0.316,0.023	-0.001,0.019	-0.012,0.031	-0.024.0.009	-0.032,0.010	-0.030,0.015	-0.010,0.010
Total(12)	NonOxyMean:	0.331	1.4	0.024	0.103	0.098	0.087	0.203	0.112
	OxyMean:	0.293	1.215	0.029	0.094	0.091	0.072	0.149	0.105
	%Change:	-11.5%	-13.2%	20.8%	-8.7%	-7.1%	-17.2%	-26.6%	-6.3%
	95% CI:	**-0.059,-0.018**	**-0.272,-0.099**	-0.003,0.014	-0.024,0.006	-0.035,0.021	**-0.030,-0.001**	-0.116,0.009	-0.002,0.017
	90% CI:	**-0.055,-0.022**	**-0.255,-0.115**	-0.001,0.012	-0.021,0.003	-0.030,0.016	**-0.027,-0.004**	**-0.105,-0.003**	-0.000,0.015
High Emitters (6)									
	NonOxyMean:	8.443	15.140	7.897	4.433	5.512	4.126	9.002	3.246
	OxyMean:	6.784	12.859	6.091	3.525	3.957	3.549	5.539	2.185
	%Change:	-19.6%	-15.1%	-22.9%	-20.5%	-28.2%	-14.0%	-38.5%	-19.2%
	95% CI:	0.262,-3.579	1.284,-5.846	0.582,-4.193	**-0.309,-1.507**	1.359,-4.470	**-0.372,-0.780**	1.105,-8.030	**-0.289,-0.959**
	90% CI:	**-0.153,-3.163**	0.513,-5.075	0.066,-3.676	**-0.438,-1.378**	0.729,-3.840	**-0.416,-0.736**	0.118,-7.042	**-0.362,-0.886**

Cells in **BOLD** indicate statistical significance

CO STATISTICS

		FTPCO	Phase1CO	Phase2CO	Phase3CO	UNIFPh1CO	UNIFPh2CO	UNIFPh3CO	RepCO
Tier 0 Vehicles									
Cars(8)	**NonOxyMean:**	11.308	40.975	3.443	3.758	5.956	4.909	7.077	9.695
	OxyMean:	10.328	37.621	3.070	3.395	6.523	4.700	4.680	8.824
	%Change:	-8.7%	-8.2%	-10.8%	-9.7%	9.5%	-4.3%	-33.9%	-9.0%
	95% CI:	-2.528,0.567	-9.881,3.173	-0.762,0.016	-1.042,0.317	-1.371,2.505	-1.284,0.861	**-4.105,-0.512**	-3.199,1.457
	90% CI:	-2.215,0.254	-8.560,1.852	**-0.684,-0.063**	-0.905,0.180	-0.979,2.113	-1.067,0.644	**-3.741,-0.875**	-2.728,0.986
Trucks(4)	**NonOxyMean:**	18.214	60.634	4.152	12.556	8.334	9.933	14.106	19.540
	OxyMean:	15.674	56.468	4.094	6.644	7.484	9.483	10.870	15.100
	%Change:	-13.9%	-6.9%	-1.4%	-47.1%	-10.2%	-4.5%	-22.9%	-22.7%
	95% CI:	-10.410,5.331	-17.473,9.141	-1.081,0.965	-23.204,11.378	-4.325,2.625	-6.693,5.793	-9.326,3.088	-10.133,1.252
	90% CI:	-3.284,8.364	-5.680,14.013	-0.699,0.815	-6.882,18.707	-3.421,1.722	-5.069,4.170	-7.712,1.474	**-8.652,-0.228**
Total(12)	**NonOxyMean:**	13.610	47.528	3.679	6.690	6.749	6.584	9.420	12.976
	OxyMean:	12.110	43.093	3.410	4.478	6.843	6.293	6.841	10.916
	%Change:	-11.0%	-9.3%	-7.3%	-33.1%	1.4%	-4.4%	-27.4%	-15.9%
	95% CI:	-3.466,0.465	-8.486,1.236	-0.603,0.067	-6.267,1.842	-1.361,1.551	-1.758,1.176	**-4.299,-0.858**	-4.229,0.107
	90% CI:	-3.092,0.092	-7.563,0.313	-0.539,0.003	-5.497,1.072	-1.085,1.274	-1.480,0.898	**-3.972,-1.185**	**-3.817,-0.305**
Tier 1 Vehicles									
Cars(8)	**NonOxyMean:**	4.678	15.832	1.364	2.494	2.729	3.807	3.407	7.003
	OxyMean:	3.938	14.132	1.028	1.713	2.064	3.200	2.702	6.620
	%Change:	-15.8%	-10.7%	-24.6%	-31.3%	-24.4%	-15.9%	-20.7%	-5.5%
	95% CI:	**-1.286,-0.194**	-3.661,0.260	-0.924,0.252	**-1.444,-0.117**	-1.615,0.286	-1.498,0.288	-1.534,0.124	-1.589,0.824
	90% CI:	**-1.175,-0.305**	**-3.264,-0.137**	-0.805,0.133	**-1.310,-0.251**	-1.423,0.093	-1.317,0.107	**-1.366,-0.043**	-1.345,0.580
Trucks(4)	**NonOxyMean:**	2.344	10.022	0.136	0.706	0.360	2.100	0.969	5.520
	OxyMean:	2.511	11.143	0.10	0.537	0.178	1.118	0.727	5.181
	%Change:	7.1%	11.2%	-26.5%	-23.9%	-50.6%	-46.8%	-25.0%	-6.1%
	95% CI:	-0.718,1.051	-2.710,4.952	-0.127,0.053	-0.546,0.208	-0.548,0.183	-2.927,0.959	-0.931,0.447	-1.530,0.855
	90% CI:	-0.488,0.821	-1.714,3.956	-0.103,0.029	-0.448,0.110	-0.453,0.088	-2.422,0.454	-0.752,0.268	-1.219,0.545
Total(12)	**NonOxyMean:**	3.900	13.895	0.955	1.898	1.940	3.239	2.594	6.508
	OxyMean:	3.463	13.135	0.719	1.321	1.435	2.507	2.044	6.141
	%Change:	-11.2%	-5.5%	-24.7%	-30.4%	-26.0%	-22.6%	-21.2%	-5.6%
	95% CI:	-0.913,0.038	-2.451,0.931	-0.601,0.134	**-1.031,-0.123**	-1.106,0.098	**-1.421,-0.042**	**-1.095,-0.006**	-1.143,0.408
	90% CI:	**-0.823,-0.053**	-2.154,0.601	-0.536,0.064	**-0.945,-0.209**	**-0.992,-0.016**	**-1.290,-0.173**	**-0.991,-0.110**	-0.995,0.261
High Emitters (6)									
	NonOxyMean:	138.244	174.141	154.269	81.066	113.091	96.829	135.384	102.014
	OxyMean:	114.902	151.717	124.219	69.646	91.813	87.639	99.451	72.145
	%Change:	-16.9%	-12.9%	-19.5%	-14.1%	-18.8%	-9.5%	-26.5%	-29.3%
	95% CI:	0.957,-47.642	11.366,-56.213	2.566,-62.665	**-3.513,-19.327**	43.824,-86.381	**-0.027,-18.354**	**-5.427,-66.440**	**-2.926,-27.956**
	90% CI:	**-4.298,-42.387**	4.059,-48.906	**-4.487,-55.611**	**-5.223,-17.617**	29.745,-72.302	**-2.009,-16.372**	**-12.024,-59.842**	**-5.632,-25.249**

Cells in **BOLD** indicate statistical significance

NOx STATISTICS

		FTPNOX	Phase1NOX	Phase2NOX	Phase3NOX	UNIFPh1NOX	UNIFPh2NOX	UNIFPh3NOX	RepNOX
Tier 0 Vehicles									
Cars(8)	**NonOxyMean:**	0.937	1.262	0.732	1.080	1.367	1.057	1.532	0.960
	OxyMean:	0.960	1.205	0.763	1.146	1.452	1.127	1.604	1.059
	%Change:	2.5%	-4.5%	4.2%	6.1%	6.2%	6.6%	4.7%	10.3%
	95% CI*:	-0.054,0.100	-0.186,0.072	-0.057,0.119	-0.011,0.143	-0.188,0.359	-0.022,0.160	-0.037,0.180	**-0.171,-0.027**
	90%CI:**	-0.039,0.084	-0.160,0.046	-0.039,0.101	**0.005,0.121**	-0.133,0.303	-0.003,0.142	-0.015,0.168	**-0.156,-0.042**
Trucks(4)	**NonOxyMean:**	1.298	2.218	0.852	1.439	2.019	1.498	2.118	1.300
	OxyMean:	1.263	2.089	0.829	1.456	1.954	1.480	2.046	1.303
	%Change:	-2.7%	-5.8%	-2.7%	1.2%	-3.2%	-1.2%	-3.4%	0.2%
	95% CI*:	-0.171,0.101	-0.456,0.196	-0.108,0.062	-0.124,0.167	-0.532,0.404	-0.223,0.186	-0.611,0.367	-0.194,0.200
	90%CI:**	-0.136,0.066	-0.370,0.112	-0.086,0.040	-0.087,0.121	-0.410,0.262	-0.170,0.132	-0.397,0.253	-0.194,0.200
Total(12)	**NonOxyMean:**	1.057	1.580	0.772	1.199	1.584	1.204	1.727	1.073
	OxyMean:	1.061	1.499	0.785	1.249	1.619	1.244	1.751	1.140
	%Change:	0.4%	-5.1%	1.7%	4.2%	2.2%	3.3%	1.4%	6.2%
	95% CI*:	-0.061,0.054	-0.026,0.187	-0.072,0.046	-0.107,0.008	-0.163,0.234	-0.036,0.115	-0.098,0.146	**0.000,0.134**
	90%CI:**	-0.050,0.043	-0.006,0.167	-0.061,0.035	**-0.096,-0.003**	-0.125,0.196	-0.021,0.101	-0.075,0.122	**0.013,0.122**
Tier 1 Vehicles									
Cars(8)	**NonOxyMean:**	0.360	0.762	0.167	0.422	0.686	0.605	0.601	0.504
	OxyMean:	0.430	0.884	0.218	0.485	0.665	0.598	0.727	0.576
	%Change:	19.4%	16.0%	30.5%	14.9%	13.5%	18.4%	21.0%	14.3%
	95% CI*:	**0.009,0.130**	**0.001,0.244**	**0.002,0.100**	**0.002,0.125**	-0.079,0.236	-0.020,0.206	-0.038,0.289	-0.018,0.162
	90%CI:**	**0.021,0.118**	**0.025,0.219**	**0.012,0.090**	**0.014,0.113**	-0.047,0.205	**0.003,0.183**	-0.005,0.256	**0.000,0.144**
Trucks(4)	**NonOxyMean:**	0.456	1.136	0.225	0.378	0.383	0.247	0.755	0.327
	OxyMean:	0.550	1.285	0.324	0.420	0.431	0.362	0.882	0.422
	%Change:	20.6%	13.1%	44.0%	11.1%	12.5%	46.6%	16.8%	29.1%
	95% CI*:	-0.275,0.463	-0.461,0.759	-0.234,0.432	-0.247,0.331	-0.223,0.319	-0.248,0.477	-0.286,0.540	-0.192,0.382
	90%CI:**	-0.179,0.367	-0.302,0.601	-0.147,0.346	-0.171,0.266	-0.152,0.249	-0.154,0.383	-0.179,0.432	-0.117,0.308
Total(12)	**NonOxyMean:**	0.392	0.886	0.186	0.407	0.518	0.419	0.663	0.445
	OxyMean:	0.470	1.018	0.253	0.464	0.587	0.519	0.778	0.525
	%Change:	19.9%	14.9%	36.0%	14.0%	13.3%	23.9%	19.1%	18.0%
	95% CI*:	-0.009,0.164	-0.016,0.278	-0.011,0.145	-0.015,0.128	-0.043,0.180	-0.003,0.203	-0.006,0.258	-0.162,0.162
	90%CI:**	**0.008,0.147**	**0.001,0.251**	**0.004,0.130**	-0.002,0.115	-0.022,0.159	**0.017,0.183**	**0.019,0.233**	**0.014,0.146**
High Emitters (6)									
	NonOxyMean:	0.612	0.786	0.376	0.926	1.076	0.753	1.150	0.906
	OxyMean:	0.752	1.039	0.493	1.030	1.092	0.719	1.200	0.695
	%Change:	22.8%	32.2%	30.9%	11.2%	1.5%	-4.6%	4.3%	-7.9%
	95% CI*:	0.344,-0.064	0.516,-0.010	0.409,-0.177	0.315,-0.107	0.214,-0.183	0.150,-0.220	0.518,-0.419	0.090,-0.234
	90% CI:**	0.300,-0.020	**0.459,0.047**	0.346,-0.113	0.269,-0.061	0.171,-0.140	0.110,-0.180	0.417,-0.317	0.066,-0.199

Cells in **BOLD** indicate statistical significance

PM STATISTICS

		FTPPM	Phase1PM	Phase2PM	Phase3PM	UNIFPh1PM	RepPM
Tier 0 Vehicles							
Cars(8)	**NonOxyMean:**	10.3	42.8	1.6	2.4	3.9	14.7
	OxyMean:	7.0	24.7	2.1	2.9	5.2	15.1
	%Change:	-32.2%	-42.4%	32.7%	23.8%	32.0%	2.4%
	95% CI:	**-5.640,-1.010**	**-31.519,-4.802**	-0.833,1.884	-1.089,2.212	-4.200,6.704	-9.344,10.047
	90% CI:	**-5.171,-1.479**	**-28.816,-7.506**	-0.558,1.609	-0.755,1.878	-3.096,5.600	-7.382,8.084
Trucks(4)	**NonOxyMean:**	19.0	64.8	3.3	13.7	7.0	25.3
	OxyMean:	9.9	37.1	1.8	4.6	5.5	18.8
	%Change:	-47.9%	-42.8%	-45.0%	-66.7%	-20.5%	-25.4%
	95% CI:	-26.143,7.986	-79.028,18.347	**-2.890,-0.073**	-35.771,17.462	-10.945,8.081	-16.486,3.655
	90% CI:	-21.705,3.548	-61.888,6.355	**-2.523,-0.439**	-28.849,10.540	-8.471,5.607	-16.486,3.655
Total(12)	**NonOxyMean:**	13.2	50.2	2.2	6.1	4.9	18.3
	OxyMean:	8.0	28.8	2.0	3.5	5.3	16.3
	%Change:	-39.7%	-42.6%	-6.6%	-43.6%	7.3%	-10.4%
	95% CI:	**-9.501,-0.984**	**-34.364,-8.361**	-1.225,0.938	-9.133,3.779	-3.604,4.319	-8.519,4.710
	90% CI:	**-8.693,-1.793**	**-31.895,-10.830**	-1.020,0.732	-7.907,2.553	-2.852,3.567	-7.263,3.454
Tier 1 Vehicles							
Cars(8)	**NonOxyMean:**	4.5	18.3	0.7	1.3	1.7	7.5
	OxyMean:	3.4	12.8	0.7	1.3	1.2	6.2
	%Change:	-25.3%	-29.9%	-1.6%	-0.2%	-29.6%	-16.4%
	95% CI:	**-2.096,-0.185**	**-9.451,-1.491**	-0.910,0.887	-1.356,1.352	-1.864,0.837	-7.125,4.673
	90% CI:	**-1.903,-0.378**	**-8.645,-2.296**	-0.728,0.706	-1.082,1.078	-1.591,0.564	-5.931,3.479
Trucks(4)	**NonOxyMean:**	6.6	28.4	0.5	1.6	2.6	12.5
	OxyMean:	4.7	19.4	0.7	1.2	2.8	14.0
	%Change:	-28.4%	-31.5%	45.7%	-28.7%	9.6%	12.7%
	95% CI:	-5.128,1.388	-22.396,4.488	-0.633,1.085	-2.100,1.157	-0.306,0.795	-1.050,6.226
	90% CI:	-4.280,0.541	-18.900,0.992	-0.410,0.861	-1.677,0.734	-0.163,0.652	-0.104,5.280
Total(12)	**NonOxyMean:**	5.2	21.7	0.6	1.4	2.0	8.8
	OxyMean:	3.8	15.0	0.7	1.3	1.7	8.8
	%Change:	-26.6%	-30.6%	11.2%	-8.1%	-13.0%	0.5%
	95% CI:	**-2.317,-0.457**	**-10.480,-2.784**	-0.512,0.648	-1.062,0.745	-1.124,0.602	-3.813,3.904
	90% CI:	**-2.135,-0.633**	**-9.773,-3.490**	-0.402,0.538	-0.890,0.573	-0.960,0.438	-3.080,3.171
High Emitters (6)							
	NonOxyMean:	146.904	297.889	142.570	41.308	43.443	54.318
	OxyMean:	51.978	131.824	30.048	33.190	28.057	28.613
	%Change:	-64.6%	-55.7%	-78.9%	-19.7%	-35.4%	-36.8%
	95% CI:	76.662,-266.514	63.101,-395.233	103.903,-328.947	54.302,-70.539	9.892,-40.665	1.637,-41.602
	90% CI:	39.555,-229.406	13.542,-345.674	57.099,-282.143	40.803,-57.040	4.426,-35.198	**-3.038,-36.927**

Cells in **BOLD** indicate statistical significance

MPG STATISTICS

		FTPMPG	Phase1MPG	Phase2MPG	Phase3MPG	UNIFPh1MPG	UNIFPh2MPG	UNIFPh3MPG	RepMPG
Tier 0 Vehicles									
Cars(8)	**NonOxyMean:**	24.8	21.0	24.9	28.5	19.2	26.7	19.7	28.1
	OxyMean:	24.3	20.8	24.4	27.8	18.9	26.0	19.7	27.6
	%Change:	-2.0%	-1.2%	-2.1%	-2.4%	-1.5%	-2.5%	0.0%	-1.9%
	95% CI*:	**-0.910,-0.070**	-0.803,0.305	**-0.922,-0.126**	**-1.224,-0.132**	-0.671,0.115	**-1.152,-0.194**	-0.418,0.498	**-0.944,-0.109**
	90%CI:**	**-0.825,-0.155**	-0.691,0.193	**-0.841,-0.206**	**-1.114,-0.243**	-0.592,0.035	**-1.055,-0.291**	-0.325,0.406	**-0.860,-0194**
Trucks(4)	**NonOxyMean:**	15.1	13.1	15.4	16.7	11.7	16.2	12.0	17.0
	OxyMean:	15.0	12.9	15.2	16.8	11.8	16.1	12.3	17.0
	%Change:	-1.0%	-1.9%	-1.3%	0.6%	0.5%	-1.0%	2.1%	0.6%
	95% CI*:	-0.516,0.273	-0.603,0.312	**-0.304,-0.089**	-0.968,1.133	-0.453,0.567	-0.324,0.028	-0.823,1.335	-0.561,0.758
	90% CI:**	-0.413,0.170	-0.484,0.193	**-0.276,-0.117**	-0.695,0.859	-0.320,0.434	**-0.279,-0.017**	-0.543,1.054	-0.389,0.586
Total(12)	**NonOxyMean:**	21.6	18.4	21.7	24.6	16.7	23.2	17.1	24.4
	OxyMean:	21.2	18.2	21.3	24.1	16.5	22.7	17.2	24.1
	%Change:	-1.7%	-1.4%	-1.9%	-1.4%	-1.0%	-2.1%	0.6%	-1.1%
	95% CI*:	**-0.659,-0.075**	-0.566,0.137	**-0.679,-0.151**	-0.890,0.040	-0.449,0.116	**-0.835,-0.161**	-0.253,0.478	-0.668,0.032
	90%CI:**	**-0.604,-0.130**	-0.499,0.070	**-0.628,-0.201**	**-0.802,-0.048**	-0.395,0.062	**-0.771,-0.225**	-0.184,0.408	**-0.602,-0.035**
Tier 1 Vehicles									
Cars(8)	**NonOxyMean:**	24.8	21.8	24.7	28.0	19.2	26.6	20.2	28.3
	OxyMean:	24.6	21.6	24.4	27.8	19.0	26.1	19.2	27.6
	%Change:	-1.0%	-0.9%	-1.2%	-0.6%	-1.2%	-1.7%	-5.1%	-2.4%
	95% CI*:	**-0.462,-0.037**	**-0.381,-0.016**	**-0.606,-0.012**	-0.462,0.142	-0.488,0.026	**-0.918,-0.007**	**-1.722,-0.345**	**-0.306,-1.065**
	90%CI.:**	**-0.419,-0.080**	**-0.345,-0.053**	**-0.546,-0.072**	-0.401,0.081	**-0.436,-0.026**	**-0.826,-0.099**	**-1.582,-0.484**	**-0.383,-0.989**
Trucks(4)	**NonOxyMean:**	16.2	14.2	16.2	18.2	12.5	17.3	13.0	18.4
	OxyMean:	15.9	13.9	15.9	17.8	12.2	16.9	12.4	18.0
	%Change:	-1.8%	-1.7%	-1.7%	-2.1%	-2.3%	-2.5%	-4.2%	-2.3%
	95% CI*:	**-0.325,-0.259**	**-0.342,-0.152**	**-0.324,-0.223**	**-0.600,-0.176**	**-0.451,-0.112**	**-0.549,-0.308**	-1.122,0.031	**-0.838,-0.001**
	90%CI:**	**-0.317,-0.268**	**-0.317,-0.176**	**-0.311,-0.236**	**-0.545,-0.231**	**-0.407,-0.156**	**-0.518,-0.339**	**-0.972,-0.119**	**-0.729,-0.110**
Total(12)	**NonOxyMean:**	21.9	19.2	21.9	24.7	17.0	23.5	17.8	25.0
	OxyMean:	21.7	19.0	21.6	24.5	16.7	23.1	16.9	24.4
	%Change:	-1.2%	-1.1%	-1.4%	-1.0%	-1.5%	-1.9%	-4.9%	-2.4%
	95% CI*:	**-0.394,-0.134**	**-0.328,-0.102**	**-0.478,-0.116**	**-0.438,-0.034**	**-0.408,-0.088**	**-0.729,-0.173**	**-1.333,-0.409**	**-0.858,-0.336**
	90%CI:**	**-0.369,-0.158**	**-0.307,-0.123**	**-0.444,-0.150**	**-0.400,-0.072**	**-0.378,-0.117**	**-0.676,-0.226**	**-1.245,-0.496**	**-0.808,-0.386**
High Emitters (6)									
	NonOxyMean:	15.810	13.629	15.548	19.035	13.171	17.586	12.966	18.887
	OxyMean:	15.982	13.444	15.884	19.156	13.122	17.502	13.049	15.898
	%Change:	1.1%	-1.4%	2.2%	0.6%	-0.4%	-0.5%	0.6%	1.0%
	95% CI*:	0.796,-0.452	0.933,-1.303	0.991,-0.318	0.477,-0.235	0.994,-1.092	0.389,-0.558	0.924,-0.757	0.766,-0.386
	90%CI:**	0.661,-0.317	0.691,-1.062	0.849,-0.177	0.400,-0.158	0.769,-0.867	0.287,-0.456	0.742,-0.576	0.642,-0.261

Cells in **BOLD** indicate statistical significance