CRC Report No. 669

2015 CRC VEHICLE EMISSIONS PROGRAM

on

Effects of 85 and 87 Anti-knock Index (AKI) Gasoline Ethanol Blends on U.S. Light-Duty Vehicle Emissions, Fuel Economy, and Performance at Two Elevations (1,000 ft. and 5,000 ft.)

Final Report on CRC Project No. E-108

March 2015

COORDINATING RESEARCH COUNCIL, INC.

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(CRC Project No. E-108)

Prepared by the

CRC Emissions Committee

of the

Coordinating Research Council

March 2015

Contents

I. Executive Summary

a. Program Summary

This Program investigated the effects of gasoline anti-knock index (AKI[1]) on vehicle fuel economy, tailpipe emissions and engine and exhaust performance parameters for a fleet of nine model year 2008 – 2013 passenger cars and light duty trucks. Three different vehicle chassis dynamometer laboratories, each possessing variable altitude, temperature, and humidity controls, performed a total of 305 vehicle tests over the course of nine months. Two test fuels, closely matched in composition and energy content, however differing in their AKI value (87 and 85 AKI) were tested. The vehicles were tested under two simulated elevations: 1,000 ft. and 5,000 ft., (305 and 1,524 m). Each fuel, vehicle, and elevation combination was tested a minimum of two times using three standard US and California vehicle tailpipe emissions test cycles: US FTP-75, LA92 Unified, and US06. The test cycles were chosen to investigate the effects of a range of driving styles and severities on vehicle octane requirement. The test cycles are described in detail in Appendix E. Statistical analyses of the nine-vehicle-fleet means, individual-vehicle means, and correlation to vehicle attributes were conducted. A Data Capture Team was responsible for the vehicle tests, while a Data Analysis Panel performed the appropriate analyses of the acquired data.

b. Quality of Data Summary – Analysis of Variation, Outliers, and Vehicle Response Drift

Rigorous quality assurance and control procedures were employed by the Data Capture Team to minimize the inherent variability introduced by testing that spanned several months and included three separate chassis dynamometer labs. Quality assurance included standardized test procedures (see Appendix B) and application of engineering judgment to flag when additional testing was needed. No data were removed without a documented engineering reason such as an emissions analyzer error or dynamometer malfunction.

The Data Analysis Panel developed statistical models and conducted outlier analyses to indicate when results from combinations of factors did not fit the generated models. Of the 259 core emissions tests collected using the 85 and 87 AKI fuels, 13 data points or 5% of the total were flagged as potential outliers outside the six sigma bounds for Studentized residuals for any of the primary measurements (NMHC, CO, CO_2, NO_x) and calculation of fuel economy. In general, the quality of data and test precision were considered to be good for a vehicle emissions program of this size.

c. Conclusions

1. The test program methodology of using standardized emissions test cycles to evaluate fuel octane number effects on vehicle response was a good approach to gain understanding. The use of a range of emissions test cycles enabled the evaluation of trends in vehicle response and showed driving style is important with respect to the impacts of fuel octane number.

2. **Mean FE, CO_2, CO Results for the Combined Nine Vehicle Fleet - Octane for Combined Elevations**

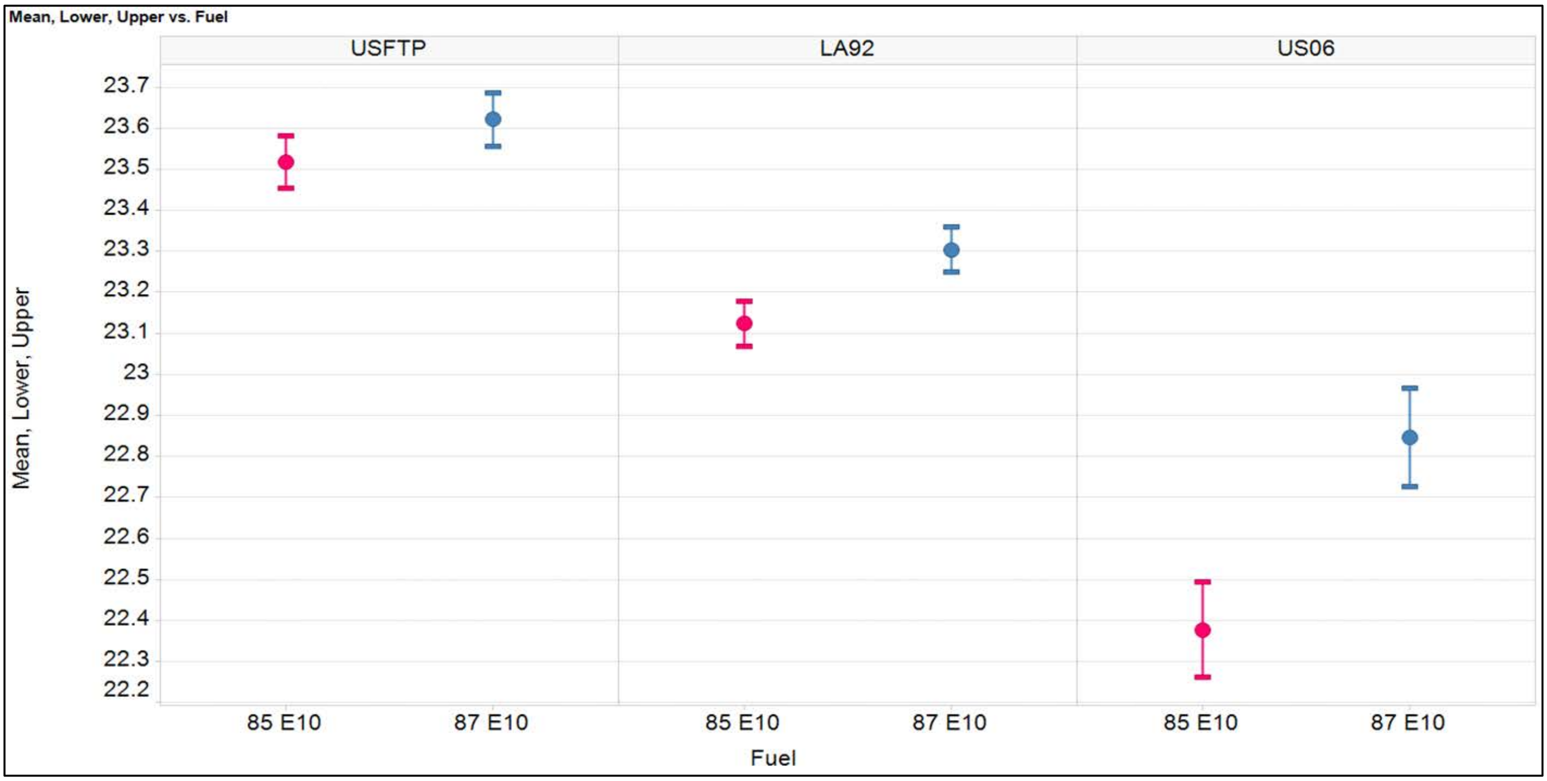
The analysis of variance (ANOVA) and linear statistical models used initially to evaluate fleet average FE, CO_2, and CO aggregated the data across the nine vehicles and two elevations but kept test cycle (US FTP-75, LA92 and US06) separate in order to understand the effects of octane number. The fleet average Fuel Economy (FE) results are shown below. The comparison intervals shown in the figure allow assessments of the statistical significance of differences in mean responses to fuel AKI at an Alpha (p-value) of 0.05. Comparison

[1] AKI is defined as the average of the Research Octane Number and Motor Octane Number ratings determined by ASTM International's test methods D2699 and D2700, respectively and calculated as AKI = (RON+MON)/2.

intervals that overlap (e.g., those for 85 AKI and 87 AKI on the US FTP-75 cycle) indicate that the differences in means are not statistically significant while those that don't overlap (e.g., those for 85 AKI and 87 AKI on the US06 cycle) indicate significantly different means.

The mean fuel economy response to fuel AKI is statistically significant when evaluated on the LA92 and US06 test cycles but not the US FTP-75.

The graph below includes the two test fuel names listed as 85 E10 and 87 E10. The two test fuels nominally contained 10% ethanol by volume (E10) and are detailed in Table 4 of the main body of this report. Some figures later in the report show the two test fuel names as simply 85 and 87 AKI, which are the same two test fuels but using a shortened naming convention.



Fleet Averaged Fuel Economy (mpg) Octane Number Effects for Combined Elevations

The three ANOVA models (for US FTP-75, LA92 and US06) yield the following conclusions:

a. The goodness-of-fit statistics (R-squared terms) for the three test cycle models are very high, i.e. greater than 0.99. Thus, the models fit the data very well.
b. Vehicle-to-vehicle variability provides the largest influence on mean fuel consumption response to fuel AKI (by two orders of magnitude as measured by the ANOVA model F-ratio statistic) for each of the three emissions driving cycles evaluated.
c. Variation in altitude (1000 ft. vs 5000 ft.) has a statistically significant effect for the US FTP-75 and LA92 models and is marginally significant (p-value between 0.05 and 0.10) for the US06.
d. The effect of variation in fuel AKI is marginally significant for the US FTP-75 model and significant for the LA92 and US06 models. Variability in fuel AKI explains a greater proportion of the total variability in measured fuel consumption as the test cycle severity increases.

e. Interaction between altitude and fuel AKI does not provide a statistically significant contribution to the total observed variance in the data for any of the three ANOVA models.

3. Mean FE, CO_2, CO Results for the Combined Nine Vehicle Fleet - Octane Effects within an Elevation

The mean FE, CO_2, and CO_2 data from the combined nine vehicle fleet are shown in the tables below along with the p-values obtained from statistical analysis.

a. P-values less than 0.05 indicate when the means are significantly different between the two fuels tested and are shaded yellow. The light gray shaded data show the p-values between 0.05 and 0.10 and are considered marginally significantly different.
b. At 5,000 ft., the US06 FE p-value is 0.11, and just outside the definition of a marginally significant effect at the 90% confidence level.
c. The nine vehicle fleet FE decreased by about 0.4% while operating on the 85 AKI fuel during the US FTP-75 tests and decreased between 1.6% and 2.4% for the US06 tests, depending on elevation.
d. Consistent with the loss of FE, the fleet CO_2 results correspondingly increased for the 85 AKI test fuel.
e. The fleet CO results showed mixed effects during the US FTP-75, with 5,000 ft. showing improvement when using 87 AKI, and CO increased by 24% to 52% for the US06 tests, regardless of elevation while operating on the 85 AKI fuel.
f. And lastly, it's noted that for a given AKI level, FE at 5,000 ft. elevation is always greater than at 1,000 ft. as a result of reduced parasitic pumping losses within the vehicle's engine due to the lower atmospheric pressure.

FE (mpg)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75	23.8775	23.9691	0.7353	-0.0916	-0.4%	23.1667	23.2834	0.5507	-0.1167	-0.5%
LA92	23.3837	23.5172	0.3083	-0.1335	-0.6%	22.8694	23.0942	0.0306	-0.2248	-1.0%
US06	22.5226	22.9002	0.1144	-0.3776	-1.6%	22.2344	22.7917	0.0122	-0.5573	-2.4%

CO2 (gpm)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75	336.3948	335.1829	0.6225	1.2119	0.4%	346.8585	345.5458	0.6155	1.3127	0.4%
LA92	344.5251	343.3285	0.7290	1.1966	0.3%	352.8187	350.2167	0.1758	2.6020	0.7%
US06	353.3398	348.2110	0.0965	5.1288	1.5%	357.8025	351.5022	0.0415	6.3003	1.8%

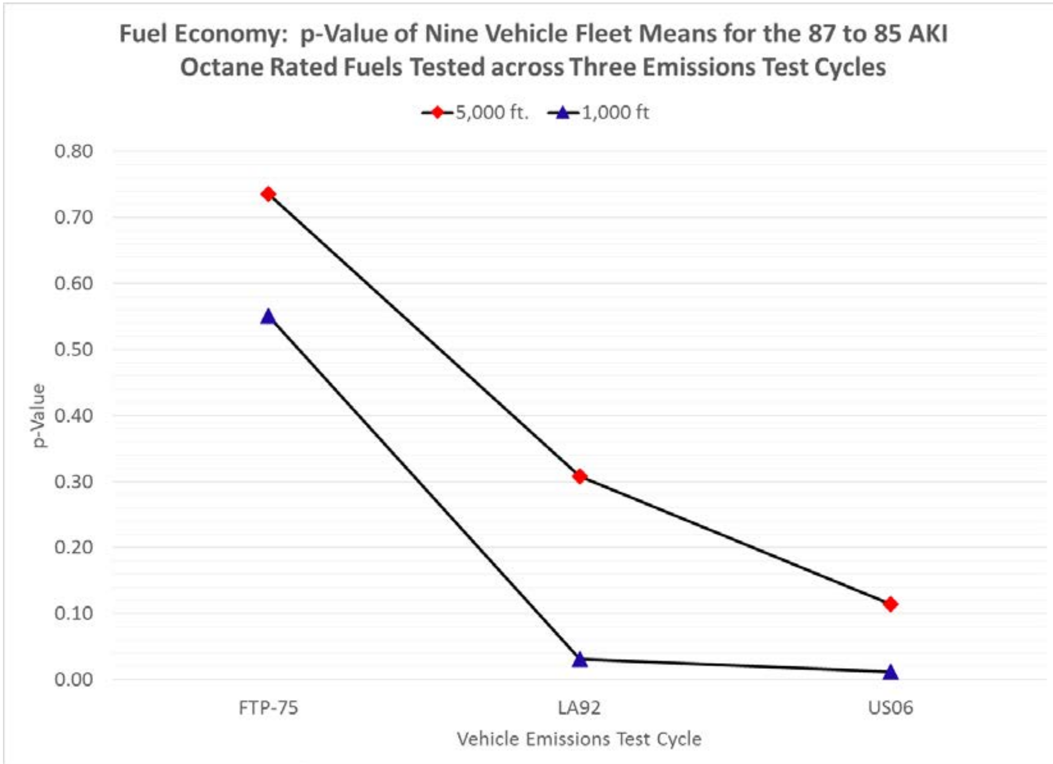
CO (gpm)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75	0.2802	0.2708	0.9348	0.0094	3.5%	0.2626	0.2772	0.7918	-0.0146	-5.3%
LA92	0.2314	0.2249	0.9905	0.0065	2.9%	0.2073	0.1796	0.4888	0.0277	15.4%
US06	1.8881	1.5199	0.3359	0.3682	24.2%	1.7008	1.1183	0.0124	0.5825	52.1%

4. **The Use of Trend Analyses versus Confidence Tests**

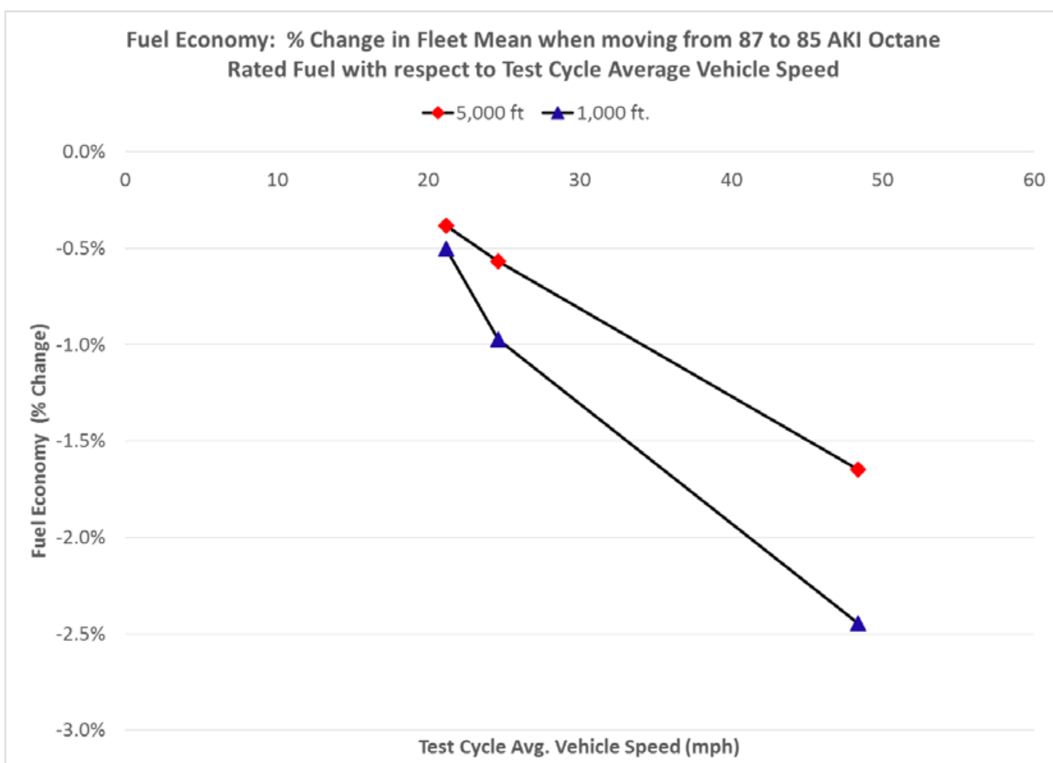
   If the vehicle fleet FE averages were truly equivalent, then one would expect fifty percent of the averages for one octane test fuel to fall below the second octane test fuel fleet averages and fifty percent above. This relatively consistent pattern of worse vehicle performance (evaluated on a fleet average basis) with the use of 85 AKI test fuel versus 87 AKI fuel led the Data Analysis Panel to conduct several binomial probability trend analyses. The statistical trend analyses indicate the probability that all six emissions cycle and altitude combinations of FE or CO_2 would show poorer performance for the 85 AKI case solely by random chance is very small. The statistical probability that all six FE averages would be in the same direction is 1.6%. (Calculation: $0.5^6 = 1/64 = 0.015625$, which is significant [$p \leq 0.05$].) While binominal trend analyses may be useful in identifying directional trends, they do not take into account the magnitude or statistical significance of the measured differences.

   The figure below shows that for a given elevation, the impact of operating the test fleet on 85 AKI fuel relative to 87 AKI fuel for FE becomes more significant (smaller p-value) as the driving cycle becomes more demanding, starting with the milder US FTP-75-type driving and up to the more aggressive US06. The p-value for the US06 case at 5,000 ft. is 0.11. A statistical analysis was conducted to determine how many test vehicles would have been required for the octane number FE effect to be significant for the US06 5,000 ft. case at a p-value of 0.05. The analysis concluded that a test fleet of twelve vehicles instead of nine would have been needed, assuming that the additional vehicles showed the same behavior as those already tested.

   The fleet average FE difference between 5,000 ft. and 1,000 ft. is significant with a p-value of 0.047 but this is due to the combined effects of lower atmospheric pressure and octane number on vehicle FE. At 5,000 ft. the lower air density requires the closed loop air-to-fuel ratio feedback control of the engine control module to open the throttle wider compared to that with more dense air at 1,000 ft., which in turn, reduces parasitic losses from engine pumping. These combined effects are discussed further below.



The chart below shows the percent change in fleet average FE with respect to test cycle average vehicle speed while operating on the 85 AKI fuel relative to the 87 AKI fuel. The test cycle average speeds are as follows: US FTP-75 (21.2 mph), LA92 (24.6 mph), and US06 (48.4 mph).



5. Mean FE, CO_2, CO Results for the Combined Nine Vehicle Fleet - Octane Effects Across Elevations

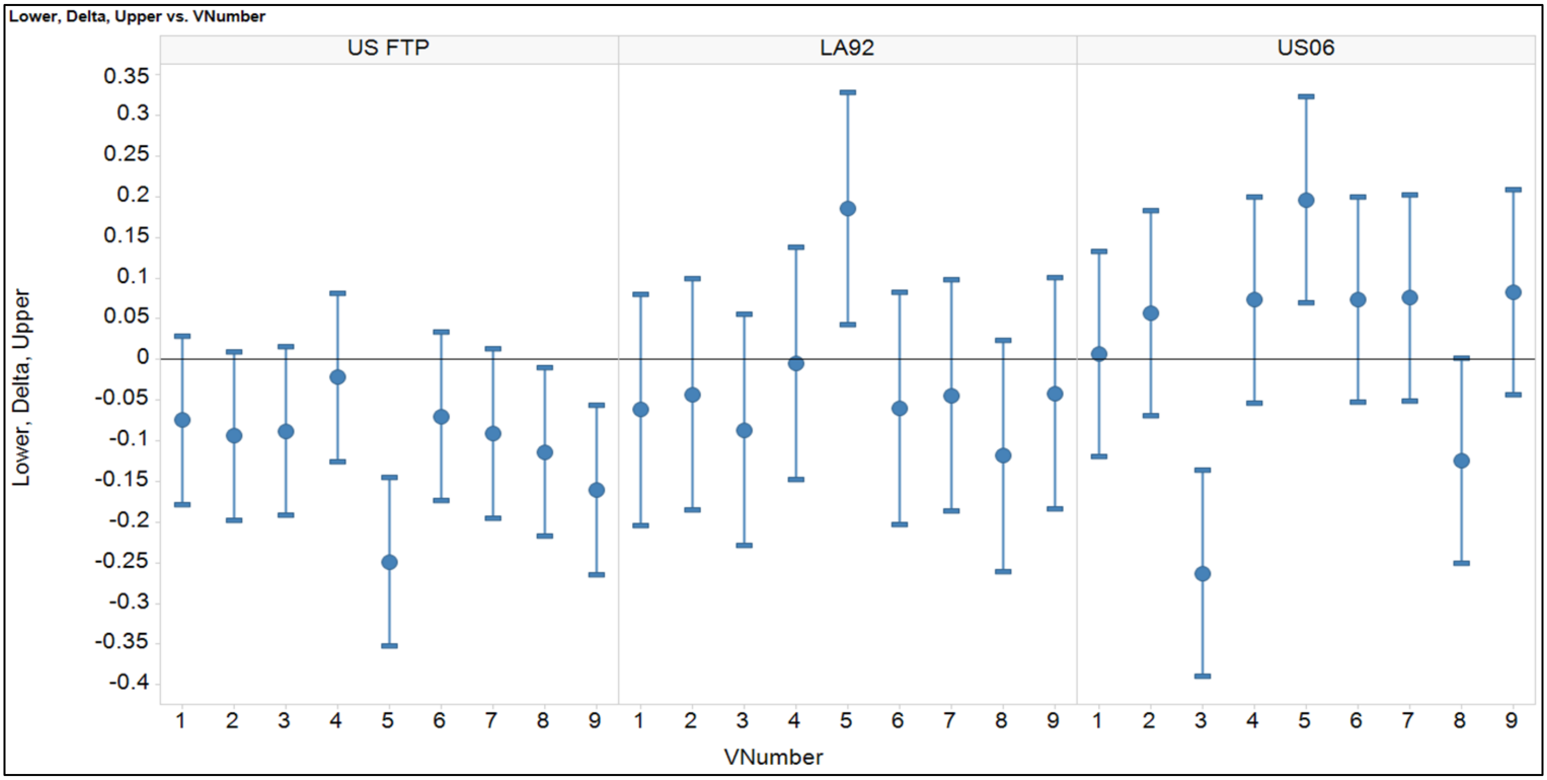
The tables below show the FE, CO_2, and CO average fleet results when operating the vehicles on 85 AKI fuel at 5,000 ft. and 87 AKI fuel at 1,000 ft. as is commonly done in today's U.S. market. Because of the lower atmospheric pressure at 5,000 ft. and the engines' response to it, the interpretation of results becomes more convoluted. When the vehicles are less knock limited as during the US FTP-75 and LA92 emissions cycle tests, the fleet average fuel economies at 85 AKI/5,000 ft. case are higher than at 87 AKI/ 1,000 ft. and the differences are statistically significant. However, when the vehicles become knock limited during the US06 cycle, the fleet average fuel economy at 85 AKI/5,000 ft. is lower than at 87 AKI/1000 ft. but the difference is not statistically significant. CO_2 in general behaves inversely to FE. Fleet average CO is higher at 85 AKI / 5,000 ft. than at 87 AKI/1000 ft. for all three emissions test cycles evaluated and is significantly higher during the more knock limited US06 test cycle.

FE (mpg)					
Outliers Removed	**5000**	**1000**	**p-value**	**Combined Effects Delta**	**% Change**
	85 AKI	**87 AKI**		**(85 - 87)**	**Delta / (87)**
FTP-75	23.8775	23.2834	<0.0001	0.5941	2.6%
LA92	23.3837	23.0942	<0.0001	0.2895	1.3%
US06	22.5226	22.7917	0.3869	-0.2691	-1.2%

CO2 (gpm)					
Outliers Removed	**5000**	**1000**	**p-value**	**Combined Effects Delta**	**% Change**
	85 AKI	**87 AKI**		**(85 - 87)**	**Delta / (87)**
FTP-75	336.3948	345.5458	<0.0001	-9.1510	-2.6%
LA92	344.5251	350.2167	<0.0005	-5.6916	-1.6%
US06	353.3398	351.5022	0.8360	1.8376	0.5%

CO (gpm)					
Outliers Removed	**5000**	**1000**	**p-value**	**Combined Effects Delta**	**% Change**
	85 AKI	**87 AKI**		**(85 - 87)**	**Delta / (87)**
FTP-75	0.2802	0.2772	0.9976	0.0030	1.1%
LA92	0.2314	0.1796	0.0642	0.0518	28.8%
US06	1.8881	1.1183	0.0025	0.7698	68.8%

The fuel consumption figure below shows that during the non- or lightly knocking US FTP-75 and LA92 cycles, the effect of lower atmospheric pressure on lower fuel consumption at 5,000 ft. relative to 1,000 ft. is apparent. However, during the more knock limited US06 cycle, seven of the vehicle mean changes in fuel consumption trend above zero. The confidence intervals shown indicate many of the differences are not statistically significant.



Individual Vehicle Fuel Consumption Deltas (85 AKI@5000' gallons - 87 AKI@1000' gallons / 100 miles)

6. **Mean Vehicle Fleet Performance Parameter Results for the Combined Vehicle Fleet - Comparisons within an Elevation:** Engine speed, Percent Engine Load, Ignition Timing, pre-Catalyst Exhaust Temperature, and mid-Catalyst Exhaust Temperature

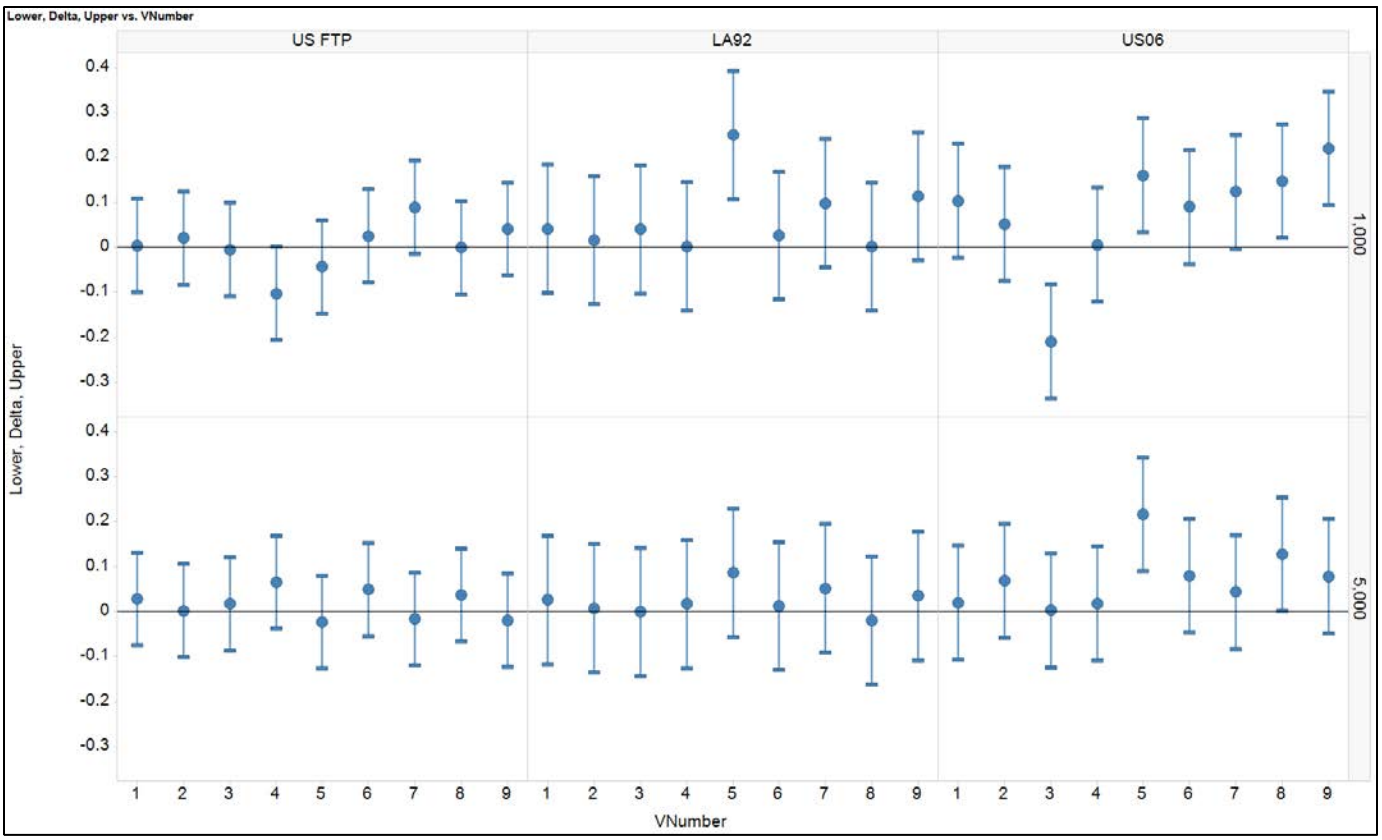
   Only eight of the nine test vehicles were instrumented with data loggers to record ECM parameters. The combined eight vehicle fleet means and percent changes for engine speed, percent load, and mid-catalyst temperatures shown in the body of the report show no statistically significant differences between operating on the 85 and 87 AKI test fuels. Spark retard (moving ignition timing closer to top dead center of piston travel) and pre-catalyst exhaust temperatures are significantly different between the two test fuels while operating on the US06 cycle at 5,000 ft. The resultant rejected in-cylinder heat from delayed combustion during the more knock-limited US06 cycle leads to increased pre-catalyst temperature differences. Summary tables focused on Ignition timing and pre-catalyst temperatures, respectively, are shown below.

Ignition Timing (° BTDC)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75 Bags 1&2	23.30	23.18	0.9344	0.13	0.5%	23.39	23.27	0.9444	0.12	0.5%
FTP-75 Bag 3	23.03	23.45	0.2459	-0.42	-1.8%	23.11	23.56	0.9606	-0.45	-1.9%
LA92	21.23	21.43	0.9182	-0.20	-0.9%	21.31	21.58	0.8085	-0.27	-1.2%
US06	21.71	22.62	0.0193	-0.92	-4.1%	21.47	22.19	0.0638	-0.72	-3.3%

Pre-Cat Temp. (°C)										
Outliers Removed	5000	5000	p-value	Delta	% Change	1000	1000	p-value	Delta	% Change
	85 AKI	87 AKI		85 - 87	87 --> 85	85 AKI	87 AKI		85 - 87	87 --> 85
FTP-75 Bags 1&2	451.88	450.88	0.7868	1.00	0.2%	457.47	457.36	0.9996	0.11	0.0%
FTP-75 Bag 3	463.01	461.97	0.9409	1.04	0.2%	467.02	464.31	0.4751	2.71	0.6%
LA92	512.64	510.26	0.6397	2.38	0.5%	514.38	510.75	0.2589	3.63	0.7%
US06	637.49	629.52	0.0124	7.97	1.3%	640.84	635.08	0.3228	5.76	0.9%

7. Mean FE, CO_2, CO Results for Individual Vehicles

The change in fuel consumption and fuel economy for each vehicle when operating on 85 compared 87 AKI gasoline within a given elevation are shown in the figure and table below, respectively for the three test cycles. For the majority of vehicles, fuel consumption averages are higher while operating on 85 AKI gasoline compared to 87 AKI fuel and the level of fuel consumption increases with test cycle severity. The confidence intervals shown indicate many of the differences are not statistically significant.



Individual Vehicle Fuel Consumption Deltas (85 AKI - 87 AKI gallons / 100 miles)

Individual Vehicle Fuel Economy Percent Change when moving from 87 to 85 AKI Fuel

VNumber	Altitude (ft.)	Fuel Economy Change (%) 87 to 85 AKI		
		US FTP	LA92	US06
1	5000	-1.06	-0.92	-0.67
2	5000	-0.07	-0.24	-2.03
3	5000	-0.55	0.02	-0.11
4	5000	-1.51	-0.40	-0.40
5	5000	0.41	-1.49	-3.48
6	5000	-1.73	-0.43	-2.44
7	5000	0.26	-0.85	-0.70
8	5000	-0.75	0.37	-2.38
9	5000	0.39	-0.75	-1.70
1	1000	-0.15	-1.40	-3.32
2	1000	-0.62	-0.47	-1.55
3	1000	0.14	-1.22	6.75
4	1000	2.40	-0.06	-0.14
5	1000	0.74	-4.26	-2.60
6	1000	-0.88	-0.89	-2.72
7	1000	-1.45	-1.56	-1.96
8	1000	0.01	-0.04	-2.62
9	1000	-0.83	-2.34	-4.60

If AKI had no consistent effect on fuel economy (FE), each of the individual vehicle percent change deltas would have a 50% chance of being positive and a 50% chance of being negative. For a given elevation, of the 27 percent change deltas (nine vehicles with three test cycles each) at each altitude, 22 FE deltas were negative with the 85 AKI fuel. The chance of flipping a fair coin 27 times and getting 22 or more tails is 0.0008, which is a significant p-value ($p < 0.05$) for the one-sided test and considers individual vehicle response. Similar binomial statistical analyses were conducted for CO_2 and CO emissions and are summarized below. While binominal trend analyses may be useful in identifying directional trends, they do not take into account the magnitude or statistical significance of the measured differences.

One-sided p-value for x out of 27 deltas (9 vehicles x 3 test cycles) with worse performance for 85 AKI (positive for emissions, negative for fuel economy)			
Measure	Altitude	x	p-value
CO	1000	17	0.12
CO_2	1000	19	0.03
Fuel Economy	1000	22	0.00
CO	5000	18	0.06
CO_2	5000	20	0.02
Fuel Economy	5000	22	0.00

8. The test program included nine test vehicles with a range of attributes; production Model Years 2008 – 2013, four passenger cars and five light duty trucks, engine displacements from 1.4 – 5.4L, two direct and seven port fuel injected, and two turbocharged and seven naturally aspirated engines.

   Evaluating the effects of 85 and 87 AKI fuels on the primary emissions metric CO_2, the data showed:

   a. Cars vs Trucks – Trucks had statistically significant higher absolute levels of CO_2 compared to the passenger cars. However, the incremental effects of 85 and 87 AKI for these two vehicle types was not significant.
   b. DI vs PFI – The fuel injection type was not statistically significant for absolute CO_2 emissions levels. However, the incremental effect of 85 and 87 AKI for these two injection types was, in some cases, statistically significant.
   c. Naturally Aspirated vs Turbo-charged – The intake air aspiration type was not found to be statistically significant for absolute, nor incremental CO_2 levels.
   d. Test fleet Hardware Attributes Balance – Having a better balanced vehicle fleet for fuel injection and induction air aspiration types in future programs will help the statistical analysis of data.
   e. Correlation with Vehicle Load Factor – Vehicle load factor is defined as vehicle mass per unit engine displacement. The exhaust CO_2 to vehicle load factor correlation R^2 values for the lighter loaded US FTP-75 and LA92 test cycles are low and both about 0.5. The US06 CO_2 to vehicle load factor R^2 decreases to 0.4 as this test cycle is more knock limited and the influence of increased CO confounds the CO_2 response. Response to 85 AKI octane is very vehicle specific and not well correlated to its load factor.

9. For the primary vehicle emissions and performance metrics of this program, a series of figures was prepared (Figures 41 – 48) to help the reader visualize the convoluted influences of fuel AKI octane number, elevation, and test cycle severity on individual vehicle response.

10. And lastly, the Appendix includes additional test program details, data analyses, and pertinent supplemental information, including the full set of Emissions and Vehicle Performance results.

II. Abstract

The Coordinating Research Council, Inc.'s (CRC) Emissions and Performance Committees jointly conducted a vehicle chassis dynamometer test program on a fleet of modern light duty motor vehicles in response to a request from ASTM International's Sub-committee D02.A to determine the effects of 85 and 87 AKI (anti-knock index) rated fuels on tailpipe emissions and general vehicle performance. The octane number effects were evaluated at two elevations, 1,000 and 5,000 ft. (305 and 1,524 m) above sea level, and used test fuels with closely matched fuel compositions, except differing in their AKI octane ratings. Nine modern light duty cars and trucks were chosen for the vehicle test fleet in order to cover a range of vehicle attributes in today's U.S. car fleet; production model years 2008 – 2013, naturally aspirated vs. turbo-charged air induction systems, port-fuel injected vs. direct injected fuel injection systems, a range of Federal Tier 2 emissions certifications, and a range of vehicle load factors (vehicle mass to engine displacement size ratios). Vehicle testing was conducted at three different automotive manufacturer's test sites using variable altitude emissions chassis dynamometers with conditioned environment capability (temperature, humidity, and pressure.) Each vehicle, fuel, and altitude combination was tested using three standard vehicle emissions certification driving cycles in order to evaluate a range of driver behaviors.

III. Introduction

CRC Project E-108 was designed to generate vehicle performance, fuel economy, and emissions data to help update the general understanding of octane and altitude effects on modern vehicle performance. The specifications for gasoline used in spark-ignition automobile engines in the United States are detailed in ASTM International's, "Standard Specification for Automotive Spark-Ignition Engine Fuel", commonly referred to as ASTM D4814. Although ASTM D4814 does not explicitly list mandatory minimum specifications for antiknock/octane number ratings, it does provide non-mandatory information in its Appendix describing the effects of altitude on vehicle antiknock requirements for pre-1984 vehicles. These older vehicles lack sophisticated closed-loop computerized engine control module controls and are predominantly large cylinder bored, carbureted, naturally aspirated designs having emissions certifications much less stringent than today's vehicles. Additionally, the D4814 Appendix shows areas in the western United States where reduced antiknock requirements for pre-1984 vehicles are applicable based on the altitude of the area. Therefore, ASTM D02, Sub-committee A is seeking to update D4814 based on controlled vehicle performance studies and data.

The importance of fuel antiknock quality is highlighted by its impact on vehicle design and performance. Modern day automobile engines are calibrated for maximum fuel economy and performance, while minimizing emissions using the octane grade of gasoline that the manufacturer recommends or requires for use in the vehicle's owner's manual. However, in order to avoid engine failure or permanent damage in case a lower fuel octane than that specified in the owner's manual is used, the engine has to be "protected" for the minimum octane fuel available in the market of sale. Consequently, the engine design and calibration is constrained by the lowest antiknock index fuel commercially available.

The CRC Emissions and Performance Committees collaboratively designed a vehicle chassis dynamometer octane performance test program, as described in the Methodology Section of this report, to help better understand the impact of gasoline octane number ratings on vehicle performance and more specifically, to quantify the change in vehicle performance when operating on 85 and 87 AKI fuels.

IV. List of Tables

V. List of Figures

VI. Acronyms and Abbreviations

AKI	Anti-knock Index	FE	Fuel Economy
BTDC	Before Top Dead Center	MON	Motor Octane Number
CO	Carbon Monoxide	MPH	Miles per Hour
CO2	Carbon Dioxide	NMOG	Non-methane Organic Gases
COV	Coefficient of Variation	OBD	On-Board Diagnostics
DVPE	Dry Vapor Pressure Equivalent	OEM	Original Equipment Manufacturer
ECM	Engine Control Module	RMSSE	Root Mean Squared Speed Error
EOT	End of Testing	RON	Research Octane Number
GPM	Gallons per Mile	SOT	Start of Testing

VII. Program Teams

a. Vehicle Data Capture Team

Blash, Eric	Fiat Chrysler Automobiles
Gian, Dave	FEV North America, Inc.
Iqbal, Asim	Fiat Chrysler Automobiles
Jenifer, Ken	Ford Motor Co.
Koushik, Sridhar	FEV North America, Inc.
Paul, Johanna	Ford Motor Co.
Studzinski, William	General Motors Co.
Winston-Galant, Mark	General Motors Co.

b. Data Analysis Panel Team

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Farenback-Brateman, Jeff	Exxon Mobil Petroleum
George, Richard	BP
Glodich, Jeffrey	Ford Motor Co.
Horn, Jerry	Chevron U.S.A
Iqbal, Asim	Fiat Chrysler Automobiles
Lax, David	American Petroleum Institute
Mason, Scott A.	Phillips 66 Co.
Monroe, Rebecca	Fiat Chrysler Automobiles
Rutherford, Jim	Chevron Oronite
Sigelko, Jenny	Volkswagen of America
Simnick, Jim	BP
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Studzinski, William	General Motors Co.
Valentine, Marie	Toyota Technical Center
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VIII. Methodology

a. General Description

One objective of the program was to evaluate fuel octane effects on vehicle performance at 5,000 ft. versus 1,000 ft. elevations. Variable pressure vehicle chassis dynamometer emissions test cells were, therefore, required in order to prevent the need for individual vehicles to be tested at two separate chassis dynamometer labs for each elevation. Moving the vehicles to a second lab for 5,000 ft. tests would introduce lab-to-lab variation on the same vehicles into the results. To avoid this additional source of variation, the emissions testing of the nine vehicles was divided up among three automotive OEM test labs, with each vehicle remaining at a single lab. The vehicles were tested over a period nine months at Fiat Chrysler, Ford, and General Motors, as emissions test cells became available.

b. Test Vehicle Matrix – Summary

A summary of the nine test vehicles is found in Table 1 and a more complete list of vehicle characteristics is found in Appendix C. The owner's manuals for each of these vehicles require the use of minimum 87 AKI gasoline for satisfactory performance. The vehicles have been randomly assigned number codes throughout the remainder of the report which do not coincide with the order presented in Table 1.

Table 1 Test Vehicle Summary

Vehicle	Model Year	Odometer	Fuel System	Induction System	Eng. Disp. (L)
Toyota Corolla	2008	13,248	PFI	Nat. Asp.	1.8
Honda Odyssey	2008	13,248	PFI	Nat. Asp.	3.5
Honda Fit	2012	19,378	PFI	Nat. Asp.	1.5
Ford Transit Connect	2010	11,860	PFI	Nat. Asp.	2.0
Ford Focus	2008	12,563	PFI	Nat. Asp.	2.0
Ford F-150 Ecoboost	2011	5,200	DI	Turbo	3.5
Ford F-150	2008	15,487	PFI	Nat. Asp.	5.4
Dodge Dart	2013	14,403	PFI	Turbo	1.4
Chevy Equinox	2010	37,396	DI	Nat. Asp.	3.0

c. Standardized Vehicle Emissions Drive Cycles - General

In order to evaluate the effect of octane rating on vehicle performance over a range of consumer driving styles, three standardized emissions tests cycles were utilized to test each vehicle, fuel, and elevation combination.

There are several benefits of using emissions test cycles in evaluating fuel octane rating effects and / or vehicle octane response effects:

1) The OEM chassis dynamometer test labs are very familiar with running these cycles, helping to minimize test-to-test and lab-to-lab data variation.
2) For a given test cycle, the vehicles are all driven over an equivalent vehicle speed trace, which holds their demanded work output requirement constant, enabling vehicle and fuel effects comparisons.
3) Each test cycle contains multiple acceleration events (modes) with varying severities, which changes the vehicle octane requirement during each mode. Because the cycle modes will not change from test to test and vehicle to vehicle, fuel effects on vehicle performance comparisons can be made over a range of driver behaviors.

The three standardized emissions test cycles used for this study are found in Table 2.

Table 2 Standardized Vehicle Emissions Test Cycle Attributes

Test Cycle	Average Vehicle Speed (mph)	Maximum Vehicle Speed (mph)	Test Cycle Distance (miles)
US FTP-75	21.2	56.7	11.04
LA92	24.6	67.2	9.80
US06	48.4	80.0	8.01

Another benefit of using well defined, well controlled, standardized emissions test cycles is the inclusion of Drive Quality Metrics defined in the SAE International J2951 Recommended Practice for Drive Quality evaluation. The following "Rationale, Foreword, and Scope" are quoted directly out of this Practice.

RATIONALE
To provide standardized metrics for evaluating drive quality on emissions and fuel economy tests. This document has been revised to include a new drive rating metric and typical driver capability ranges.

FOREWORD
It is generally recognized that the manner in which a vehicle is driven during a chassis dynamometer test can impact emissions and fuel economy results. The speed vs. time tolerances used to validate a test do limit this impact, but even within these constraints drive-related effects can be significant contributors to test variability. This document provides drive quality metrics intended to enable improved monitoring and characterization of driver-related variability.

SCOPE
This SAE Recommended Practice establishes uniform procedures for evaluating conformity between the actual and target drive speeds for chassis dynamometer testing utilizing standard fuel economy and emissions drive schedules.

The SAE J2951 RMSSE metric provides the driver's performance in meeting the schedule speed trace throughout the test cycle in terms of the Root Mean Squared (RMS) Speed Error. The value is always a positive number with lower values (closer to zero) indicating better performance. RMSSE has units of miles per hour (mph). Based on discussions with Emissions Lab personnel, it is typical for RMSSE to increase with driving cycle severity but should be kept below 1.0 for all vehicle emissions tests. Values greater than 1.0 indicate drivers having difficulty keeping up with the vehicle speed trace. Drivers "falling behind" the vehicle speed trace would need to increase throttle, which may momentarily impact in-cylinder air-to-fuel ratios and resultant emissions. The drive quality metrics for 2 of the 3 chassis dynamometer laboratories are summarized in Table 3 below.

Table 3 SAE J2951 Drive Quality Metrics

	Average Root Mean Squared Speed Error (RMSSE) for Two of the Three Chassis Dyno Labs* ("N" (number of tests per average) is 14 or 15.)			
	85 AKI / 1000 ft.	85 AKI / 5,000 ft.	87 AKI / 1000 ft.	87 AKI / 5,000 ft.
US FTP-75	0.44	0.47	0.45	0.43
LA92	0.51	0.57	0.53	0.53
US06	0.61	0.67	0.62	0.62
(*) One lab was unable to report their RMSSE values.				

d. Data Capture Procedure – Description and Flow Chart

The core of the test program design plan consisted of 9 vehicles x 2 fuels x 2 elevations x 3 driving cycles x 2 repeats, which equates to 216 tests, minimally. Dynamometer cell temperatures were set to nominally 75°F and relative humidity between 35 – 40%. Five of the vehicles began testing on the 87 AKI fuel and switched to the 85 AKI fuel and four vehicles began on the 85 AKI fuel and switched to 87 AKI. Figure 1 shows a flowchart of the test procedures for the core emissions program, which aided in keeping procedures the same between the three test laboratories. Frequent review of the emissions and performance test data occurred. Additional test repeats were conducted if the vehicle emission results were not precise and did not meet the following emissions test precision "rules of thumb": CO < 20% COV, CO_2 < 1% COV, FE < + / - 0.3 mpg, where COV is the Coefficient of Variation and is defined as

$$COV = \frac{1\sigma}{\bar{x}} \times 100$$

where 1σ equals one standard deviation and $\bar{x}$ is the average of individual observations for a given vehicle, octane, and altitude combination. Also, before the data capture team approved the data from each emissions cycle, each vehicle emissions data file was reviewed to verify the data was valid and that no test equipment or analyzer calibration errors occurred. In addition to the core emissions tests, bracket US FTP-75 duplicate emissions tests were conducted prior to the start of testing (SOT) and then again at the end of testing (EOT) with Tier 2 Federal emissions certification fuel. This was done to ensure that the vehicles showed no illuminated on-board diagnostic (OBD) malfunction lights and also to be able to compare the baseline tailpipe emissions of each vehicle to those of the reported federal emissions certification vehicles. No anomalies were found and the vehicles emissions systems were deemed representative for each vehicle emissions class family. The US FTP-75 Tier 2 emissions data taken at the EOT then allowed an analysis of the vehicle emissions system response drift over the months of testing, and this is detailed later in the report. In total at the beginning of the program, 252 emissions tests were estimated to be needed and in the end 305 tests were conducted.

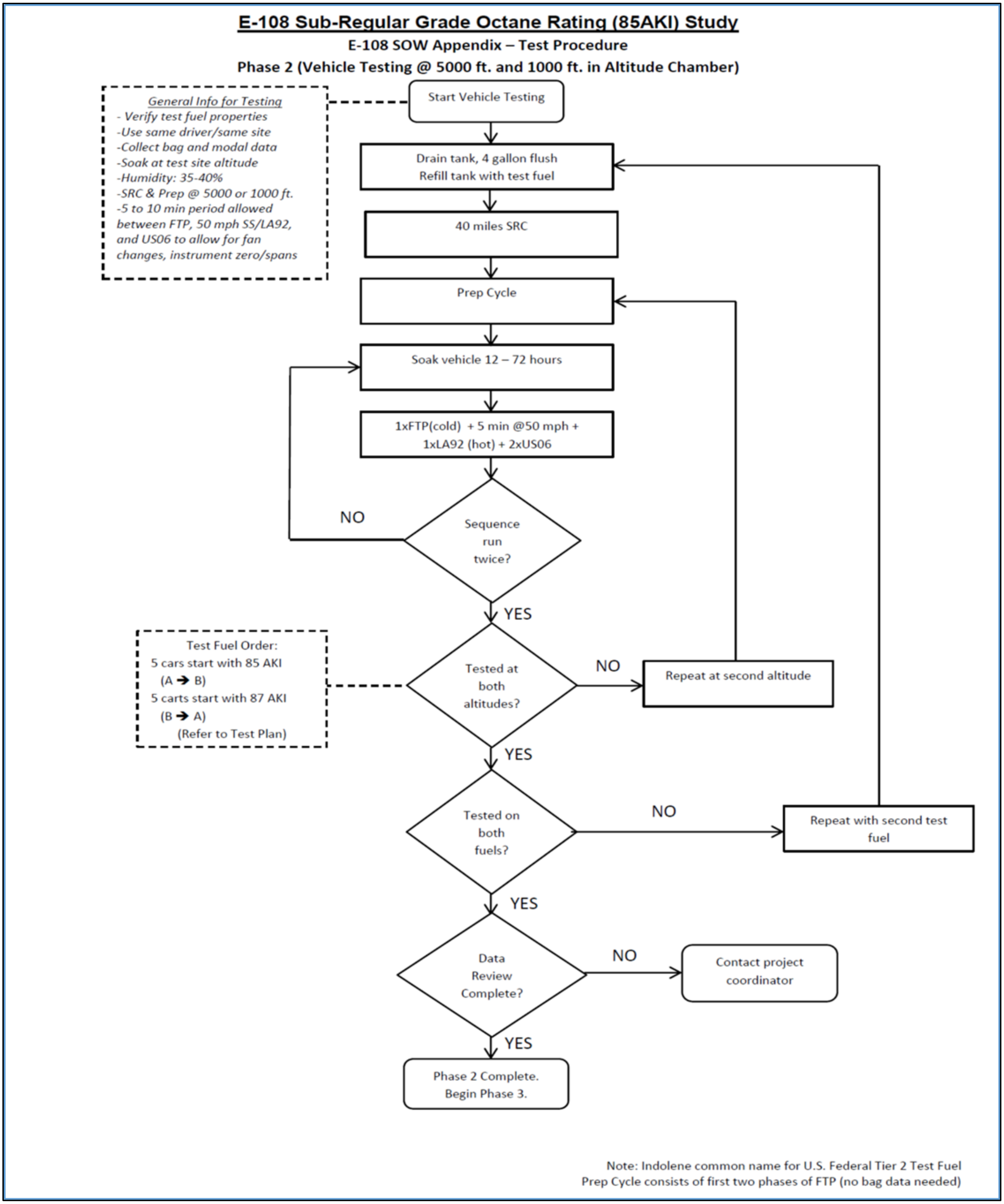


Figure 1 Vehicle Emissions Test Procedure Flow Chart-Core Program (85 and 87 AKI Tests)

e. Octane Test Fuels - Summary

Four independent fuel quality labs analyzed the two test fuels. The results are summarized below in Table 4. The full set of results for all labs is found in Appendix D. Care was given to meet the targeted respective 85 and 87 AKI octane ratings of the two fuels while minimizing differences in density, volatility, energy content and any other properties that may influence the combustion process and result in changes to engine efficiency and emissions. The two test fuels differ only in that a slight amount of zero octane rating n-heptane was added to the 87 AKI E10 blend. The unwashed gum values of fuels are indicative of the presence of detergents and do not impact the octane number effects.

Table 4 Test Fuel Composition and Property Summary

Test	Units	85 AKI E10			87 AKI E10		
		Average	Std	% CoV	Average	Std	% CoV
RON		87.9	0.4	0.5%	90.7	0.3	0.4%
MON		82.0	0.3	0.4%	83.9	0.6	0.7%
AKI		84.9	0.2	0.2%	87.3	0.3	0.4%
Sensitivity		5.8	0.7	11.6%	6.8	0.6	9.4%
Relative Density	S.G. 60/60F	0.7360	0.0	0.1%	0.7366	0.0	0.0%
DVPE	psi @ 100F	8.39	0.2	2.1%	8.71	0.1	1.7%
Distillation	deg. F						
IBP		100.8	2.6	2.6%	100.3	4.8	4.8%
T5		126.8	1.4	1.1%	124.3	1.7	1.3%
T10		133.8	0.8	0.6%	131.3	1.1	0.8%
T20		143.0	0.7	0.5%	141.0	0.4	0.3%
T30		149.7	1.0	0.7%	147.8	0.4	0.3%
T40		162.4	2.7	1.6%	154.3	0.9	0.6%
T50		216.1	2.7	1.2%	211.4	1.9	0.9%
T60		240.4	0.9	0.4%	242.6	1.4	0.6%
T70		261.7	1.9	0.7%	265.1	0.5	0.2%
T80		286.1	1.8	0.6%	286.7	1.0	0.4%
T90		313.7	0.9	0.3%	313.6	1.1	0.4%
T95		336.5	4.6	1.4%	337.0	4.2	1.3%
FBP		359.9	1.2	0.3%	361.0	1.7	0.5%
Residue		1.0	0.0	0.0%	1.1	0.1	9.5%
DI		1186.1	11.1	0.9%	1168.5	6.0	0.5%
Aromatics	v%	11.6	2.1	17.6%	11.6	1.4	11.8%
Olefins		8.2	1.5	17.8%	8.7	1.7	19.0%
Paraffins		70.3	3.9	5.6%	69.7	3.5	5.0%
Ethanol		9.9	0.6	6.3%	10.1	0.7	6.9%
Sum							
Sulfur	ppm	0.3	---	---	0.2	---	---
Carbon	wt%	81.6	0.1	0.1%	81.8	0.2	0.2%
Hydrogen	wt%	14.5	0.0	0.3%	14.4	0.2	1.1%
H/C Ratio		2.1	0.0	0.0%	2.1	0.0	1.8%
NHV*	btu/lb	18746.7	799.5	4.3%	18730.4	849.4	4.5%
Existent Gum	mg/100ml						
- Unwashed		11.5	5.2	45.1%	10.4	5.7	55.0%
- Washed		0.1	0.2	173.2%	0.1	0.2	173.2%
(*) Note:							

Wide variation in NHV from two labs. Chrysler re-analyzed the 87 AKI test fuel. NHV = 41.52 MJ/kg (17,894 BTU/lb). Used D240 test method. Lab 3 appears to have reported HHV, not NHV. Confirmed that each of the 3 OEM Emissions Sites used the Average NHV from this spreadsheet. FE numbers should not be compared to those reported to EPA (plus these are not Tier 2 Cert Fuels.)

IX. Data Summaries

a. Statistical Analysis Methodology

As previously mentioned, the core of the test program design plan consisted of 9 vehicles x 2 fuels x 2 elevations x 3 driving cycles x 2 repeats, which equates to 216 tests. Including additional repeats, 265 core emissions tests were conducted. US FTP-75 Tier 2 emissions tests were conducted before and after core testing for each vehicle to monitor vehicle response drift, Nominally, this would have included 9 vehicles x 2 times (before and after) x 2 repeats or 36 tests. As some vehicles had more than two repeat measurements and one vehicle had no post Tier 2 tests, the total number of US FTP-75 Tier 2 emissions tests was 40.

Table 5 Minimum Test Plan for each Vehicle

Fuel	Altitude (ft.)	Test Cycle	Planned Tests
85 AKI	1000	US FTP-75	2
		LA92	2
		US06	2
	5000	US FTP-75	2
		LA92	2
		US06	2
87 AKI	1000	US FTP-75	2
		LA92	2
		US06	2
	5000	US FTP-75	2
		LA92	2
		US06	2
Tier 2 Cert Fuel	Site Elevation	SOT US FTP-75	2
		EOT US FTP-75	2

For the emissions data, the "usual" transformations were used as a first step in analyses. Emissions in grams per mile theoretically do not go below zero, have increased variability with increased grams per mile, and tend to be impacted multiplicatively rather than additively by both controlled and random factors. For this reason, CRC traditionally has found natural logarithmic transformation (transformed emission = natural logarithm of emission) to yield datasets that more closely satisfy assumptions involved in statistical analyses. Fuel economy in miles per gallon as measured in equal distance emissions tests are also traditionally inverted to gallons per mile for better analysis. This transformation generally yields datasets that more closely satisfy assumptions involved in statistical analyses and also puts the variable being estimated (fuel used) in the numerator rather than the fixed value (miles) which creates more reliable analyses.

For core emissions testing, repeat measurements for each of the 36 combinations of vehicle, fuel, and elevation were averaged after transformation.

The data analysis in this study uses linear models as implemented in SAS®. For example, for the core emissions analyses, model fits for the form transformed emissions = f(vehicle, altitude, fuel) + e where 'f' is linear function of the design factors and 'e' are residuals with the assumptions $\sum e_i = 0$, and $e \sim iid\ N(0, \sigma^2)$, that is the errors are distributed identically and independently as Normal or Gaussian random variables with mean zero and variance, σ^2. Significance tests are reported based on these linear models with α=0.05 unless otherwise stated.

Residuals were examined from each of the models to assess whether assumptions on the analyses were based upon could be assumed to be valid. Potential outliers were identified based on externally Studentized residuals. An externally Studentized residual is the difference between actual result and the value predicted by the fitted model divided by an estimate of standard deviation in the residuals from the model fitted without that result. As a rule of thumb, an observation was flagged as a potential outlier when the externally Studentized residual was greater than 3 or less than -3. This should occur purely by chance less than three times in a thousand. Note that flagging as a potential outlier is not proof the observation should be omitted from analyses, but only evidence the observation might have arisen from a process different from the rest of the data. Eliminating potential outliers is an engineering judgment. For the core program data analyses in this report, potential outliers were removed. Outlier analysis was not conducted on data from the Tier 2 bracket fuels for the analysis of drift. In most cases, data were analyzed with and without potential outliers to ensure that their removal did not lead to different conclusions.

b. Data Outlier Analysis

The flagged outlier rate among repeat measurements was considered to be a partial indication of data quality. The outlier flags indicate when results from combinations of factors did not fit the model as well as other combinations.

Of the 259 core emissions tests, 13 (or 5%) were flagged as potential repeatability outliers. The Data Analysis Panel removed these 13 tests before averaging within the 36 (9 vehicles x 2 fuels x 2 altitudes) combinations for each of the 3 test cycles. Of the 36 core emissions tests means only one potential outlier was flagged.

Of the 128 core performance tests, (8 vehicles x 2 fuels x 2 altitudes x 4 test cycles) 125 combinations had analyzable averages. Of these, five means (or 4%) were flagged as potential outliers and were excluded from the final presented analyses.

An example of the low FE vehicle drift response is shown in Figure 2 with additional figures and tables summarizing the drift response located in Appendix G. The vehicle response drift over the course of the program did not change the conclusions of the data.

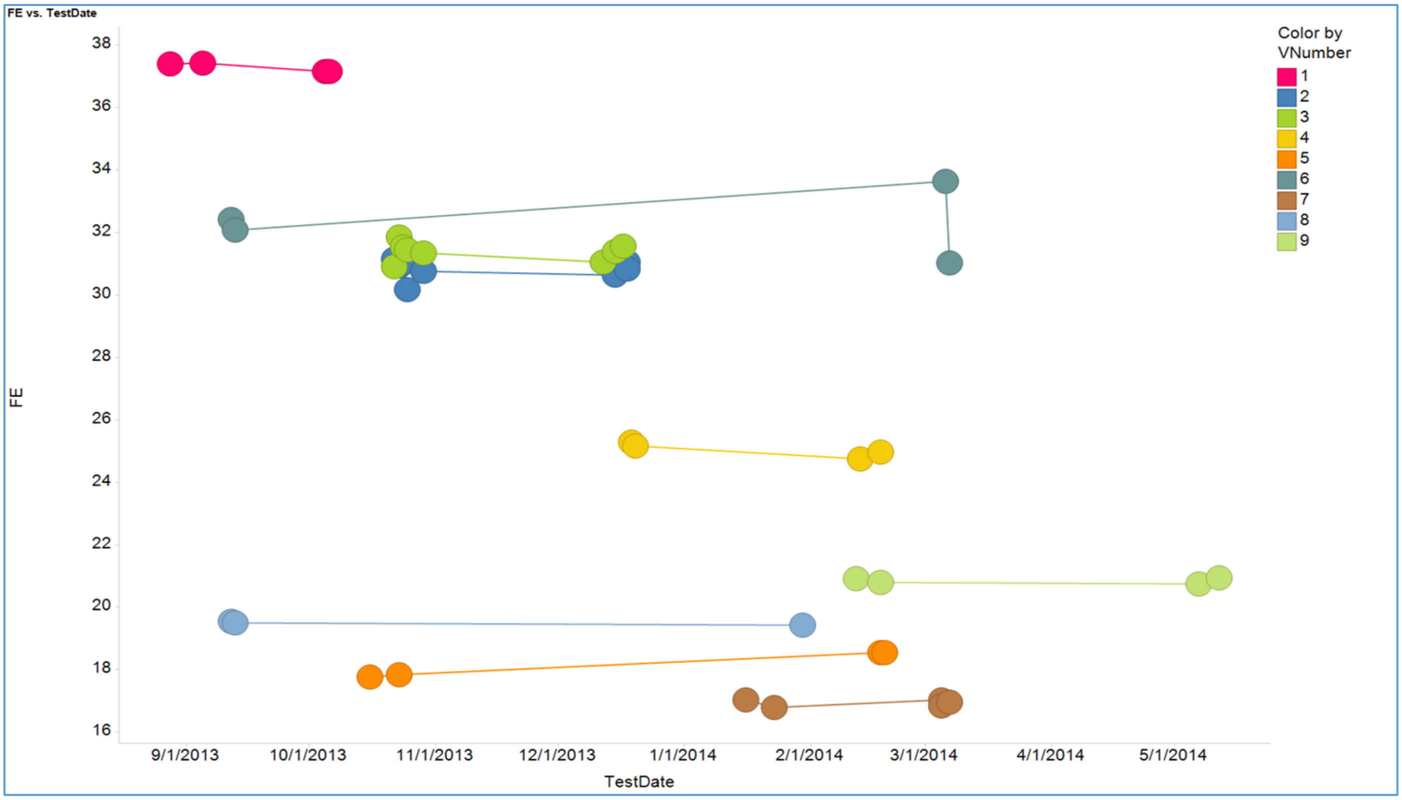


Figure 2 Vehicle Fuel Economy Drift from SOT to EOT [US FTP-75 FE with Tier 2 Certification Fuel]

c. Description of General Statistical Analysis Approach

The individual test fleet vehicles differ in their engine hardware, emissions certification requirements, and ECM calibration anti-knock mitigation strategies resulting in a wide variation of vehicle performance as a result of octane number and elevation. To better understand how vehicle characteristic variation contributes to the precision of the findings, several statistical confidence analyses and trend analyses are presented for both the fleet averaged and individual vehicle results. Likewise, when interpreting the fuel, elevation, and driver style effects on vehicle performance, comparisons of test fleet averaged results versus individual vehicle results are shown to offer good contrast in understanding their magnitude and statistical significance.

d. Vehicle Emissions and Performance Data

i. Initial Vehicle Fleet Fuel Economy / Fuel Consumption Linear Models and ANOVAs

For the reasons described in the Statistical Analysis Methodolgy section above the linear models were created using fuel consumption data (gal/mile), however througout the paper, the figures are then converted to Fuel Economy (gpm). (See Figure 3 and Table 6 below.)

For the report figures that include “whiskers”, these confidence intervals indicate the comparison bars for 95% confidence level statistics. While comparing any of the means to another within a figure, overlapping bars indicate the differences in means are not statistically significant at an Alpha (p-value) of 0.05. Whiskers that don’t overlap for any of the fleet means indicate significantly different means.

Figure 3 shows the fuel economy results from the fuel consumption linear models when the vehicle and elevation data are grouped together but when the three test cycles are kept separate to understand the effects of octane number. The effects of the fuels are significantly different from each other for the LA92 and US06 test cycles and not the US FTP-75.

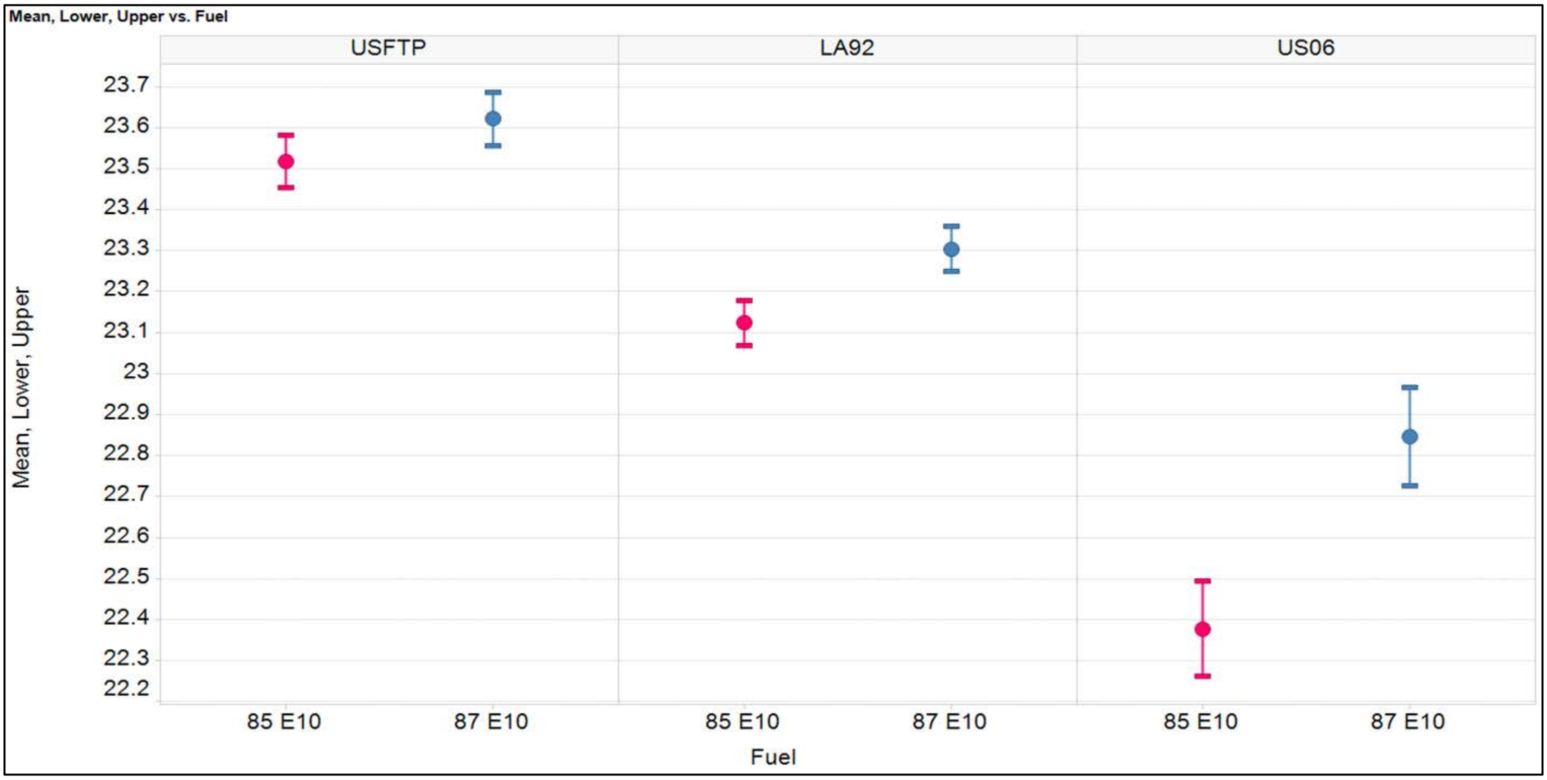


Figure 3 Fleet Averaged Fuel Economy (mpg)

Table 6 shows the ANOVAs generated for the three Fuel Consumption models (US FTP-75, LA92 and US06). The following observations may be drawn from the table:

a. The R-squared terms for all three models are very high, i.e. greater than 0.99, and indicate a very good data fit and that the models can be used with confidence
b. CRC Emissions programs use p-values magnitudes less than 0.05 to determine if two populations are significantly different at 95% confidence. P-values less than 0.05 are highlighted in yellow indicating a rejection of the null hypothesis. And, p-values between 0.05 and 0.10 are considered marginally significant differences at 90% confidence
c. For each of the three models, the vehicle variable (VNumber) in the ANOVA shows the highest F-ratios indicating that the vehicle variation is the largest influence on the model by two orders of magnitude.
d. The Altitude variable is significant for the US FTP-75 and LA92 models and marginally significant for the US06.
e. The Fuel variable is marginally significant for the US FTP-75 model and significant for the LA92 and US06 models. The Fuel f-ratios show increasing contribution to the model as the test cycle severity increases.
f. The interactive model term “Altitude*Fuel” is not significant for any of the three models.

Table 6 Linear Model for Fleet Averaged Fuel Economy (as measured by Fuel Consumption (gal/mile))

	Fuel Consumption (gal / mile)				
TestCycle=US FTP					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	0.00503781	0.00045798	4201.93	<.0001
Error	23	0.00000251	0.00000011		
Corrected Total	34	0.00504032			
R-Square	Coeff Var	Root MSE	FC_Mean Mean		
0.999503	0.779085	0.00033	0.042376		
Source	DF	Type III SS	Mean Square	F Value	Pr > F
VNumber	8	0.00502541	0.00062818	5763.44	<.0001
Altitude	1	0.00001365	0.00001365	125.21	<.0001
Fuel	1	0.00000031	0.00000031	2.81	0.1075
Altitude*Fuel	1	0.00000001	0.00000001	0.06	0.804
TestCycle=LA92					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	0.00483024	0.00043911	5236.61	<.0001
Error	23	0.00000193	0.00000008		
Corrected Total	34	0.00483217			
R-Square	Coeff Var	Root MSE	FC_Mean Mean		
0.999601	0.679044	0.00029	0.042645		
Source	DF	Type III SS	Mean Square	F Value	Pr > F
VNumber	8	0.00480765	0.00060096	7166.66	<.0001
Altitude	1	0.00000654	0.00000654	78.04	<.0001
Fuel	1	0.00000097	0.00000097	11.51	0.0025
Altitude*Fuel	1	0.00000007	0.00000007	0.86	0.3635
TestCycle=US06					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	0.0052596	0.00047815	1101.27	<.0001
Error	23	0.00000999	0.00000043		
Corrected Total	34	0.00526959			
R-Square	Coeff Var	Root MSE	FC_Mean Mean		
0.998105	1.476268	0.000659	0.044634		
Source	DF	Type III SS	Mean Square	F Value	Pr > F
VNumber	8	0.00524218	0.00065527	1509.23	<.0001
Altitude	1	0.00000133	0.00000133	3.05	0.094
Fuel	1	0.00000725	0.00000725	16.69	0.0005
Altitude*Fuel	1	0.00000029	0.00000029	0.67	0.4208

ii. Vehicle Fleet Fuel Economy and Emissions Means (Comparisons within an Elevation)

1. Fuel Economy (FE)

Figure 4 shows the fuel economy results for the same fuel consumption ANOVA found in Table 6 but this time the two elevations are separated out, which reduces the number of data points making up each average by half. The figure shows that for a given octane number, FE is always greater at 5,000 ft. than 1,000 ft. This is due to the atmospheric effects of operating a vehicle at the different elevations. The lower air density requires the engine control module's closed loop air-to-fuel ratio control to open the throttle wider than with more dense air, which in turn, reduces parasitic losses from engine pumping. In the field, a second reason for improved fuel economy at higher elevation is from a lower drag coefficient on a vehicle at higher elevation. This effect, however, was not taken into account during laboratory chassis dynamometer tests, and therefore, does not apply for this data set.

Figure 4 also starts to show the consistent pattern of higher fleet average FE for the 87 AKI relative to the 85 AKI fuel. When evaluated over the US FTP-75 cycle (the data points shown in blue in Figure 4), the confidence intervals around the mean 85 AKI and 87 AKI values overlap for both the 5,000 ft. and 1,000 ft. cases. The overlapping confidence intervals lead one to conclude that the population averages are not significantly different. If the population averages were truly equal however, then given enough measurements with the same variation half of the 85 AKI averages would be less than the 87 AKI ones, which is not the case. These persistent trends are analyzed further in the report sections below.

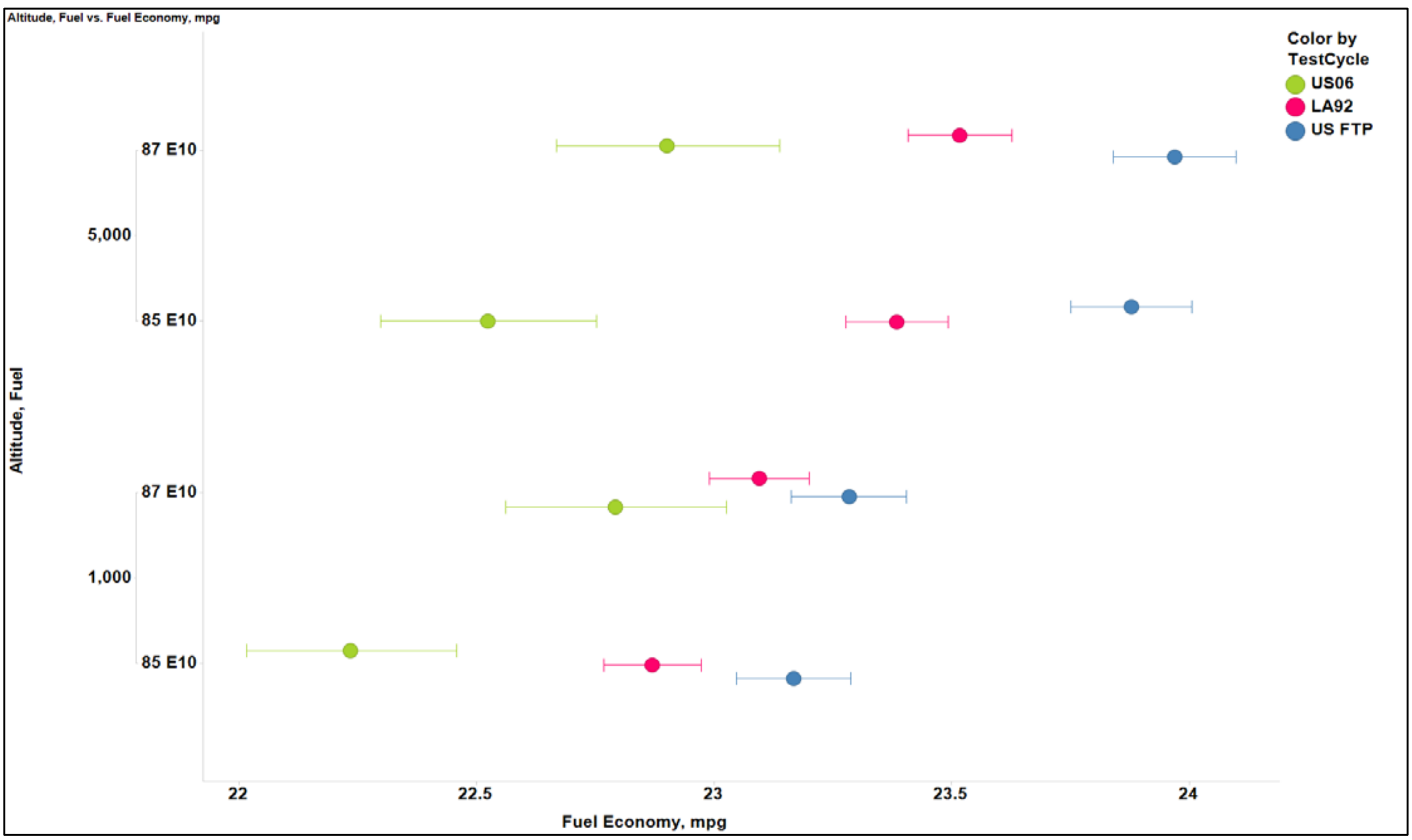


Figure 4 Nine Vehicle FE (mpg) Means with Confidence Intervals

2. **Carbon Dioxide (CO_2)**

Figure 5, shown below, describes information similar to that presented in the previous Fuel Economy section. This similarity is expected because CO_2 is the main component in calculating the FE of a vehicle. The difference, however, is the data trends in an opposite direction to FE. This is also expected because as a vehicle emits less CO_2, the fuel economy improves.

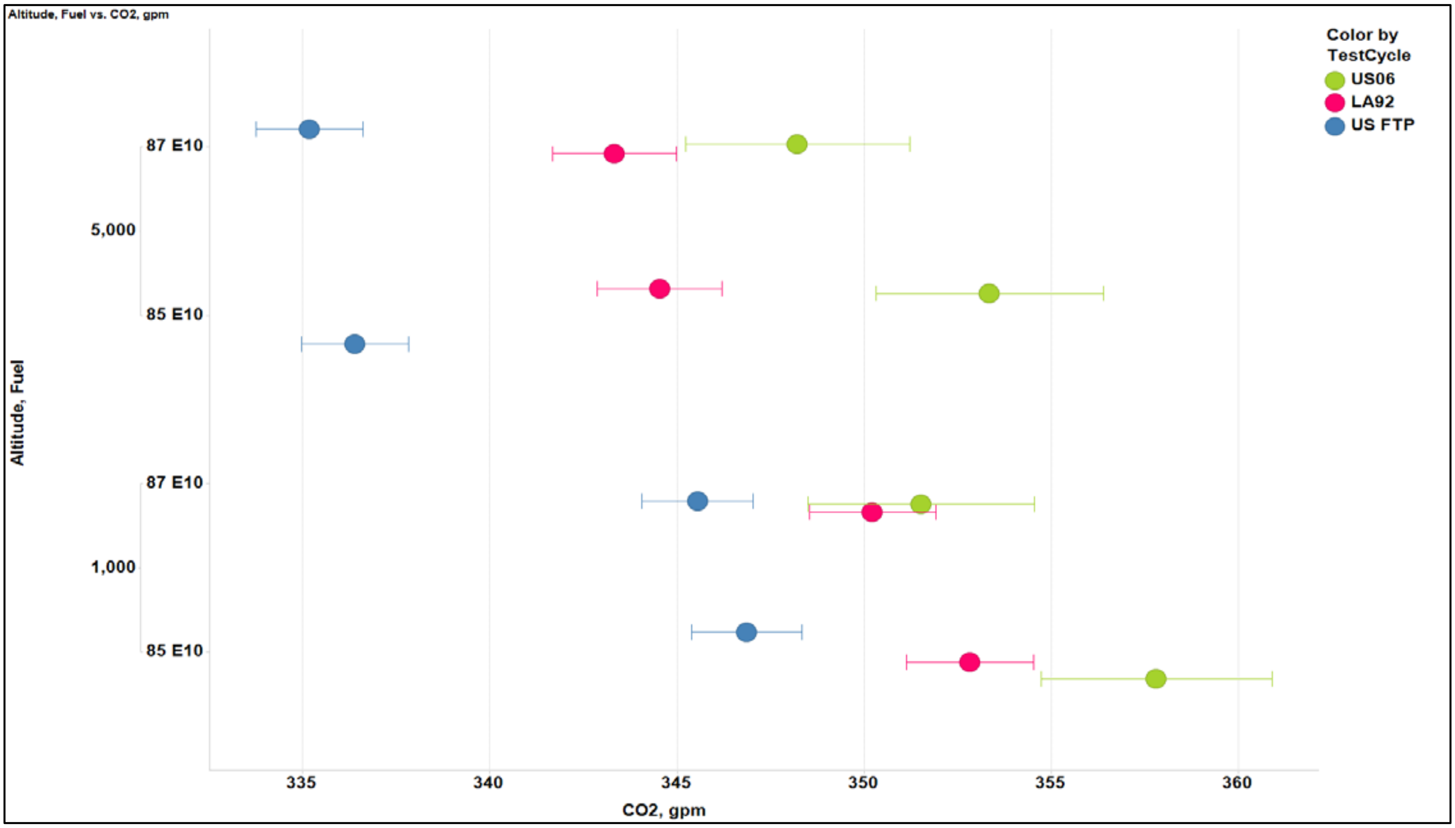


Figure 5 Nine Vehicle CO2 (gpm) Mean with Confidence Intervals

Table 7 CO_2 (gpm) Linear Models within an Elevation

		ln CO2 (gpm)			
TestCycle=US FTP					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.7807231	0.25279301	6390.72	<.0001
Error	23	0.00090979	0.00003956		
Corrected Total	34	2.7816329			
R-Square	Coeff Var	Root MSE	lnCO2_Mean Mean		
0.999673	0.107889	0.006289	5.829492		
Source	DF	Type III SS	Mean Square	F Value	Pr > F
VNumber	8	2.77432467	0.34679058	8767.02	<.0001
Altitude	1	0.00805853	0.00805853	203.72	<.0001
Fuel	1	0.00011831	0.00011831	2.99	0.0971
Altitude*Fuel	1	0.00000007	0.00000007	0	0.9663
TestCycle=LA92					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.53846311	0.23076937	4568.29	<.0001
Error	23	0.00116186	0.00005052		
Corrected Total	34	2.53962497			
R-Square	Coeff Var	Root MSE	lnCO2_Mean Mean		
0.999543	0.121674	0.007107	5.841382		
Source	DF	Type III SS	Mean Square	F Value	Pr > F
VNumber	8	2.52775791	0.31596974	6254.9	<.0001
Altitude	1	0.00411583	0.00411583	81.48	<.0001
Fuel	1	0.00025577	0.00025577	5.06	0.0343
Altitude*Fuel	1	0.00003324	0.00003324	0.66	0.4256
TestCycle=US06					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.60301219	0.23663747	1470.29	<.0001
Error	23	0.00370176	0.00016095		
Corrected Total	34	2.60671395			
R-Square	Coeff Var	Root MSE	lnCO2_Mean Mean		
0.99858	0.215937	0.012686	5.875079		
Source	DF	Type III SS	Mean Square	F Value	Pr > F
VNumber	8	2.59146987	0.32393373	2012.68	<.0001
Altitude	1	0.00104176	0.00104176	6.47	0.0181
Fuel	1	0.00226597	0.00226597	14.08	0.001
Altitude*Fuel	1	0.00002139	0.00002139	0.13	0.7188

3. Carbon Monoxide (CO)

Figure 6 shows the nine vehicle fleet averages for CO emissions. Similar to the Figures 4 and 5, Figure 6 shows a confidence interval plot for each test cycle, categorized by fuel octane rating and simulated test elevation. The amount of CO emitted increases as cycle severity also increases. At the most severe test cycle, US06, the fleet average emissions from operation on 85 AKI fuel are greater than those from the 87 AKI fuel, but the difference is only statistically significant for the 1,000 ft. elevation case.

Carbon monoxide emissions, however, are indicative of factors in addition to the fuel and elevation tested. These factors include OEM combustion strategy and driver behavior. The latter was mitigated as much as possible by limiting the number of different drivers who tested the vehicles, to a reasonable degree. The former should be a limited contributor to the overall fleet average because the vehicles originated from a bevy of manufacturers.

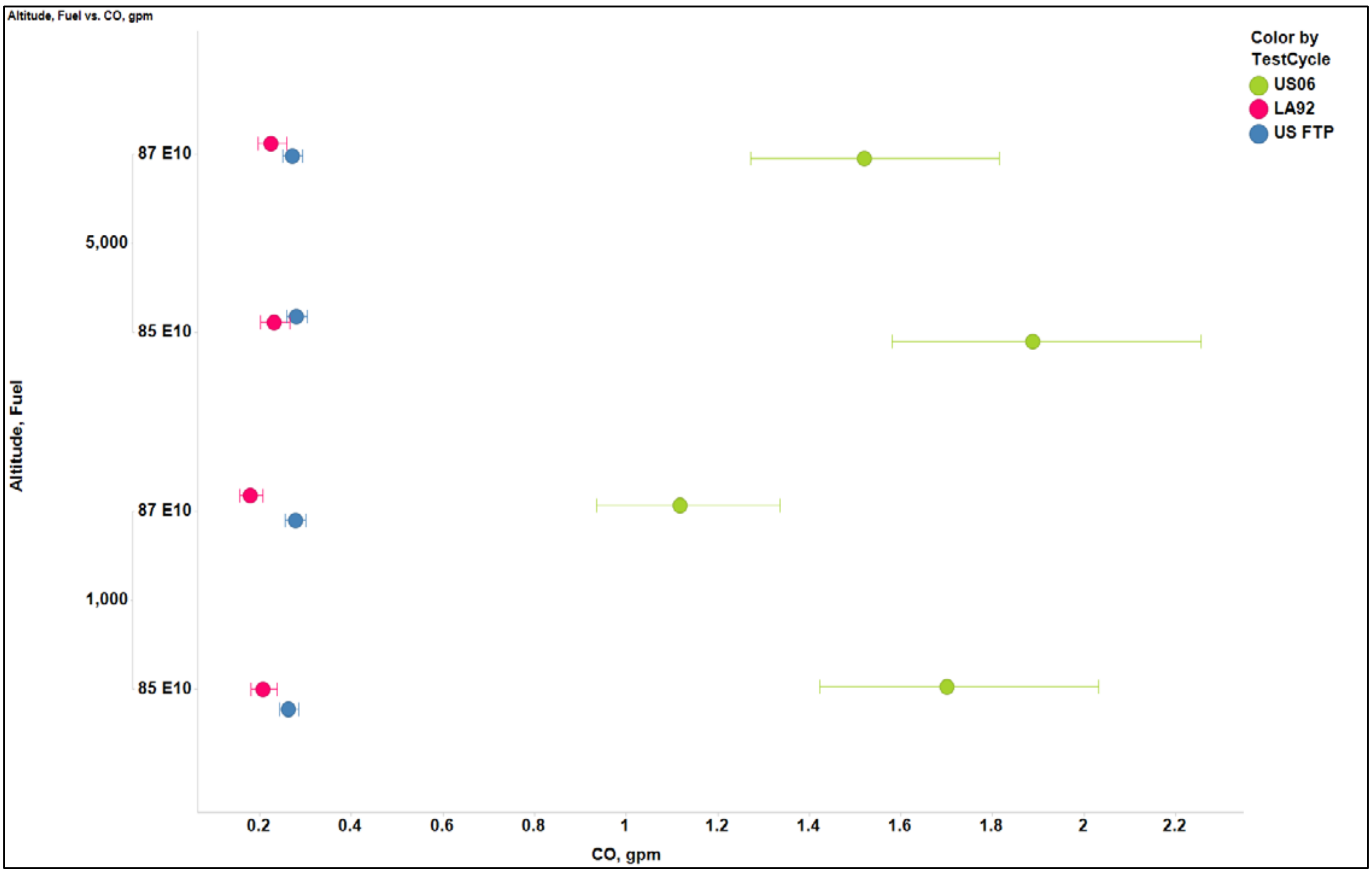


Figure 6 Nine Vehicle CO (gpm) Mean with Confidence Intervals

Table 8 CO (gpm) Linear Models within an Elevation

		ln CO (gpm)			
TestCycle=US FTP					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	11	20.43993696	1.85817609	121.38	<.0001
Error	24	0.36741644	0.01530902		
Corrected Total	35	20.80735341			
R-Square	**Coeff Var**	**Root MSE**	**nCO_Mean Mean**		
0.982342	-9.5195	0.12373	-1.29975		
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
VNumber	8	20.41767317	2.55220915	166.71	<.0001
Altitude	1	0.00387475	0.00387475	0.25	0.6195
Fuel	1	0.00087077	0.00087077	0.06	0.8135
Altitude*Fuel	1	0.01751828	0.01751828	1.14	0.2954
TestCycle=LA92					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	11	41.61994505	3.78363137	91.58	<.0001
Error	23	0.9501983	0.04131297		
Corrected Total	34	42.57014335			
R-Square	**Coeff Var**	**Root MSE**	**nCO_Mean Mean**		
0.977679	-12.9257	0.203256	-1.572496		
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
VNumber	8	41.24618049	5.15577256	124.8	<.0001
Altitude	1	0.24275267	0.24275267	5.88	0.0236
Fuel	1	0.06399254	0.06399254	1.55	0.2258
Altitude*Fuel	1	0.02854297	0.02854297	0.69	0.4144
TestCycle=US06					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	11	35.59741153	3.23612832	47.14	<.0001
Error	23	1.57882969	0.06864477		
Corrected Total	34	37.17624123			
R-Square	**Coeff Var**	**Root MSE**	**nCO_Mean Mean**		
0.957531	56.44325	0.262001	0.464186		
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
VNumber	8	33.31124261	4.16390533	60.66	<.0001
Altitude	1	0.36545529	0.36545529	5.32	0.0304
Fuel	1	0.87429692	0.87429692	12.74	0.0016
Altitude*Fuel	1	0.08849718	0.08849718	1.29	0.2679

iii. Percent Change in Nine Vehicle Fleet Means for FE and Emissions

1. Fuel Economy

The nine vehicle fuel economy means for each of the three test cycles at each elevation are shown in Table 9 along with the deltas between the two means. Table 9 also shows the p-value showing whether the two means are significantly different and the percent change in moving from 87 to 85 AKI test fuels. P-values less than 0.05 are highlighted in yellow.

Table 9 shows that the FE fleet means for the 85 AKI gasoline are all trending lower than the 87 AKI fuel within an elevation comparison, however the p-values are greater than 0.05 except for the LA92 and US06 test cycles for the 1,000 ft. case.

Table 9 Fuel Economy – Nine Vehicle Fleet Means, Deltas, Percent Change, and p-values

FE (mpg)										
Outliers Removed	5000	5000	p-value	Delta	% Change	1000	1000	p-value	Delta	% Change
	85 AKI	87 AKI		85 - 87	87 --> 85	85 AKI	87 AKI		85 - 87	87 --> 85
FTP-75	23.8775	23.9691	0.7353	-0.0916	-0.4%	23.1667	23.2834	0.5507	-0.1167	-0.5%
LA92	23.3837	23.5172	0.3083	-0.1335	-0.6%	22.8694	23.0942	0.0306	-0.2248	-1.0%
US06	22.5226	22.9002	0.1144	-0.3776	-1.6%	22.2344	22.7917	0.0122	-0.5573	-2.4%

Figure 8 shows that the impact of operating the test fleet on 85 AKI fuel relative to 87 AKI fuel for FE becomes more significant (smaller p-value) as the driving cycle becomes more demanding from the US FTP-75-type driving and through to the more aggressive US06.

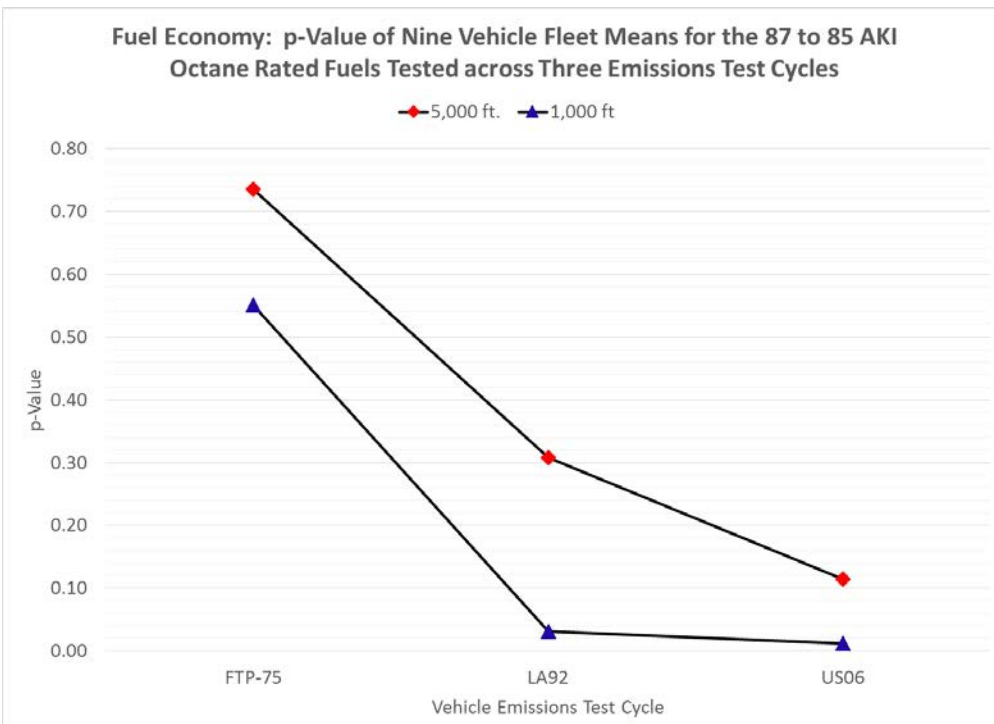


Figure 7 Fuel Economy p-Values with Respect to Emissions Test Cycle

Figure 9 shows the fleet average percent change in fuel economy moving from 87 to 85 AKI fuel with respect to the average vehicle speed for the emissions cycles tested.

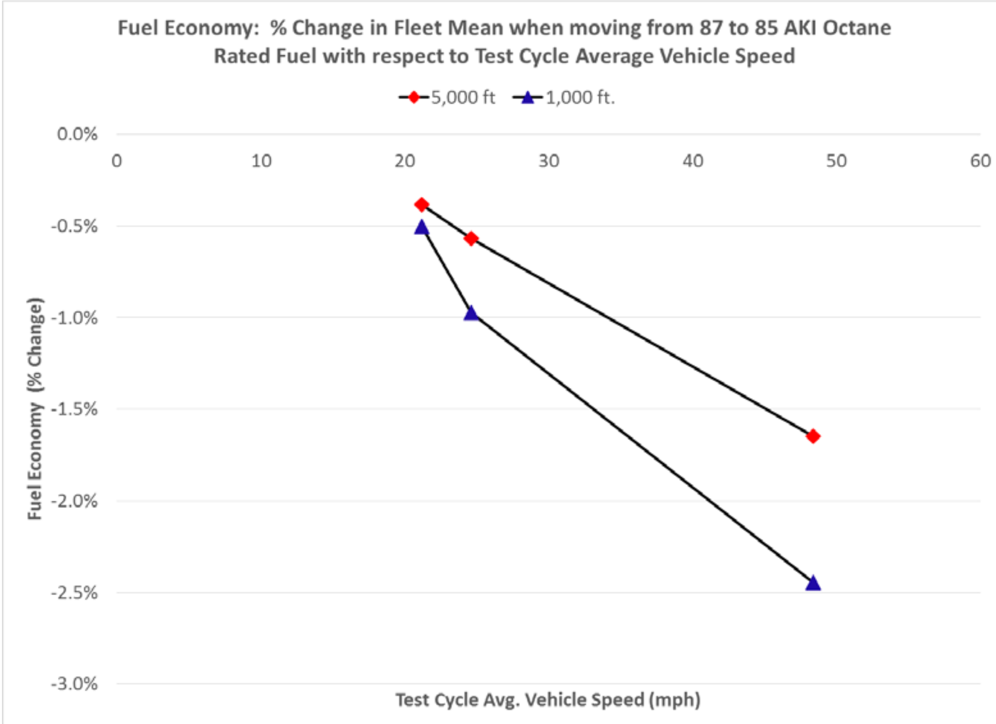


Figure 8 Average Percent Change in FE with Respect to Emissions Test Cycle Average Speed

2. Carbon Dioxide

For the remaining tailpipe emissions and performance parameter summary tables that follow, an additional light gray shading is used to show p-values between 0.05 and 0.10, while yellow continues to show $p < 0.05$ effects.

Table 10 Carbon Dioxide – Nine Vehicle Fleet Means, Deltas, Percent Change, and p-values

CO2 (gpm)										
Outliers Removed	5000	5000	p-value	Delta	% Change	1000	1000	p-value	Delta	% Change
	85 AKI	87 AKI		85 - 87	87 --> 85	85 AKI	87 AKI		85 - 87	87 --> 85
FTP-75	336.3948	335.1829	0.6225	1.2119	0.4%	346.8585	345.5458	0.6155	1.3127	0.4%
LA92	344.5251	343.3285	0.7290	1.1966	0.3%	352.8187	350.2167	0.1758	2.6020	0.7%
US06	353.3398	348.2110	0.0965	5.1288	1.5%	357.8025	351.5022	0.0415	6.3003	1.8%

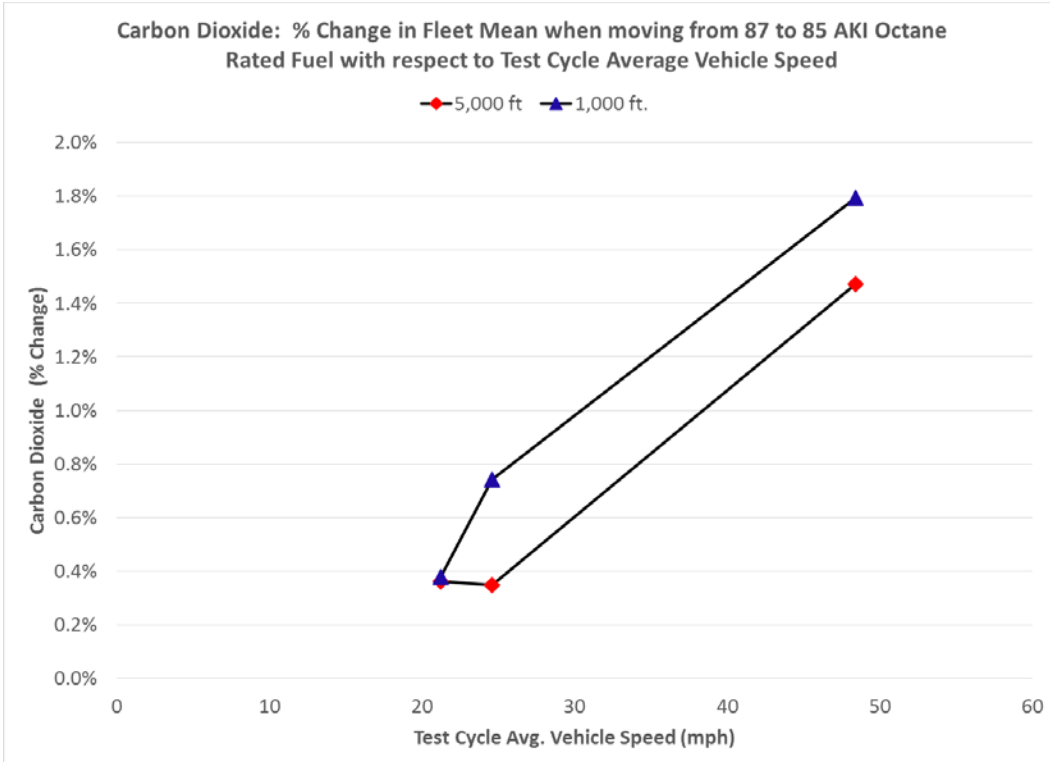


Figure 9 Average Percent Change in CO_2 with Respect to Emissions Test Cycle Average Speed

3. Carbon Monoxide

The nine vehicle carbon monoxide (CO) means for each of the three test cycles at each elevation are shown in Table 11 along with the deltas between the two means and p-values. CO is an internal combustion engine partial oxidation species resulting from incomplete combustion. Combustion auto-ignition (knock) is a potentially engine damaging phenomena that is often managed by in-cylinder fuel enrichment, which leads to increased CO emissions and lower FE. Table 11 shows large percent changes in CO for the average fleet when operating on 85 versus 87 AKI test fuels as the test cycles become more knock limited.

Table 11 Carbon Monoxide – Nine Vehicle Fleet Means, Deltas, Percent Change, and p-values

CO (gpm)										
Outliers Removed	5000	5000	p-value	Delta	% Change	1000	1000	p-value	Delta	% Change
	85 AKI	87 AKI		85 - 87	87 --> 85	85 AKI	87 AKI		85 - 87	87 --> 85
FTP-75	0.2802	0.2708	0.9348	0.0094	3.5%	0.2626	0.2772	0.7918	-0.0146	-5.3%
LA92	0.2314	0.2249	0.9905	0.0065	2.9%	0.2073	0.1796	0.4888	0.0277	15.4%
US06	1.8881	1.5199	0.3359	0.3682	24.2%	1.7008	1.1183	0.0124	0.5825	52.1%

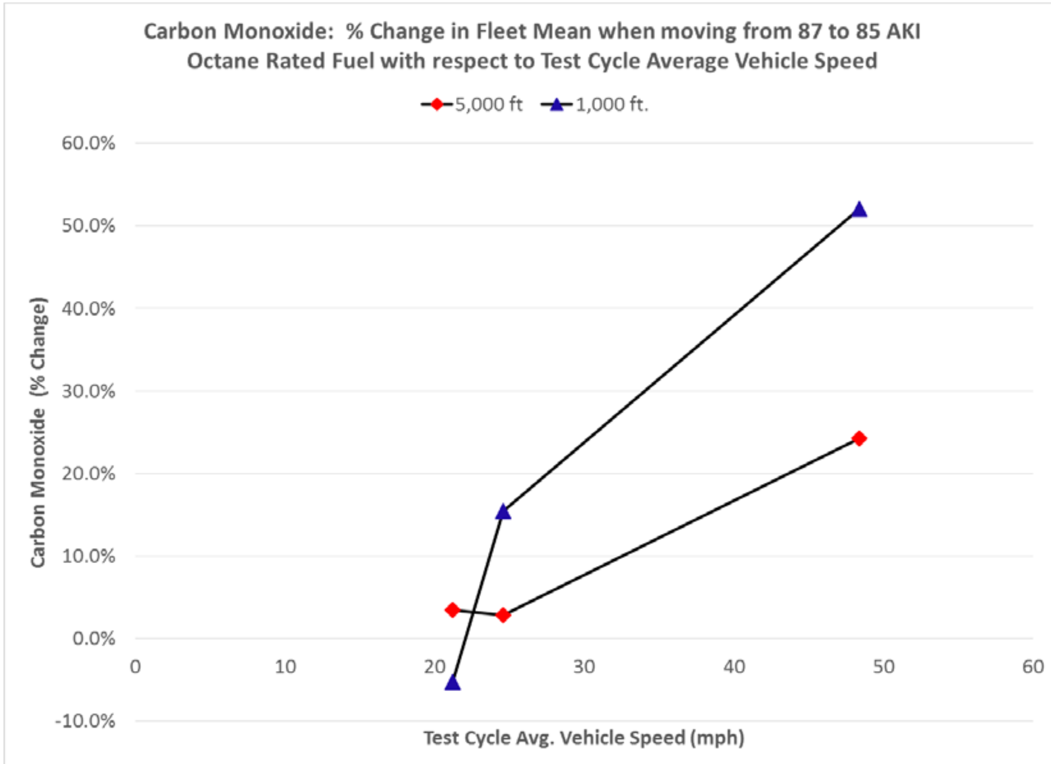


Figure 10 Average Percent Change in CO with Respect to Emissions Test Cycle Average Speed

iv. Fuel Economy and Emissions Averages for Individual Vehicles

Individual vehicle averages for FE, CO2, and CO are shown in this section and are the average of at least two and often three tests.

1. Fuel Economy

Figure 12 shows the average fuel economy (FE) results for each of the nine vehicles for the two test fuels, two elevations, and three emissions test cycles. In absolute numbers, the vehicle test fleet FE covered a large range from approximately 16 to 38 mpg depending on type of vehicle, test conditions and fuel octane level. The FE of the US06 results is generally lower than the US FTP-75 and LA92 primarily as a result of higher vehicle loading as well as being a more knock limited test cycle where fuel enrichment is used to mitigate knock.

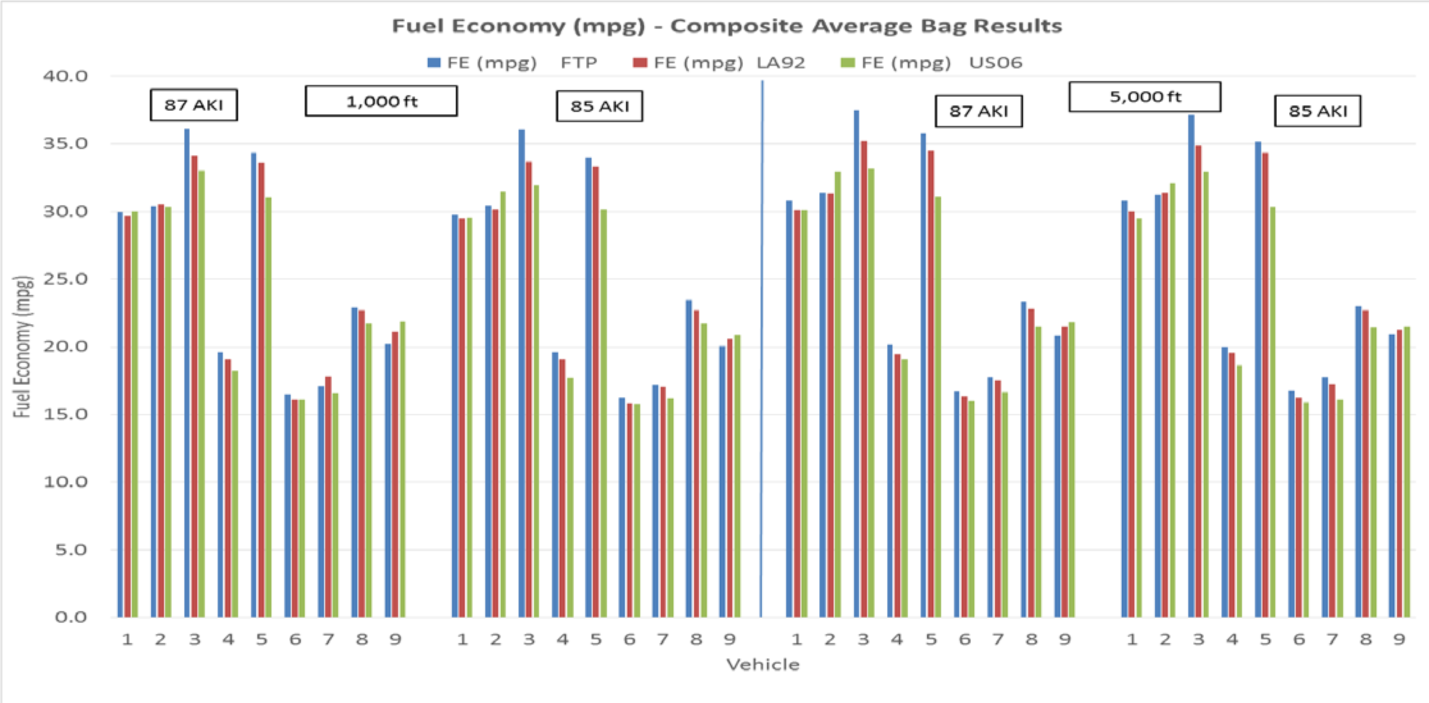


Figure 11 Individual Vehicle Average Fuel Economy

2. Fuel Consumption – Vehicle Fuel Consumption Changes for 85 and 87 AKI Fuels

The Engine Control Module (ECM) calibration strategies used by vehicle manufacturers vary greatly with respect to managing the effects of autoignition and protecting engine hardware. Consequently, the effect of using 85 AKI gasoline in a vehicle calibrated for 87 AKI is likely to differ across different vehicle makes and models. In order to understand the statistical significance of the individual vehicle FE differences measured in this test program, a heuristic significance test for each vehicle was developed using an estimate of repeatability.

Figures 13, 15, and 17 include intervals showing a heuristic indication of whether the change from 87 to 85 AKI gasoline was significant for each vehicle. Throughout the test program, the test vehicles were first fueled, conditioned, and tested with the specified octane test fuel at the appropriate simulated altitude. Then two or more back-to-back sets of tests were run on the vehicle before changing fuel and repeating the vehicle conditioning. (See Figure 1.) While this "back-to-back" test repeat sequence was needed to conduct the large number of tests in a reasonable amount of time and volume of test fuel available, the test repeats did not truly alternate between 85 and 87 AKI for the individual test observations. Due to the lack of true replication in this study, a rigorous test of individual vehicle response to the fuel AKI difference could not be performed. However for the purpose of this heuristic exercise, analyses were conducted as if the back-to-back tests were replicates and recognize that resultant estimate of residual error for comparisons is biased low due to correlation among back-to-back tests. A simple repeatability type comparison was used for each vehicle without accounting for multiple comparisons. The risk of concluding a significant difference if it were truly by chance is actually greater than the nominal 5% for which these intervals were calculated. With all these caveats, the interpretation for Figures 13, 15, and 17 is that when the interval does not cross zero for the deltas or one for the ratios, there is purported significant evidence of a difference for that individual vehicle.

Figure 13 shows the change in fuel consumption per 100 miles for each vehicle when fueled with 85 versus 87 AKI gasoline for the three test cycles at 5,000 and 1,000 ft. simulated altitudes. Most of the vehicle fuel consumption averages were higher with 85 AKI however their heuristic confidence intervals include the zero point indicating no statistical difference from zero. The deltas between 85 and 87 AKI increase as the test cycle becomes more demanding.

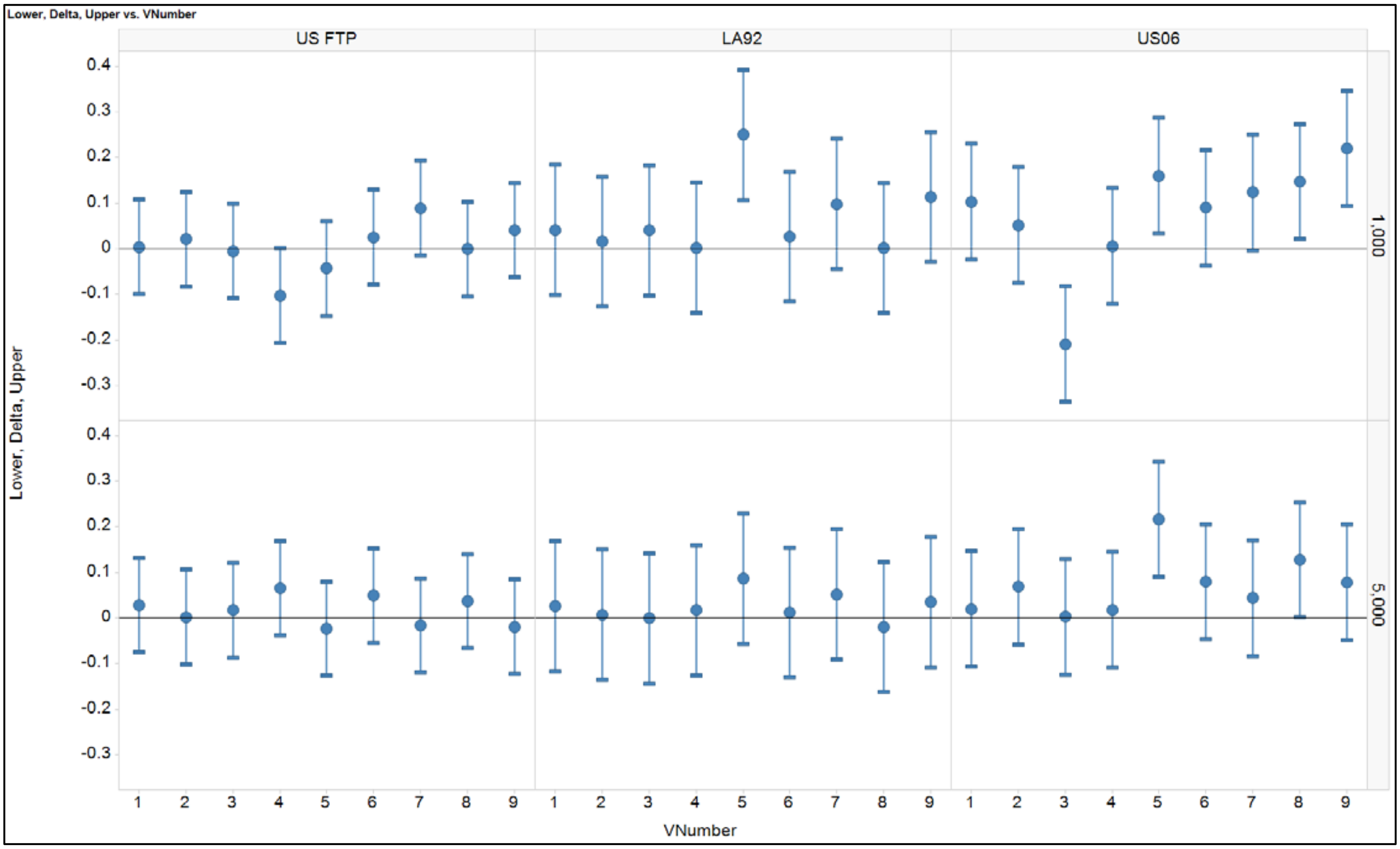


Figure 12 Individual Vehicle Fuel Consumption Deltas (85 AKI - 87 AKI gallons / 100 miles)

Investigating the trends of the averages in Figure 13, if AKI had no consistent effect on fuel economy, each of the deltas would have a 50% chance of being positive and a 50% chance of being negative. For a given altitude, of the 27 percent changes (nine vehicles times three test cycles), 22 were negative or had poorer FE on 85 AKI test fuel. The chance of flipping a fair coin 27 times and getting 22 or more tails is 0.0008. This is a p-value for the one-sided test of whether 85 versus 87 AKI gasoline had significantly lower fuel economy across the nine vehicles and three test cycles at either 5000 or 1000 foot simulated altitude. While binominal trend analyses may be useful in identifying directional trends, they do not take into account the magnitude or statistical significance of the measured differences.

Table 12 below summarizes the binomial probabilities for FE, CO, and CO2. The table shows the probability of the majority of percent deltas resulting in poorer CO_2 and CO emissions and FE while operating on 85 AKI gasoline relative to 87 AKI gasoline at both elevations tested and across all three test cycles arising purely by chance is very low.

Table 12 P-Value Summary for Individual Vehicle Response

One-sided p-value for x out of 27 deltas (9 vehicles x 3 test cycles) with worse performance for 85 AKI (positive for emissions, negative for fuel economy)			
Measure	Altitude	x	p-value
CO	1000	17	0.12
CO_2	1000	19	0.03
Fuel Economy	1000	22	0.00
CO	5000	18	0.06
CO_2	5000	20	0.02
Fuel Economy	5000	22	0.00

Table 13 Average Vehicle Fuel Economy Change when moving from 87 to 85 AKI Fuel

		Fuel Economy Change (%) 87 to 85 AKI		
VNumber	Altitude (ft.)	US FTP	LA92	US06
1	5000	-1.06	-0.92	-0.67
2	5000	-0.07	-0.24	-2.03
3	5000	-0.55	0.02	-0.11
4	5000	-1.51	-0.40	-0.40
5	5000	0.41	-1.49	-3.48
6	5000	-1.73	-0.43	-2.44
7	5000	0.26	-0.85	-0.70
8	5000	-0.75	0.37	-2.38
9	5000	0.39	-0.75	-1.70
1	1000	-0.15	-1.40	-3.32
2	1000	-0.62	-0.47	-1.55
3	1000	0.14	-1.22	6.75
4	1000	2.40	-0.06	-0.14
5	1000	0.74	-4.26	-2.60
6	1000	-0.88	-0.89	-2.72
7	1000	-1.45	-1.56	-1.96
8	1000	0.01	-0.04	-2.62
9	1000	-0.83	-2.34	-4.60

3. Carbon Dioxide – Absolute Values

Carbon dioxide (CO_2) is the primary exhaust constituent impacting the calculation of a vehicle's fuel economy using the carbon balance methodology. Detailed information on the carbon balance procedure for measuring fuel consumption as it relates to the carbon products of a vehicle's exhaust can be found in the Code of Federal Register, 40 CFR Part 600. In practice, because vehicle exhaust CO_2 is generally three orders of magnitude higher in concentration than the other carbon constituents, it is highly inversely proportional to FE. Each vehicle's average CO_2 emission rates are shown in Figure 14 and ranged approximately from 220 to 525 g/mile.

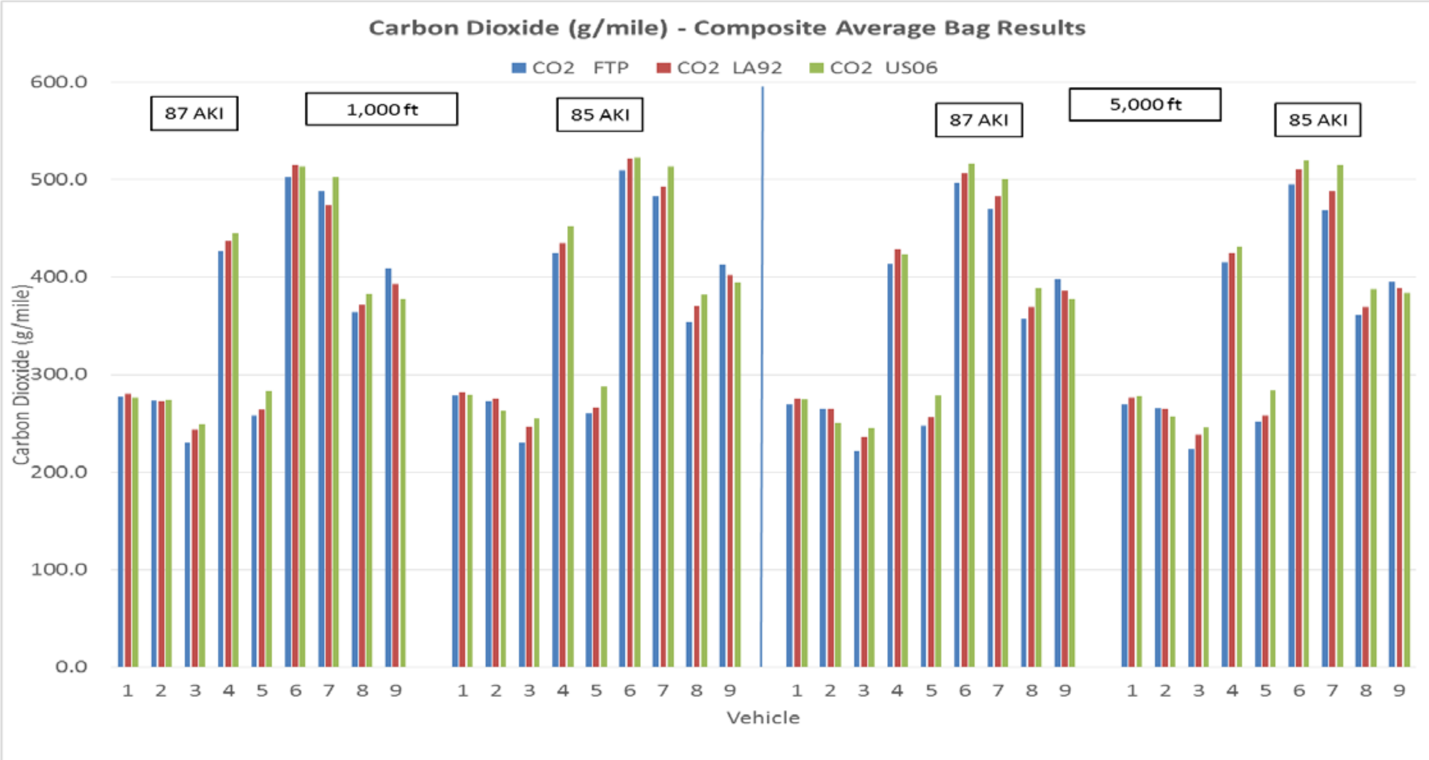


Figure 13 Individual Vehicle Average CO2 Emissions

4. Carbon Dioxide – Change when moving from 87 to 85 AKI

In order to help visualize the effects octane level, test cycle, and elevation on CO_2, Figure 15 shows the average change in CO_2 for each vehicle when fueled with 85 versus 87 AKI gasoline. Within an elevation, CO_2 was generally higher while operating on 85 AKI test fuel and the difference increased with test cycle severity, i.e. more differences were higher as the test cycle became more demanding or more spark knock limited. See Table 12 above for the probability of this occurring and its statistical significance.

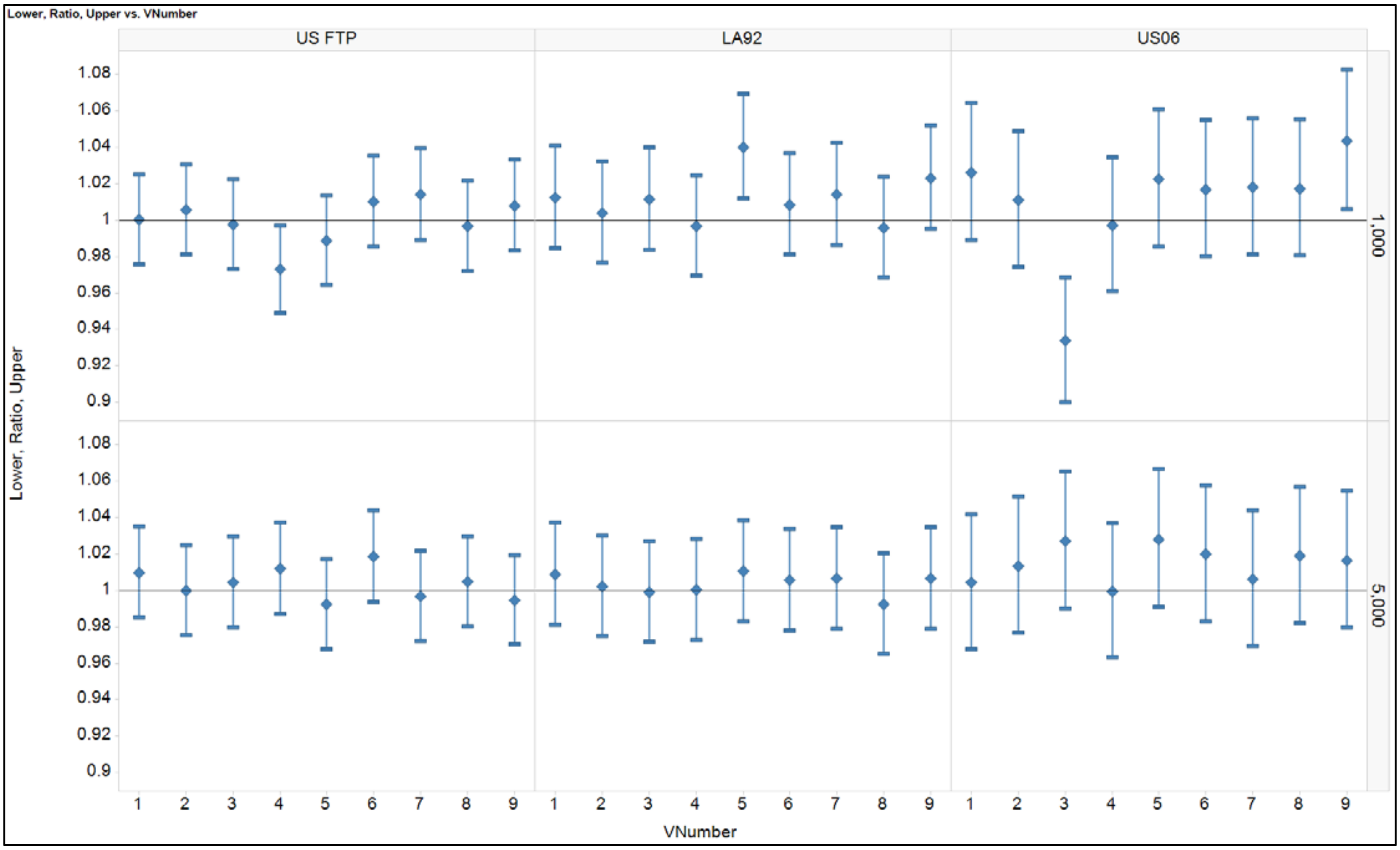


Figure 14 Individual Vehicle CO2 Ratio (85 AKI gpm / 87 AKI gpm)

Table 14 Average Vehicle *CO_2 Percent Change when moving from 87 to 85 AKI Fuel*

VNumber	Altitude (ft.)	CO_2 Change (%) 87 to 85 AKI		
		US FTP	LA92	US06
1	5000	0.98	0.89	0.41
2	5000	0.00	0.22	1.34
3	5000	0.45	-0.10	2.70
4	5000	1.18	0.02	-0.06
5	5000	-0.78	1.04	2.79
6	5000	1.86	0.56	1.97
7	5000	-0.32	0.65	0.61
8	5000	0.46	-0.76	1.88
9	5000	-0.53	0.64	1.65
1	1000	0.03	1.22	2.62
2	1000	0.55	0.40	1.08
3	1000	-0.23	1.15	-6.62
4	1000	-2.71	-0.33	-0.27
5	1000	-1.11	4.01	2.24
6	1000	1.02	0.85	1.68
7	1000	1.40	1.42	1.79
8	1000	-0.33	-0.39	1.75
9	1000	0.80	2.32	4.36

5. Carbon Monoxide – Absolute Values

The individual vehicle carbon monoxide (CO) averages for each of the three test cycles and each elevation are shown in Figure 16. CO is an internal combustion engine partial oxidation species resulting from incomplete combustion. For a warmed-up engine and exhaust system CO generally occurs during times of in-cylinder enrichment and for a cold engine CO generally occurs during the initial rich warm-up operation of the engine and prior to catalyst light-off, although more and more vehicles are utilizing stoichiometric starts and fast light off systems. Abnormal combustion auto-ignition (knock) is a potentially engine damaging phenomena occurring in a fully warmed up engine that is often managed by in-cylinder fuel enrichment and leads to increased CO emissions and lower FE. Figure 16 shows one vehicle in the test fleet consistently demonstrated higher tailpipe CO levels than the others and the nine test vehicle CO values ranged from 0.10 to 10 g/mile. CO emissions rates were highest during the US06 knock limited test cycle.

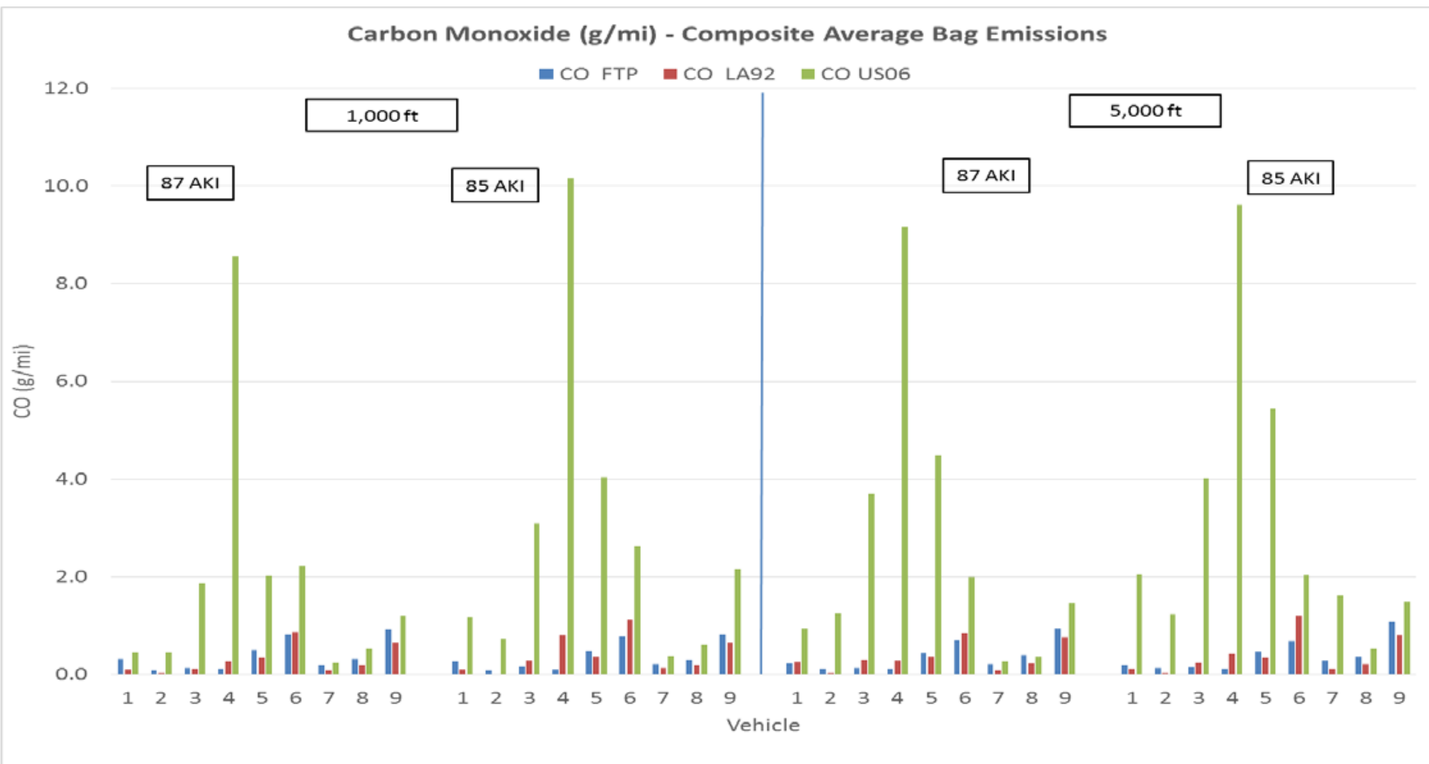


Figure 15 Individual Vehicle Average CO Emissions

6. Carbon Monoxide – Percent Change when moving from 87 to 85 AKI

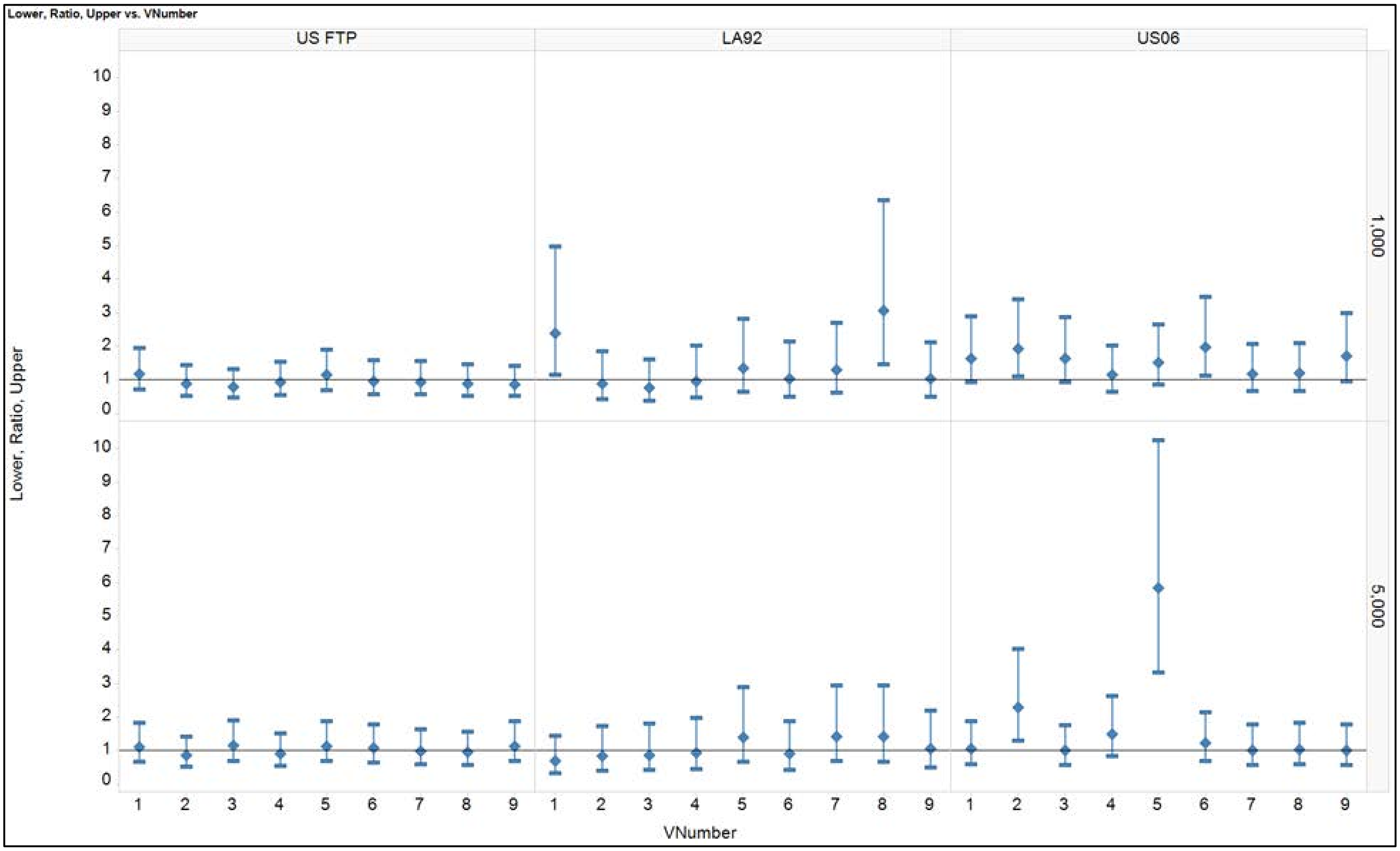


Figure 16 Individual Vehicle CO Ratio (85 AKI gpm / 87 AKI gpm)

Table 15 Average Vehicle CO Percent Change when moving from 87 to 85 AKI Fuel

VNumber	Altitude (ft.)	CO Change (%) 87 to 85 AKI		
		US FTP	LA92	US06
1	5000	11.64	-30.56	64.74
2	5000	-13.71	-16.59	94.27
3	5000	15.94	-12.96	63.39
4	5000	-8.57	-5.12	14.88
5	5000	14.18	39.26	51.14
6	5000	8.30	-9.62	97.53
7	5000	-1.37	42.59	18.69
8	5000	-4.46	42.06	20.08
9	5000	14.43	6.06	70.38
1	1000	18.34	139.51	64.74
2	1000	-12.08	-10.18	94.27
3	1000	-20.35	-22.15	63.39
4	1000	-6.71	-2.65	14.88
5	1000	14.90	36.24	51.14
6	1000	-3.90	3.95	97.53
7	1000	-5.56	30.42	18.69
8	1000	-10.86	206.38	20.08
9	1000	-14.38	2.41	70.38

v. Vehicle Performance Data Means for Eight Vehicle Fleet Means

In the Vehicle Performance series of charts, there are four composite mean results for each vehicle performance parameter compared to only three composite means for the tailpipe emissions data. This is due to an artifact of the emissions test cycle details and the data recording devices monitoring the signals coming from the vehicle engine control module (ECM). During the US FTP-75 cycle, the vehicle is turned off between the 2nd and 3rd phases. Upon "key-on" for the 3rd phase, the restart triggers the data acquisition unit to start a new and separate data file. The reader should also note that there are only eight vehicles included in these mean results because one of the test vehicles was not equipped with an ECM data logger. The ninth test vehicle without the data logger did complete the same set of emissions tests as the others, however, no ECM Performance data were captured from it.

1. Engine Speed

For a given emissions cycle, each of the vehicles is being commanded to run a series of maneuvers in exactly the same way and therefore, the composite mean vehicle speed across the entire emissions cycle is equivalent and precise from test to test. The engine speed, however, is a measure of how fast or slow the engine had to operate to drive the commanded vehicle speed trace under a given combination of elevation and fuel octane level. Note that engine speed in rpm is different than vehicle speed in mph or kph.

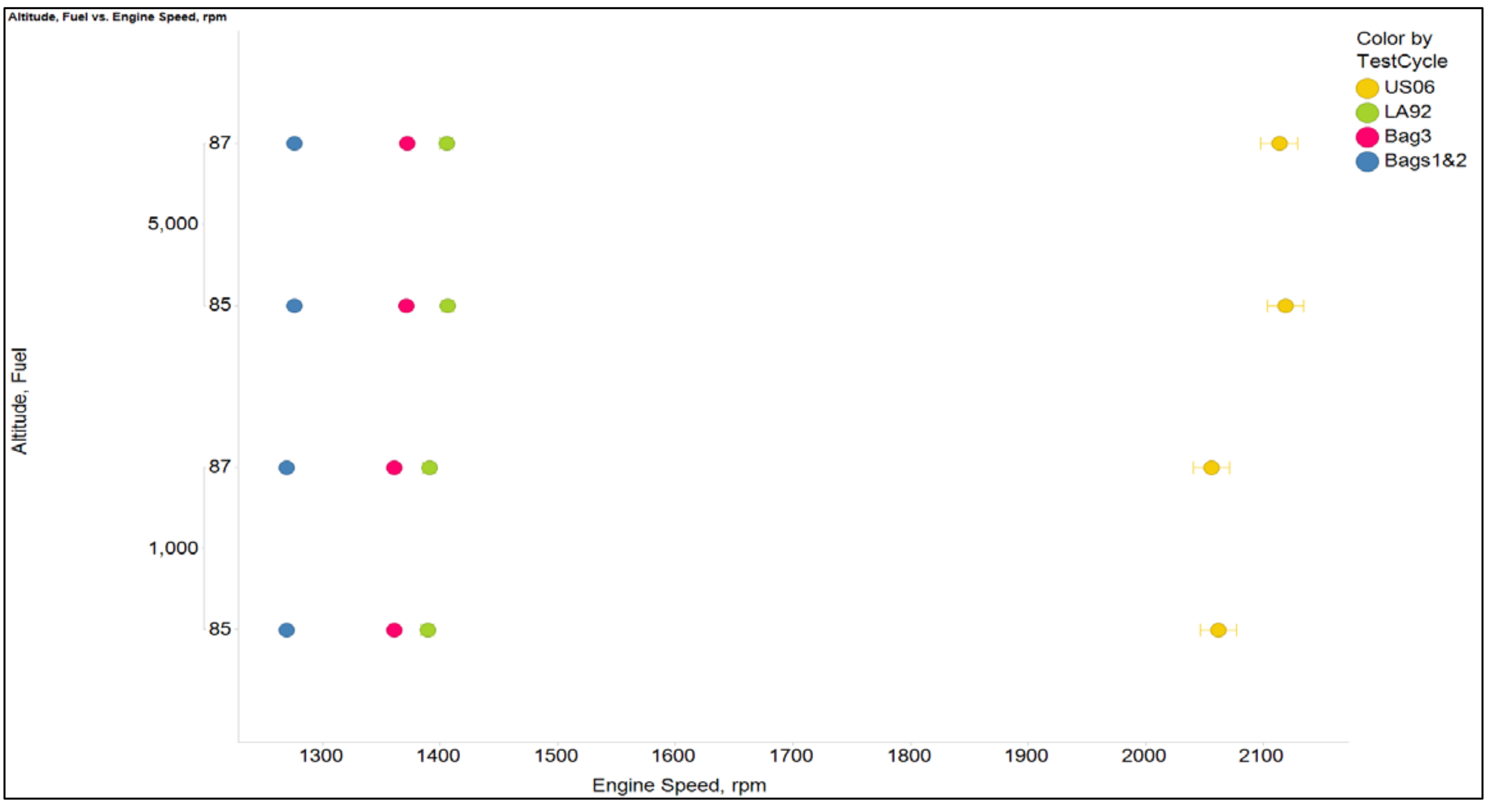


Figure 17 Eight Vehicle Fleet Engine Speed (rpm) Means with Confidence Intervals

2. Engine Percent Load

Figure 18 Eight Vehicle Fleet Engine Load (%) Means with Confidence Intervals

3. Ignition Timing

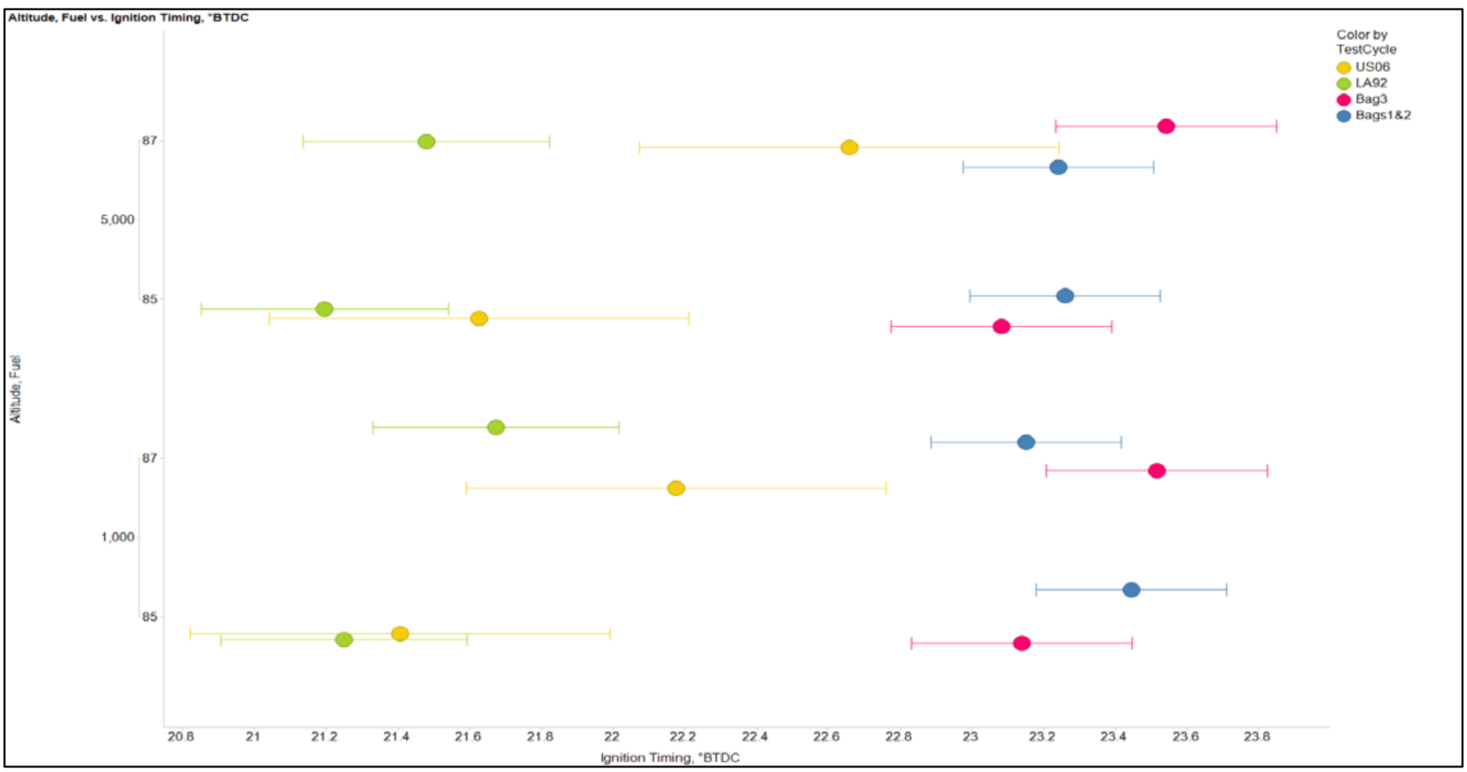


Figure 19 Eight Vehicle Fleet Ignition Timing (°BTDC) Means with Confidence Intervals

4. Pre-Catalyst Temperature

For this octane study, the Pre-Cat temperature is indicative of the effect of octane on engine combustion temperature whereas the Mid-Cat temperature is indicative of impact of octane and the knock control response system on the heat release across the catalyst system (and potentially catalyst durability.) The average eight vehicle test fleet pre- and mid- catalyst temperature changes with octane shown in Figures 21 and 22 are small for the reasons described above regarding the vehicle to vehicle calibration differences in mitigating knock. The fleet average temperatures for 85 AKI test fuel compared to the 87 AKI temperatures on average were higher for the LA92 and US06 test cycles but not significant.

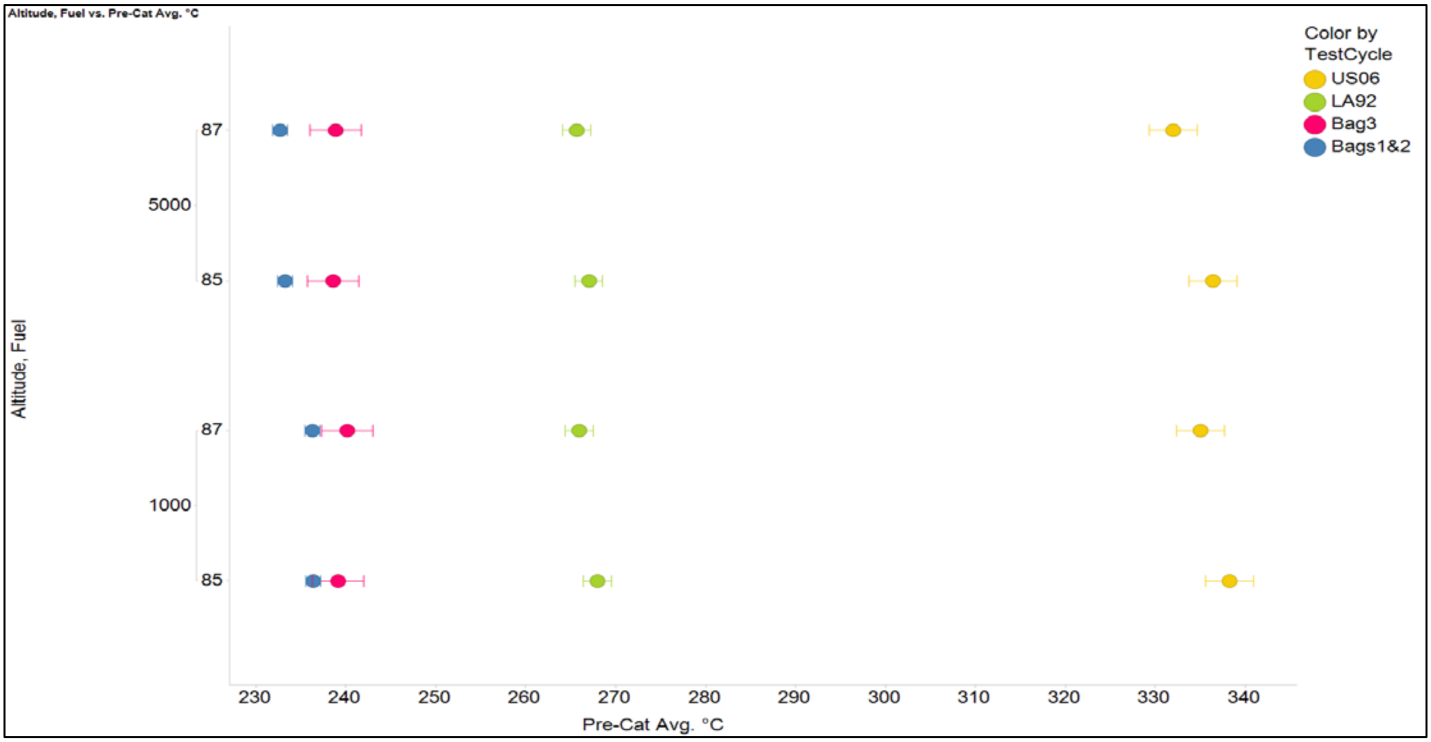


Figure 20 Eight Vehicle Fleet Pre-Catalyst Temperature (°C) Means with Confidence Intervals

5. Mid-catalyst Temperature

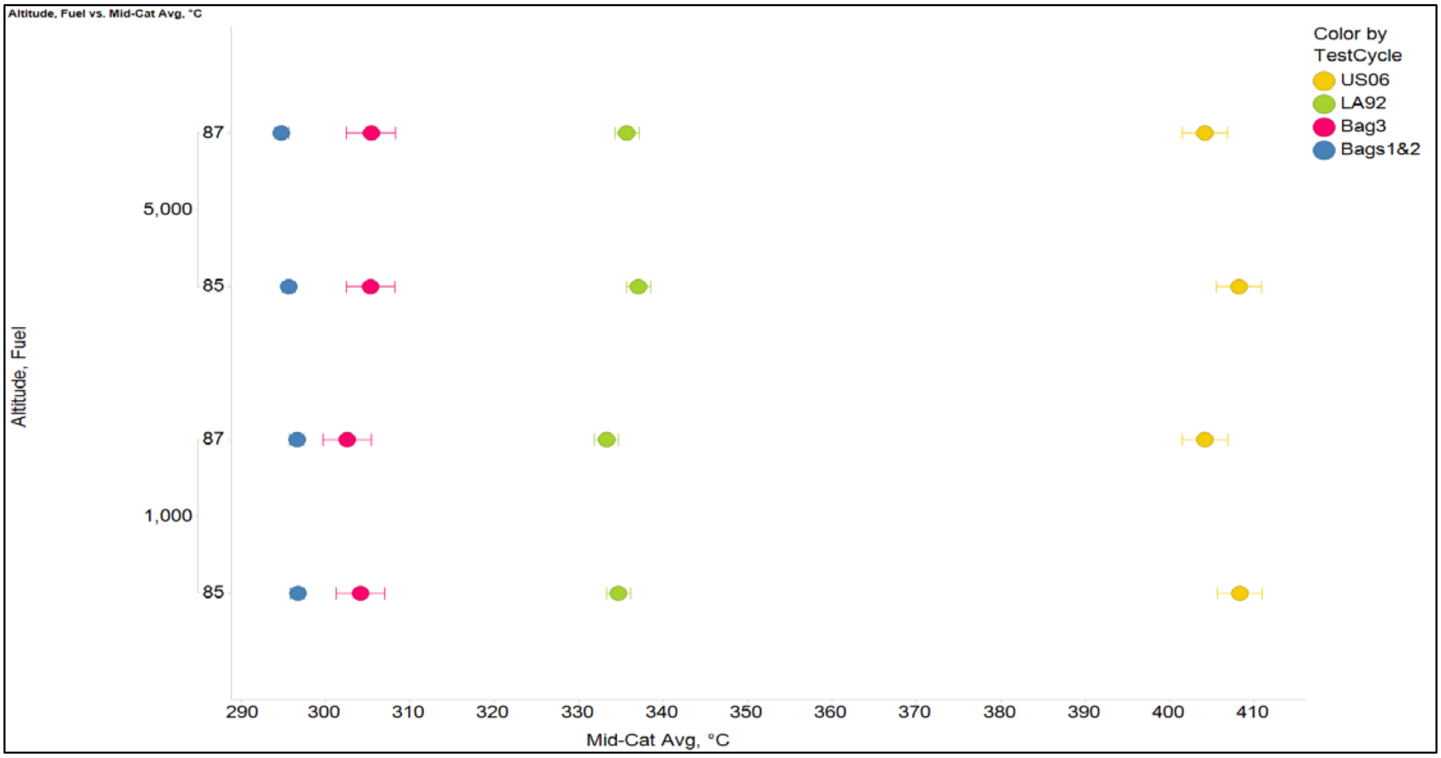


Figure 21 Eight Vehicle Fleet Mid-Catalyst Temperature (°C) Means with Confidence Intervals

vi. Percent Change in the Fleet Vehicle Performance Means: Engine speed, Percent Load, Ignition Timing, pre-Catalyst Exhaust Temperature, and mid-Catalyst Exhaust Temperature

The combined eight vehicle fleet means and percent changes for engine speed, percent load, and mid-catalyst temperatures show no significant differences while operating on the 85 and 87 AKI test fuels. Table 16 shows that spark retard (moving ignition timing closer to top dead center of piston travel) is however significantly different between the two test fuels while operating on the US06 cycle at 5,000 ft. and the resultant rejected in-cylinder heat from delayed combustion starts to show up in Table 17 as increased pre-catalyst (engine out) temperature differences.

1. Ignition Timing

Table 16 Fleet Average Ignition Timing

Ignition Timing (° BTDC)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75 Bags 1&2	23.30	23.18	0.9344	0.13	0.5%	23.39	23.27	0.9444	0.12	0.5%
FTP-75 Bag 3	23.03	23.45	0.2459	-0.42	-1.8%	23.11	23.56	0.9606	-0.45	-1.9%
LA92	21.23	21.43	0.9182	-0.20	-0.9%	21.31	21.58	0.8085	-0.27	-1.2%
US06	21.71	22.62	0.0193	-0.92	-4.1%	21.47	22.19	0.0638	-0.72	-3.3%

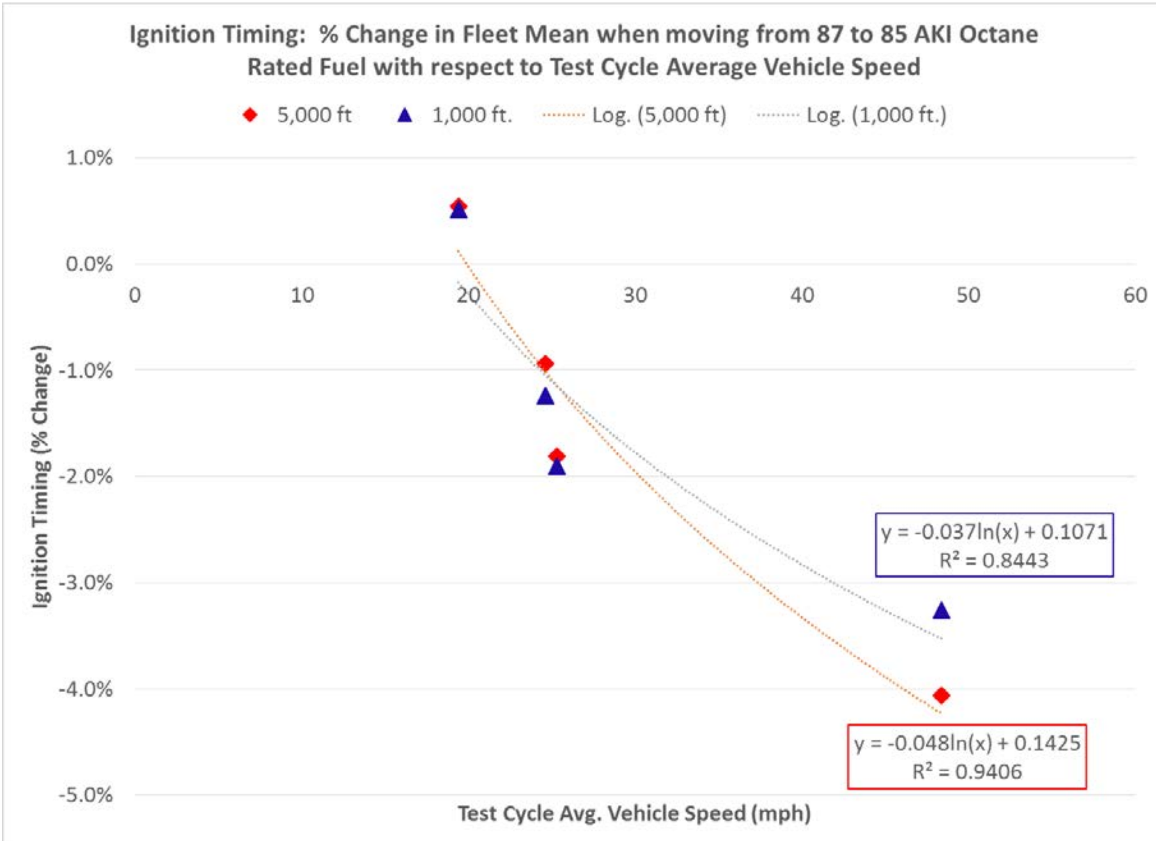


Figure 22 Percent Change in Ignition Timing with Respect to Average Vehicle Speed

2. Pre-Catalyst Temperature

Table 17 Fleet Average Pre-Catalyst Temperature

Pre-Cat Temp. (°C)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75 Bags 1&2	451.88	450.88	0.7868	1.00	0.2%	457.47	457.36	0.9996	0.11	0.0%
FTP-75 Bag 3	463.01	461.97	0.9409	1.04	0.2%	467.02	464.31	0.4751	2.71	0.6%
LA92	512.64	510.26	0.6397	2.38	0.5%	514.38	510.75	0.2589	3.63	0.7%
US06	637.49	629.52	0.0124	7.97	1.3%	640.84	635.08	0.3228	5.76	0.9%

3. Engine Speed

Table 18 Fleet Average Engine Speed

Engine Speed (rpm)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75 Bags 1&2	1276.09	1276.28	0.9998	-0.19	0.0%	1269.58	1269.54	1.0000	0.04	0.0%
FTP-75 Bag 3	1370.89	1372.28	0.9206	-1.39	-0.1%	1360.87	1360.85	1.0000	0.02	0.0%
LA92	1406.36	1405.44	0.9952	0.92	0.1%	1389.40	1390.70	0.9850	-1.30	-0.1%
US06	2118.66	2113.33	0.9623	5.33	0.3%	2061.89	2055.54	0.9306	6.35	0.3%

4. **Engine Load**

Table 19 Fleet Average Engine Load

Engine Load (%)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75 Bags 1&2	27.78	27.66	0.9238	0.12	0.4%	28.75	29.08	0.3396	-0.33	-1.1%
FTP-75 Bag 3	29.12	28.96	0.8173	0.16	0.6%	30.25	30.07	0.7730	0.18	0.6%
LA92	30.02	29.94	0.9899	0.07	0.2%	31.15	31.00	0.9164	0.15	0.5%
US06	41.43	40.93	0.6360	0.50	1.2%	43.32	43.22	0.9947	0.10	0.2%

5. **Mid-Catalyst Temperature**

Table 20 Fleet Average Mid-Catalyst Temperature

Mid-Catalyst Temp. (°C)										
Outliers Removed	**5000**	**5000**	**p-value**	**Delta**	**% Change**	**1000**	**1000**	**p-value**	**Delta**	**% Change**
	85 AKI	**87 AKI**		**85 - 87**	**87 --> 85**	**85 AKI**	**87 AKI**		**85 - 87**	**87 --> 85**
FTP-75 Bags 1&2	564.20	562.67	0.6146	1.53	0.3%	566.12	565.93	0.9986	0.20	0.0%
FTP-75 Bag 3	581.67	581.73	1.0000	-0.06	0.0%	579.56	576.60	0.5130	2.96	0.5%
LA92	638.79	636.25	0.4787	2.54	0.4%	634.48	631.91	0.4718	2.56	0.4%
US06	766.67	759.46	0.2350	7.20	0.9%	766.92	759.55	0.1861	7.38	1.0%

vii. Individual Vehicle Performance Data Ignition Timing and Pre-Catalyst Exhaust Temperatures

The following series of charts show the percent change and absolute unit change due to the octane number and test cycle severity effects for each vehicle as it was driven over the many acceleration and deceleration modes of the emissions test cycles. In absolute terms, the averaged incremental vehicle ignition timing and exhaust temperature effects appear small relative to the FE and emissions impacts shown previously. Here analysis of modal emissions data, where vehicle acceleration maneuvers are separated from decelerations would help to better understand the true magnitude of octane number effects on spark timing and exhaust temperatures. The magnitude of emissions and FE effects are considered cumulative responses while ECM parameter impacts are essentially instantaneous differences.

1. **Ignition Timing - Percentage Change for Individual Vehicles**

Figure 24 and Table 21 show the ignition timing percent change while operating on 85 AKI relative to 87 AKI fuel. A negative number indicates “spark retard” as a control strategy of coping with auto-ignition. The amount of spark retard increases with test cycle severity. These percent change deltas do not include confidence intervals. Table 16 indicates that the intervals for the US FTP-75 and LA92 test cycles would cross zero and not be statistically different. The same conclusion can be drawn for the pre-catalyst temperature percent change deltas in Figure 25.

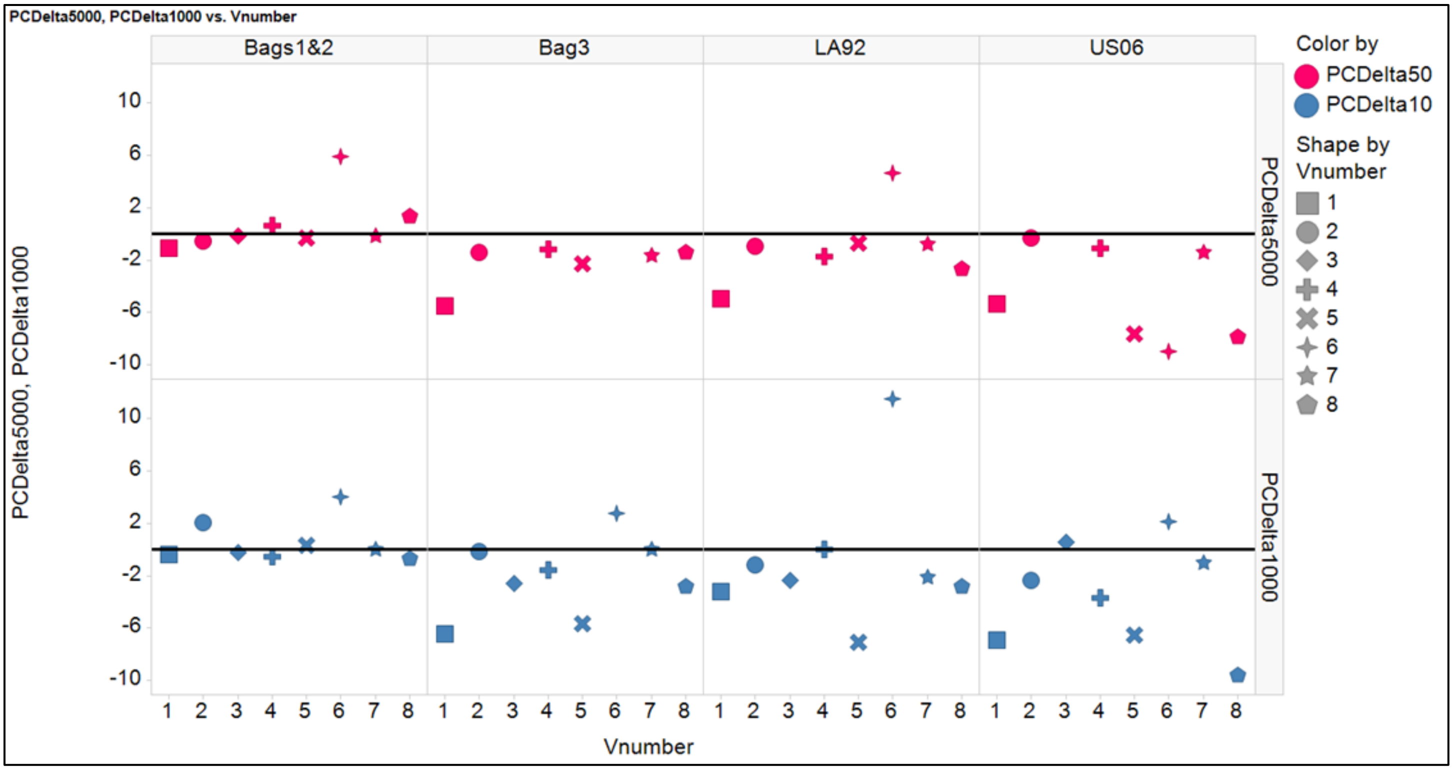


Figure 23 Average Vehicle Ignition Timing Percent Change when moving from 87 to 85 AKI Fuel

Table 21 Average Vehicle Ignition Timing Percent Change when moving from 87 to 85 AKI Fuel

VNumber	Altitude (ft.)	Ignition Timing Change (%) 87 to 85 AKI			
		Bags1&2	Bag3	LA92	US06
1	5000	-1.10	-5.52	-4.92	-5.37
2	5000	-0.53	-1.37	-0.95	-0.33
3	5000	-0.15	na	na	na
4	5000	0.66	-1.16	-1.69	-1.07
5	5000	-0.30	-2.25	-0.69	-7.66
6	5000	5.88	na	4.68	-8.99
7	5000	-0.15	-1.68	-0.76	-1.43
8	5000	1.33	-1.38	-2.71	-7.86
1	1000	-0.35	-6.42	-3.19	-6.95
2	1000	2.03	-0.13	-1.21	-2.34
3	1000	-0.23	-2.60	-2.32	0.54
4	1000	-0.53	-1.57	0.02	-3.67
5	1000	0.36	-5.64	-7.05	-6.50
6	1000	4.02	2.73	11.50	2.14
7	1000	0.03	0.04	-2.15	-1.05
8	1000	-0.67	-2.85	-2.86	-9.60

Table 22 Average Vehicle Ignition Timing Change (°BTDC) when moving from 87 to 85 AKI Fuel

VNumber	Altitude (ft.)	Ignition Timing Change (°BTDC) 87 to 85 AKI			
		Bags1&2	Bag3	LA92	US06
1	5000	-0.22	-1.01	-0.81	-1.00
2	5000	-0.14	-0.38	-0.26	-0.10
3	5000	-0.03	na	na	na
4	5000	0.17	-0.32	-0.43	-0.29
5	5000	-0.07	-0.49	-0.13	-1.50
6	5000	1.03	na	0.68	-1.33
7	5000	-0.04	-0.44	-0.19	-0.40
8	5000	0.32	-0.32	-0.57	-1.48
1	1000	-0.07	-1.18	-0.51	-1.30
2	1000	0.54	-0.04	-0.33	-0.71
3	1000	-0.05	-0.62	-0.54	0.13
4	1000	-0.14	-0.43	0.00	-0.99
5	1000	0.08	-1.24	-1.45	-1.26
6	1000	0.73	0.57	1.80	0.31
7	1000	0.01	0.01	-0.54	-0.28
8	1000	-0.16	-0.65	-0.58	-1.67

2. Exhaust Pre-Catalyst Percent Change Deltas for Individual Vehicles

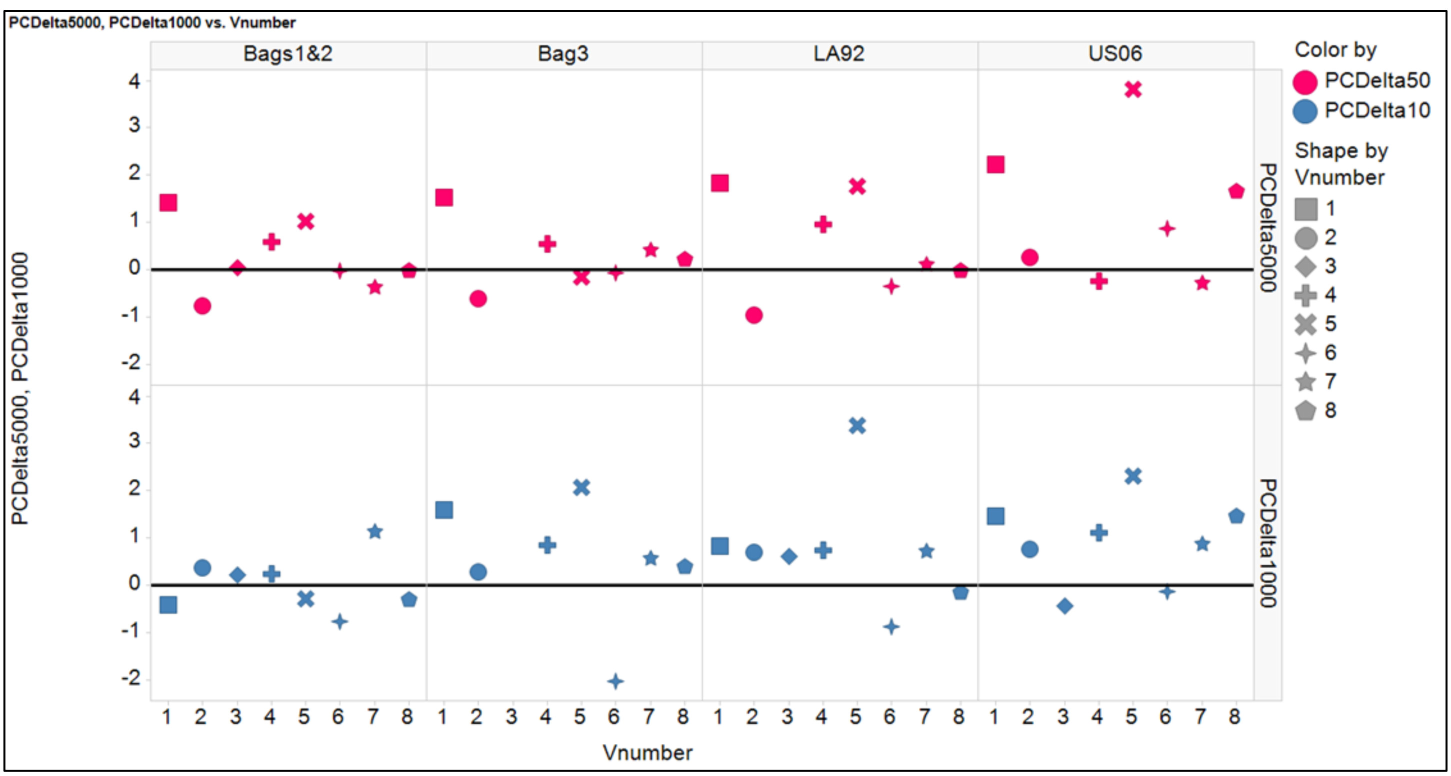


Figure 24 Average Vehicle Exhaust Pre-catalyst Percent Change when moving from 87 to 85 AKI Fuel

Table 23 Average Vehicle Exhaust Pre-catalyst Percent Change when moving from 87 to 85 AKI Fuel

VNumber	Altitude (ft.)	Exhaust Precatalyst Temperature Change (%) 87 to 85 AKI			
		Bags1&2	Bag3	LA92	US06
1	5000	1.42	1.52	1.83	2.23
2	5000	-0.76	-0.61	-0.97	0.27
3	5000	0.03	na	na	na
4	5000	0.58	0.54	0.96	-0.23
5	5000	1.03	-0.17	1.77	3.82
6	5000	-0.02	-0.08	-0.35	0.87
7	5000	-0.38	0.41	0.10	-0.30
8	5000	-0.02	0.22	-0.01	1.65
1	1000	-0.41	1.60	0.82	1.47
2	1000	0.36	0.27	0.70	0.75
3	1000	0.22	na	0.61	-0.45
4	1000	0.24	0.86	0.74	1.10
5	1000	-0.29	2.07	3.38	2.32
6	1000	-0.77	-2.03	-0.87	-0.14
7	1000	1.14	0.56	0.71	0.87
8	1000	-0.31	0.39	-0.16	1.46

Table 24 Average Vehicle Exhaust Pre-Catalyst Temperature Change (°C) when moving from 87 to 85 AKI Fuel

VNumber	Altitude (ft.)	Exhaust Precatalyst Temperature Change (°C) 87 to 85 AKI			
		Bags1&2	Bag3	LA92	US06
1	5000	6.3	7	9.1	13.2
2	5000	-3.6	-2.9	-5.1	1.7
3	5000	0.2	na	na	na
4	5000	2.8	2.8	5.4	-1.6
5	5000	4	-0.6	8.1	21.8
6	5000	-0.1	-0.3	-1.6	5.4
7	5000	-1.6	1.7	0.5	-1.8
8	5000	-0.1	1.1	-0.1	11.2
1	1000	-1.9	7.5	4.1	8.8
2	1000	1.7	1.3	3.7	4.7
3	1000	1.1	na	3.2	-2.9
4	1000	1.2	4.4	4.1	7.5
5	1000	-1.2	8	15.4	13.3
6	1000	-3.2	-8.3	-4	-0.9
7	1000	4.8	2.4	3.4	5.3
8	1000	-1.6	2.1	-0.9	10.2

e. Mean FE, CO_2, CO Results for the Combined Nine Vehicle Fleet - Octane Effects across Elevations

The tables below show the FE, CO_2, and CO average fleet results when operating the vehicles on 85 AKI fuel at 5,000 ft. and 87 AKI fuel at 1,000 ft. as is commonly done in today's U.S. market. Because of the lower atmospheric pressure at 5,000 ft. and the engines' response to it, the interpretation of results becomes more convoluted. During the US FTP-75 and LA92 emissions cycle tests when the vehicles are less knock limited the FEs are statistically significantly higher for the 85 AKI/5,000 ft. case than the 87 AKI/ 1,000 ft. case but when the vehicles become knock limited during the US06 cycle 85 AKI/5,000 ft. the average is lower but not significantly. CO_2 behaves generally inversely to FE. CO shows higher averages in all cases for the 85 AKI / 5,000 ft. combination and is significantly higher value during the more knock limited US06 test cycle.

FE (mpg)					
Outliers Removed	**5000**	**1000**	**p-value**	**Combined Effects Delta**	**% Change**
	85 AKI	**87 AKI**		**(85 - 87)**	**Delta / (87)**
FTP-75	23.8775	23.2834	<0.0001	0.5941	2.6%
LA92	23.3837	23.0942	<0.0001	0.2895	1.3%
US06	22.5226	22.7917	0.3869	-0.2691	-1.2%

CO2 (gpm)					
Outliers Removed	**5000**	**1000**	**p-value**	**Combined Effects Delta**	**% Change**
	85 AKI	**87 AKI**		**(85 - 87)**	**Delta / (87)**
FTP-75	336.3948	345.5458	<0.0001	-9.1510	-2.6%
LA92	344.5251	350.2167	<0.0005	-5.6916	-1.6%
US06	353.3398	351.5022	0.8360	1.8376	0.5%

CO (gpm)					
Outliers Removed	**5000**	**1000**	**p-value**	**Combined Effects Delta**	**% Change**
	85 AKI	**87 AKI**		**(85 - 87)**	**Delta / (87)**
FTP-75	0.2802	0.2772	0.9976	0.0030	1.1%
LA92	0.2314	0.1796	0.0642	0.0518	28.8%
US06	1.8881	1.1183	0.0025	0.7698	68.8%

f. Mean FE, CO_2, CO Results for the Individual Vehicles - Octane Effects across Elevations

Figures 26, 27, and 28 show the individual vehicle responses for Fuel Consumption, CO2, and CO, respectively when evaluating 85 AKI fuel at 5,000 ft. and 87 AKI fuel at 1,000 ft. During the non- or lightly knocking US FTP-75 and LA92 cycles the lower atmospheric pressure impacts on improved FE at 5,000 ft. can be seen relative to 1,000 ft. elevation. When octane is required as is the case during the US06 cycle, the benefits of higher octane show up.

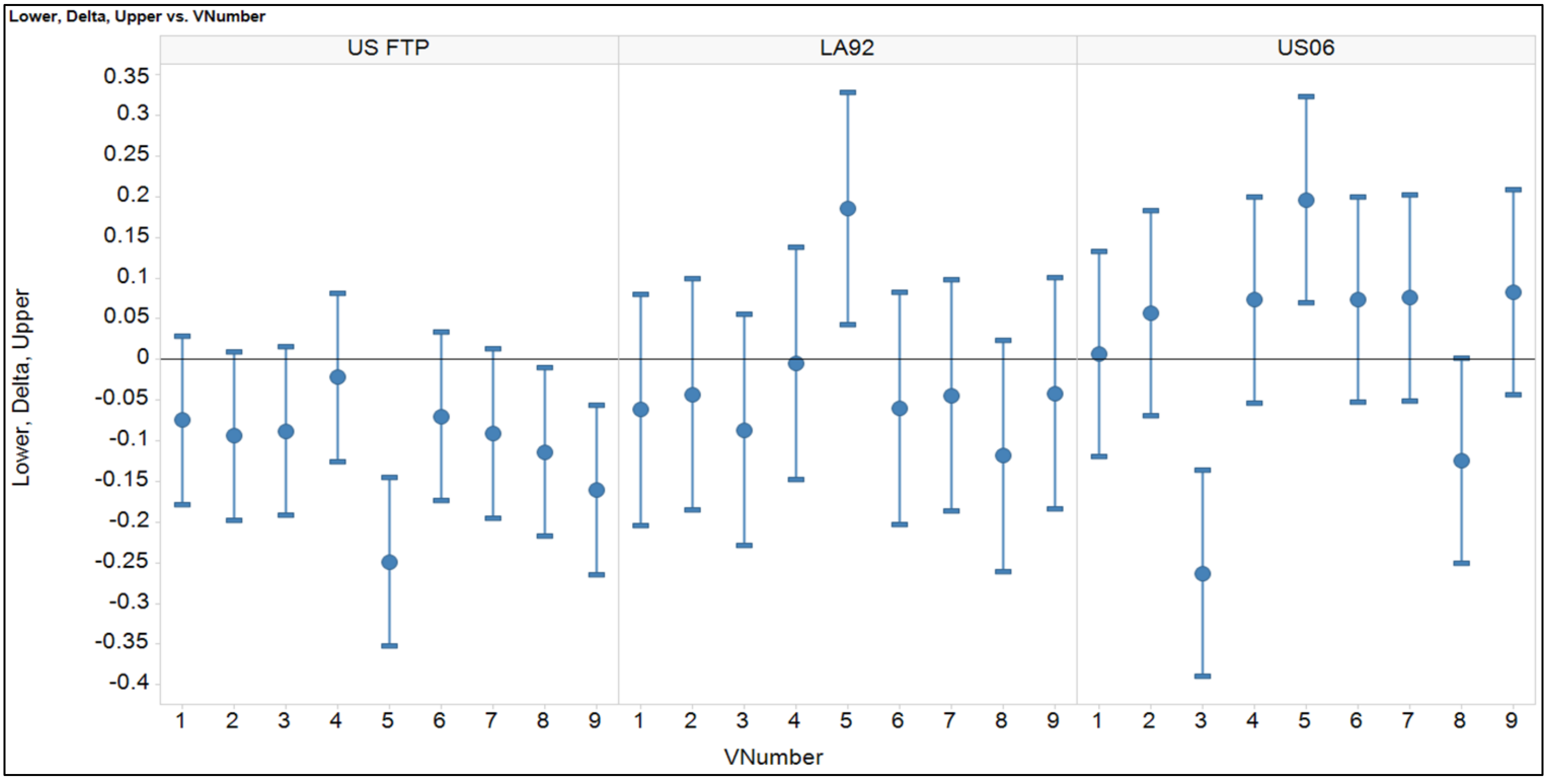


Figure 25 Individual Vehicle Fuel Consumption Deltas (85 AKI@5000' gallons - 87 AKI@1000' gallons / 100 miles)

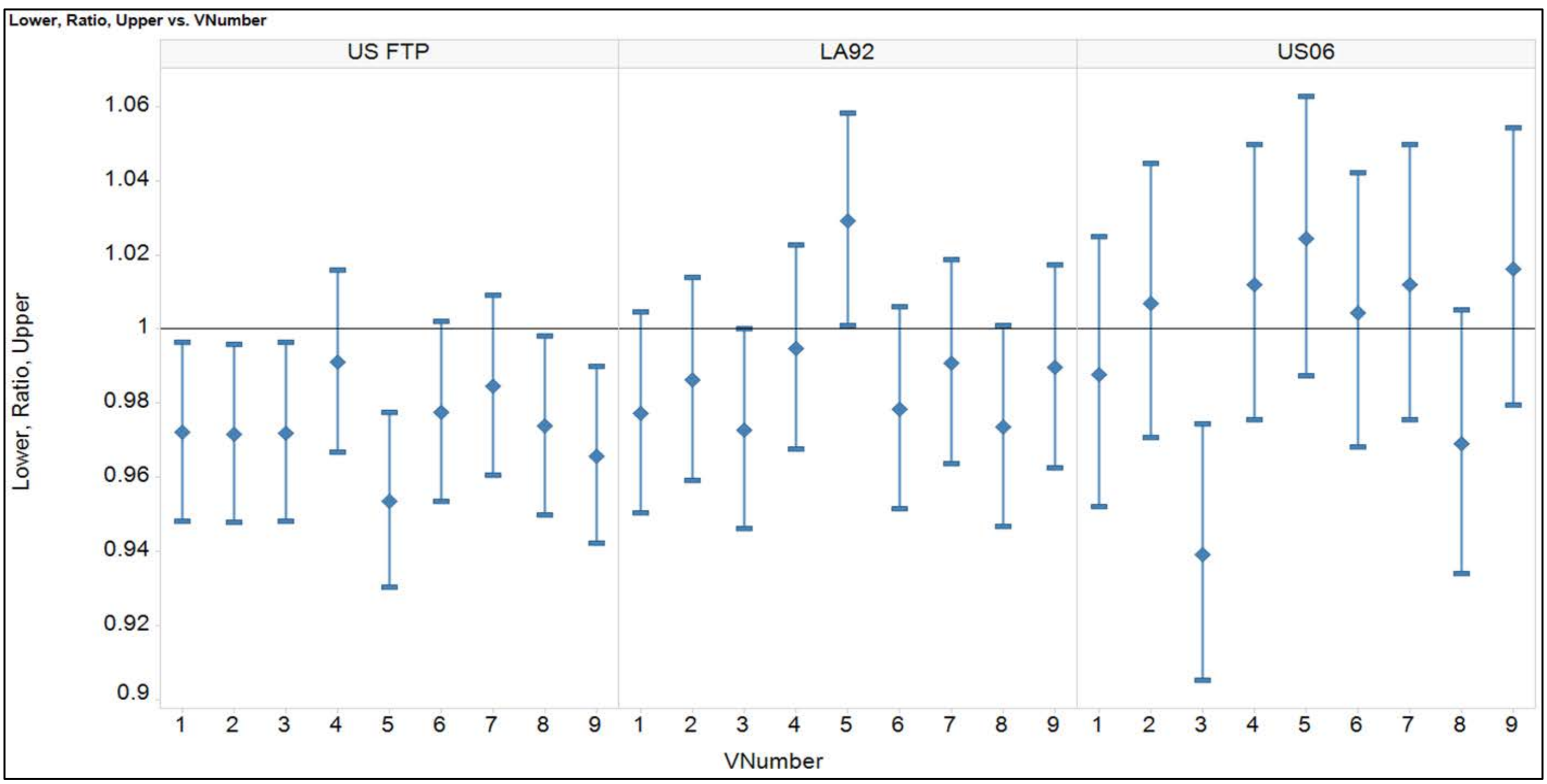


Figure 26 Individual Vehicle CO2 Ratio (85 AKI@5000' gpm / 87 AKI@1000' gpm)

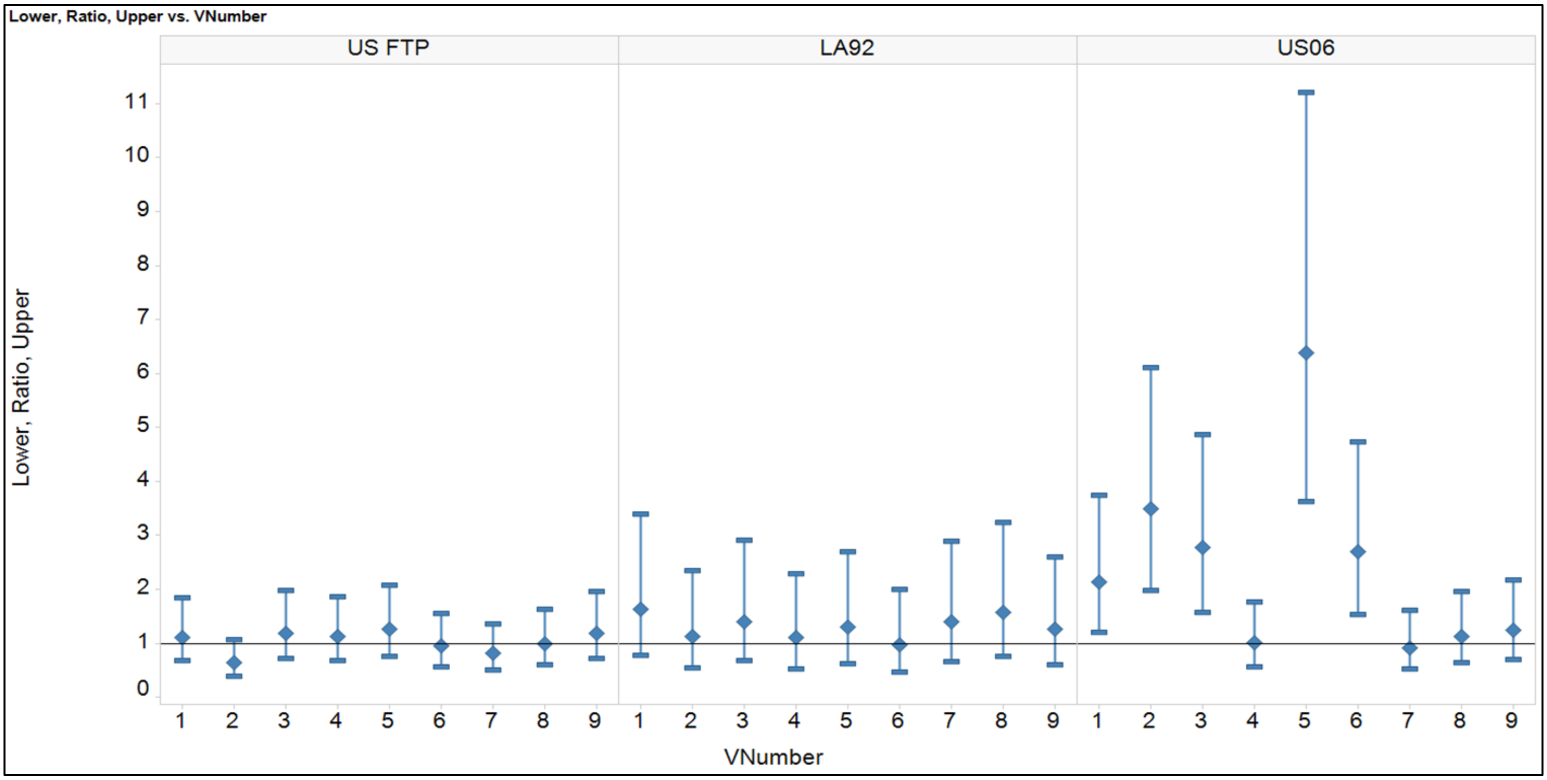


Figure 27 Individual Vehicle CO Ratio (85 AKI@5000' gpm / 87 AKI@1000' gpm)

g. Vehicle Attribute Analyses

The test program included nine test vehicles with a range of attributes; production Model Years 2008 – 2013, four passenger cars and five light duty trucks, engine displacements from 1.4 – 5.4L, two direct and seven port fuel injected, and two turbocharged and seven naturally aspirated engines.

A series of general box plots were created to visualize how the vehicle attributes, test fuels, and emissions test cycles affected CO_2 tailpipe emissions; Cars vs Trucks, DI vs PFI, and Natural Aspiration vs Turbocharged. A Box Plot describes the range of data, its median, and 25th and 75th percentile data. A general example of the information a Box Plot shows is described in Figure 29.

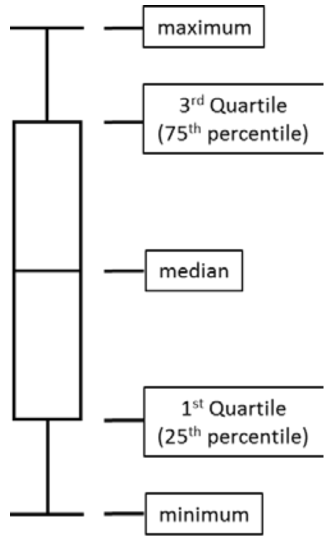


Figure 28 Box Plot Statistical Representation of Data

i. CO_2 – Trucks versus Cars

Cars and trucks have different regulatory emissions certification levels and vehicle masses so it is not surprising that the four passenger cars and five light duty trucks of this study had significantly different levels of CO_2 (g/mile) from each other. (See Figure 30.) Significance testing showed them to have a p-value of <0.0001 for all emissions cycles and elevations tested. (See Figure 33.) However, looking at the impact of the incremental change (percent delta) in octane number from 85 to 87 AKI, neither of the two group (cars and trucks) mean CO_2 values were found to have a significant effect. (See bottom portion of Figure 33.) In other words, the incremental impacts of 85 and 87 AKI octane are very vehicle specific as described earlier in this report.

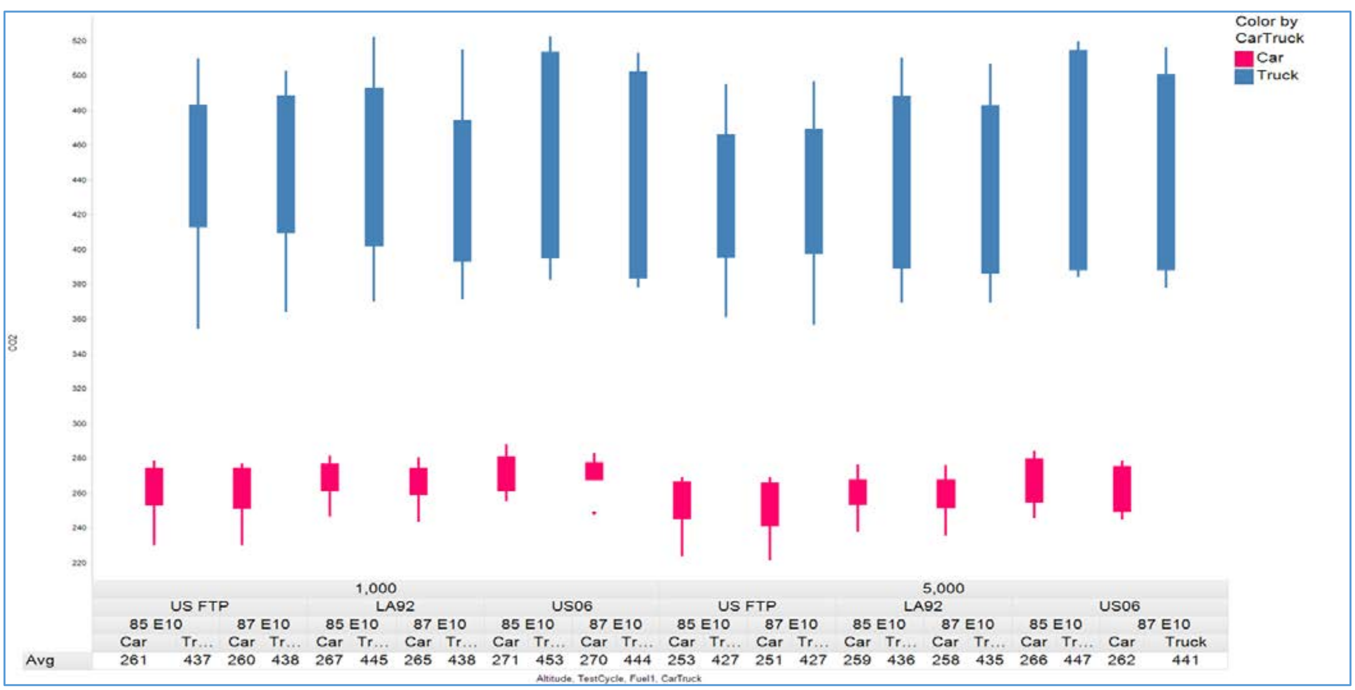


Figure 29 CO_2 (g/mile) Car and Truck Test Vehicles

ii. CO_2 – DI versus PFI

CO_2 levels from the two Direct Injected and seven Port Fuel Injected vehicles were not significantly different. p-values ranged from 0.15 – 0.25.

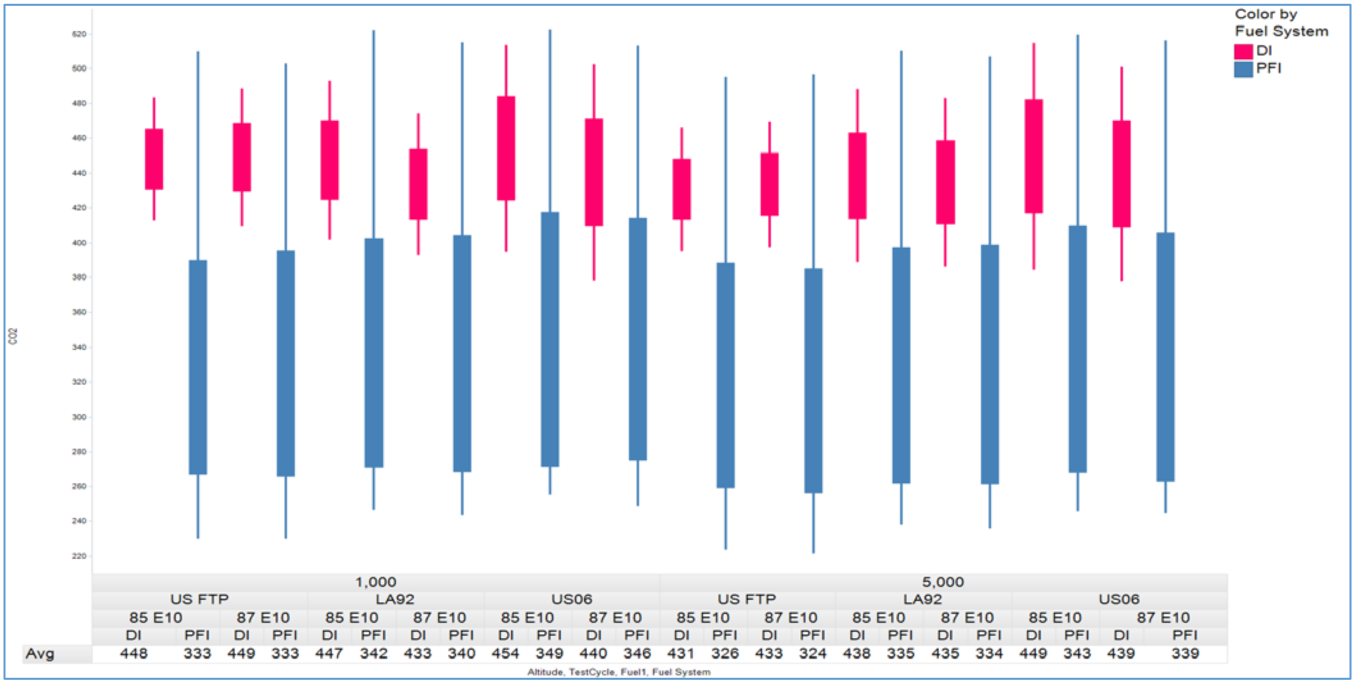


Figure 30 CO2 (g/mile) Direct Injected and Port Fuel Injected Test Vehicles

iii. CO_2 - Naturally Aspirated versus Turbocharged

CO_2 levels from the two turbocharged and seven naturally aspirated test vehicles were not significantly different. P-values ranged from 0.68 – 0.94. This may be a result of the fact that of the turbocharged vehicles, half (one) of them was a truck and the other a car. Of the seven naturally aspirated vehicles, three were cars and four were trucks. With an even distribution of cars and trucks within both naturally aspirated and turbocharged vehicles, it is unsurprising the p-values showed little statistical difference between the two attributes.

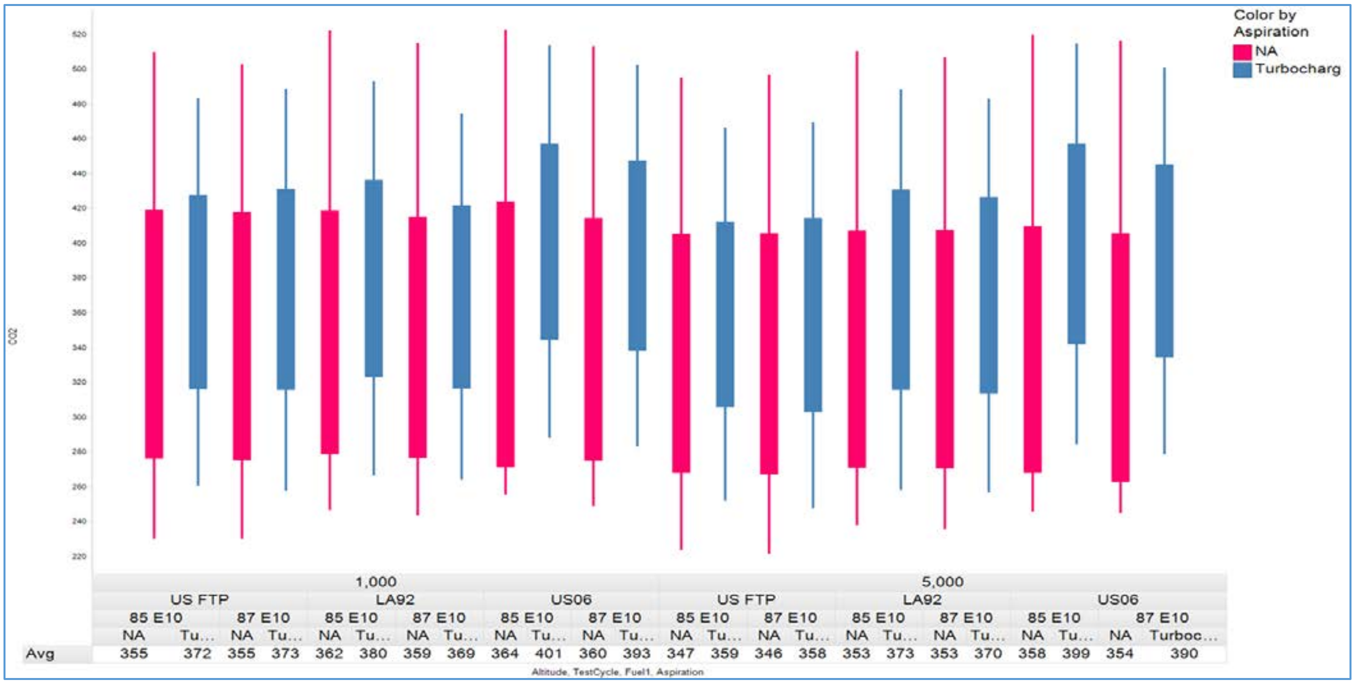


Figure 31 CO_2 (g/mile) Naturally Aspirated and Turbocharged Test Vehicles

iv. Significance of Vehicle Attributes for Carbon Dioxide Emissions

Statistical analysis of the CO_2 (g/mile) test vehicle means with respect to several vehicle attributes shows Cars to be significantly lower than Trucks. There were insignificant differences for the effects of the Fuels System type (DI vs PFI) and the Aspiration type (Naturally Aspirated vs Turbocharged.) (See top half of Figure 33.)

Statistical analysis of the percent changes in CO_2 within each vehicle using 87 versus 85 AKI fuel within an elevation and across elevations shows the Fuel System type to be significant in some cases. The Aspiration type becomes more significant while the differences between Cars and Trucks becomes less significant. (See bottom half of Figure 33.)

			Car/Truck		Fuel System		Aspiration	
	Altitude	Fuel1	Car vs. Truck	p-value	DI vs. PFI	p-value	NA vs. Turbo	p-value
US FTP	**1,000**	**85 E10**	<	<.0001	>	0.15	<	0.89
	1,000	**87 E10**	<	<.0001	>	0.15	<	0.89
	5,000	**85 E10**	<	<.0001	>	0.17	<	0.93
	5,000	**87 E10**	<	<.0001	>	0.15	<	0.93
LA92	**1,000**	**85 E10**	<	<.0001	>	0.19	<	0.89
	1,000	**87 E10**	<	<.0001	>	0.23	<	0.94
	5,000	**85 E10**	<	<.0001	>	0.18	<	0.88
	5,000	**87 E10**	<	<.0001	>	0.19	<	0.90
US06	**1,000**	**85 E10**	<	<.0001	>	0.20	<	0.72
	1,000	**87 E10**	<	<.0001	>	0.25	<	0.75
	5,000	**85 E10**	<	<.0001	>	0.20	<	0.68
	5,000	**87 E10**	<	<.0001	>	0.21	<	0.72

		Car/Truck		Fuel System		Aspiration	
	Percent Change	Car vs. Truck	p-value	DI vs. PFI	p-value	NA vs. Turbo	p-value
US FTP	87 to 85 AKI @ 5000'	>	0.17	<	0.05	<	0.77
	87 to 85 AKI @ 1000'	>	0.42	<	0.92	<	0.99
	85@5000 to 87@1000	>	0.97	>	0.02	<	0.25
LA92	87 to 85 AKI @ 5000'	>	0.87	>	0.18	<	0.23
	87 to 85 AKI @ 1000'	<	0.62	>	0.01	<	0.15
	85@5000 to 87@1000	>	0.15	<	0.04	>	0.16
US06	87 to 85 AKI @ 5000'	>	0.76	>	0.26	<	0.16
	87 to 85 AKI @ 1000'	<	0.33	>	0.17	<	0.66
	85@5000 to 87@1000	>	0.26	<	0.20	>	0.34

Figure 32 Significance of Vehicle Attributes for CO2 Emissions

v. Correlation of CO2 (g/mile) and Vehicle Load Factor (kg/L)

Vehicle load factor, as defined here, is the ratio of vehicle mass (kg) to engine displacement (L). The trend in most global markets is toward higher efficiency vehicles and load factors, with older less efficient vehicles and performance vehicles generally having lower load factors. The load factors represented in this program span from 441 kg/L to 1,032 kg/L and this distribution was chosen to better understand the influence of gasoline octane number on a broad range of U.S. marketplace vehicles. Figure 33 shows the Model Year 2013 U.S. passenger car and light duty truck load factor distribution.

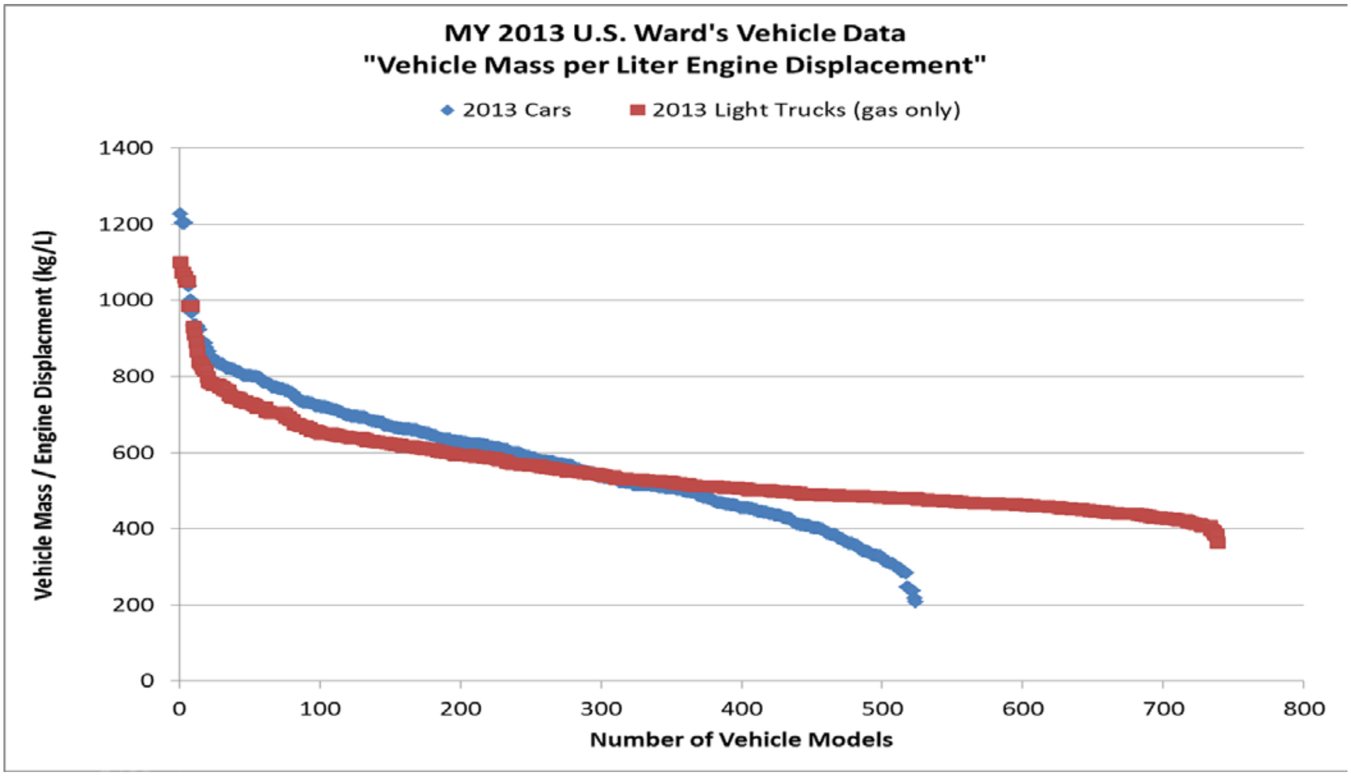


Figure 33 MY 2013 U.S. Passenger Car and Light Duty Truck Load Factor Distributions

Figures 35 through 37 show the general trend of lower load factor vehicles producing more CO_2 emissions (g/mile) than higher load factor vehicles for the three emissions test cycles and nine test vehicles used throughout this program. The statistical R^2 “goodness of fit to the modeled equation” value is low and approximately 0.5 for the US FTP-75 and LA92 test cycles and decreases to approximately 0.4 for the US06 more aggressive drive cycle.

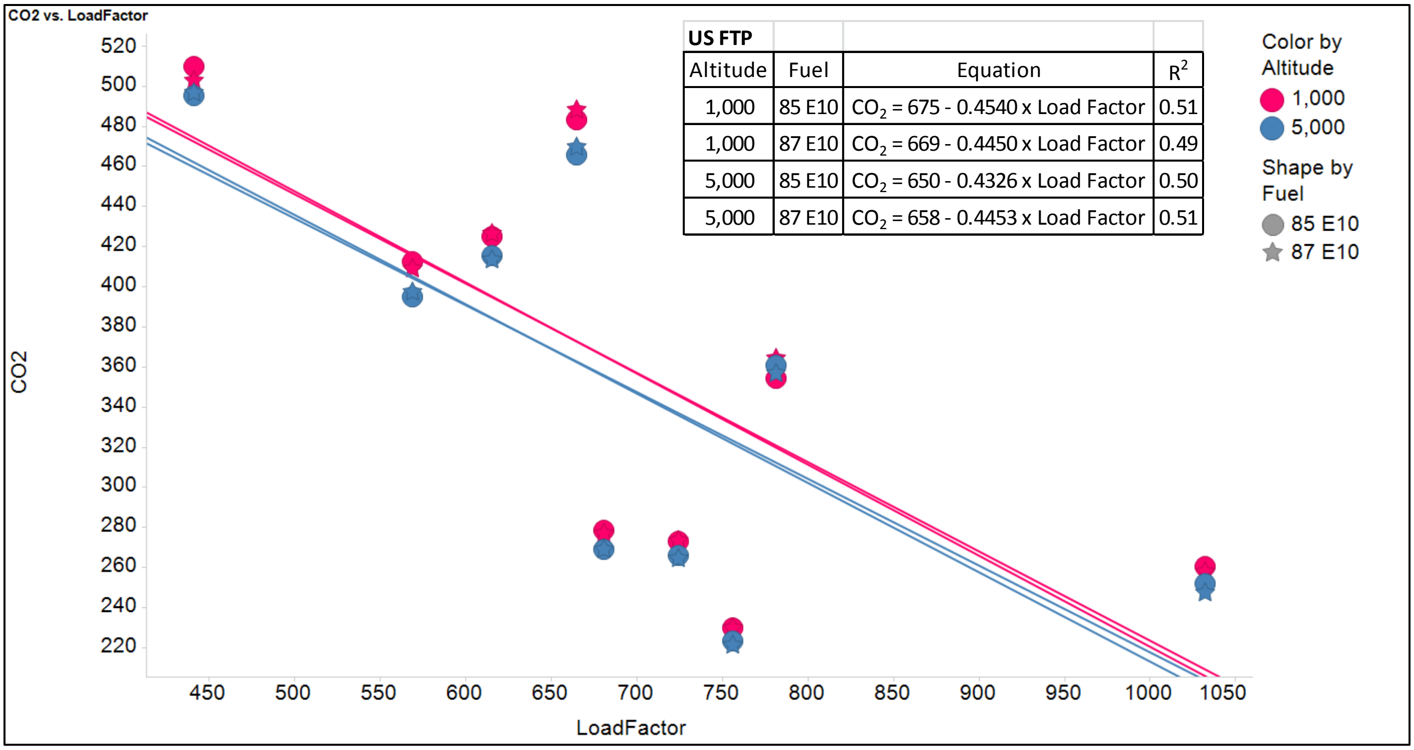


Figure 34 Correlation of Vehicle Load Factor to CO_2 Emissions for US FTP-75 Tests

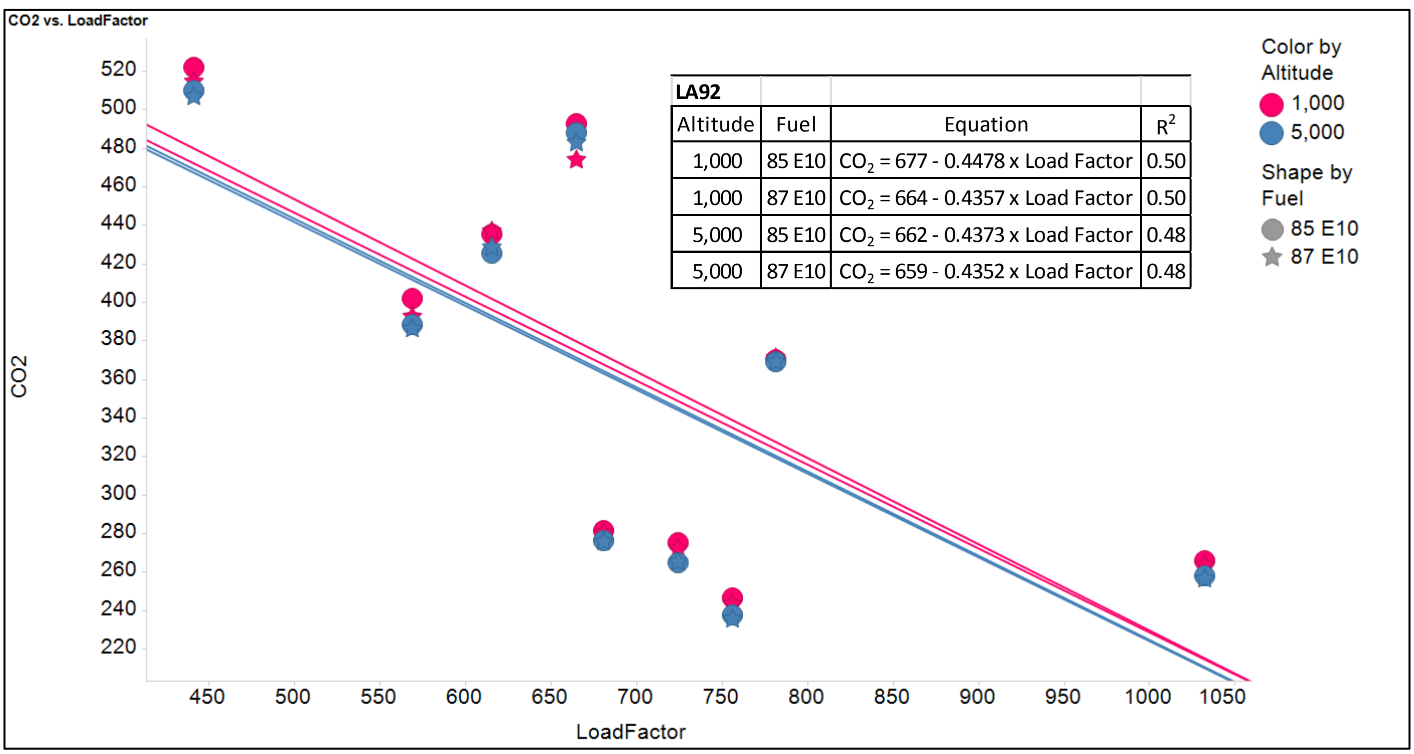
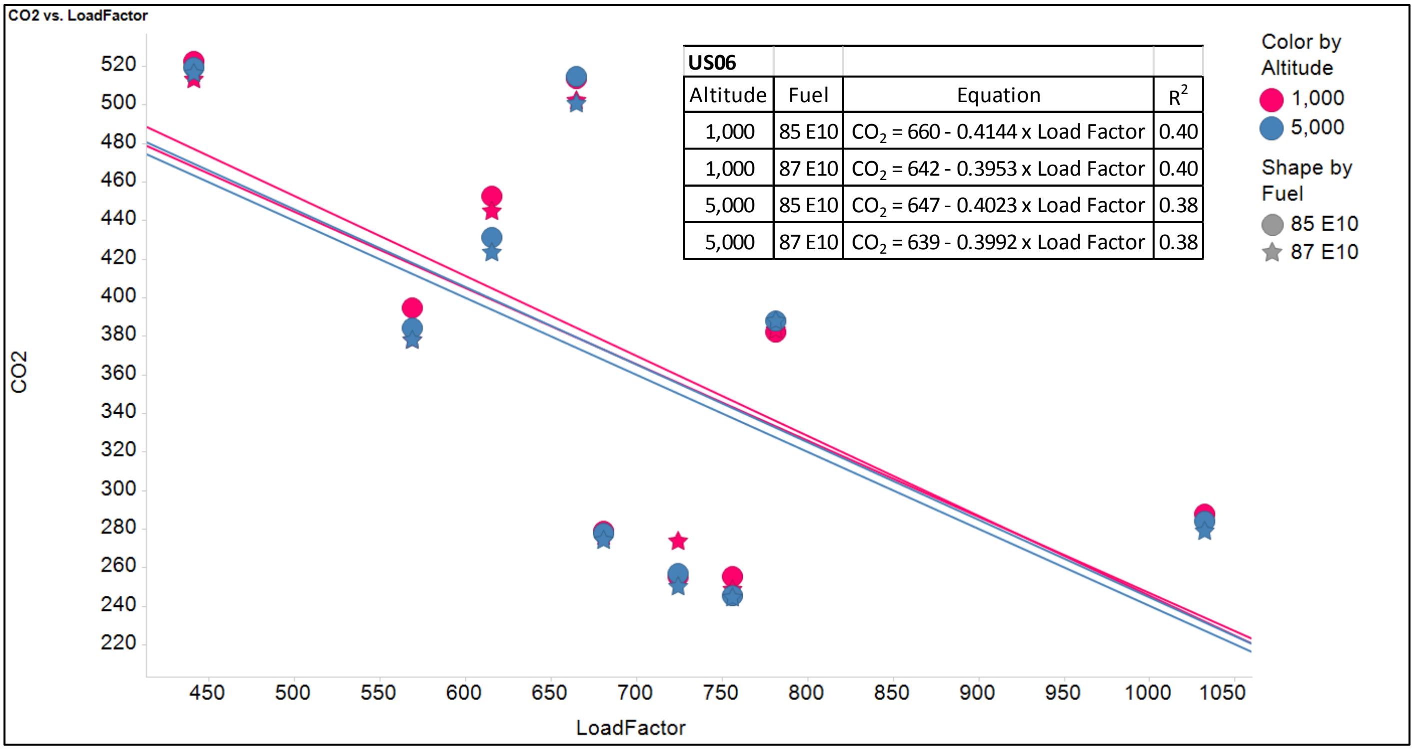


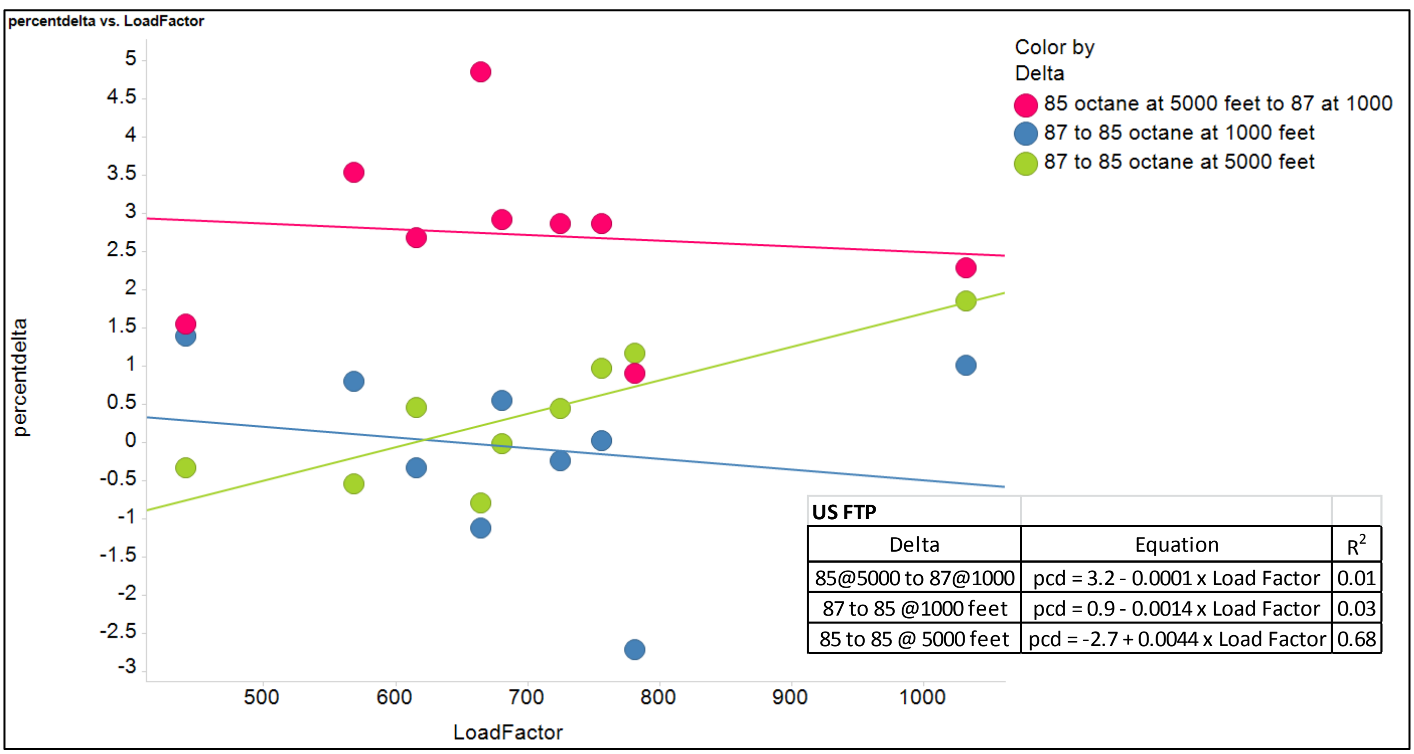
Figure 35 Correlation of Vehicle Load Factor to CO_2 Emissions for LA92 Tests



US06			
Altitude	Fuel	Equation	R^2
1,000	85 E10	CO_2 = 660 - 0.4144 x Load Factor	0.40
1,000	87 E10	CO_2 = 642 - 0.3953 x Load Factor	0.40
5,000	85 E10	CO_2 = 647 - 0.4023 x Load Factor	0.38
5,000	87 E10	CO_2 = 639 - 0.3992 x Load Factor	0.38

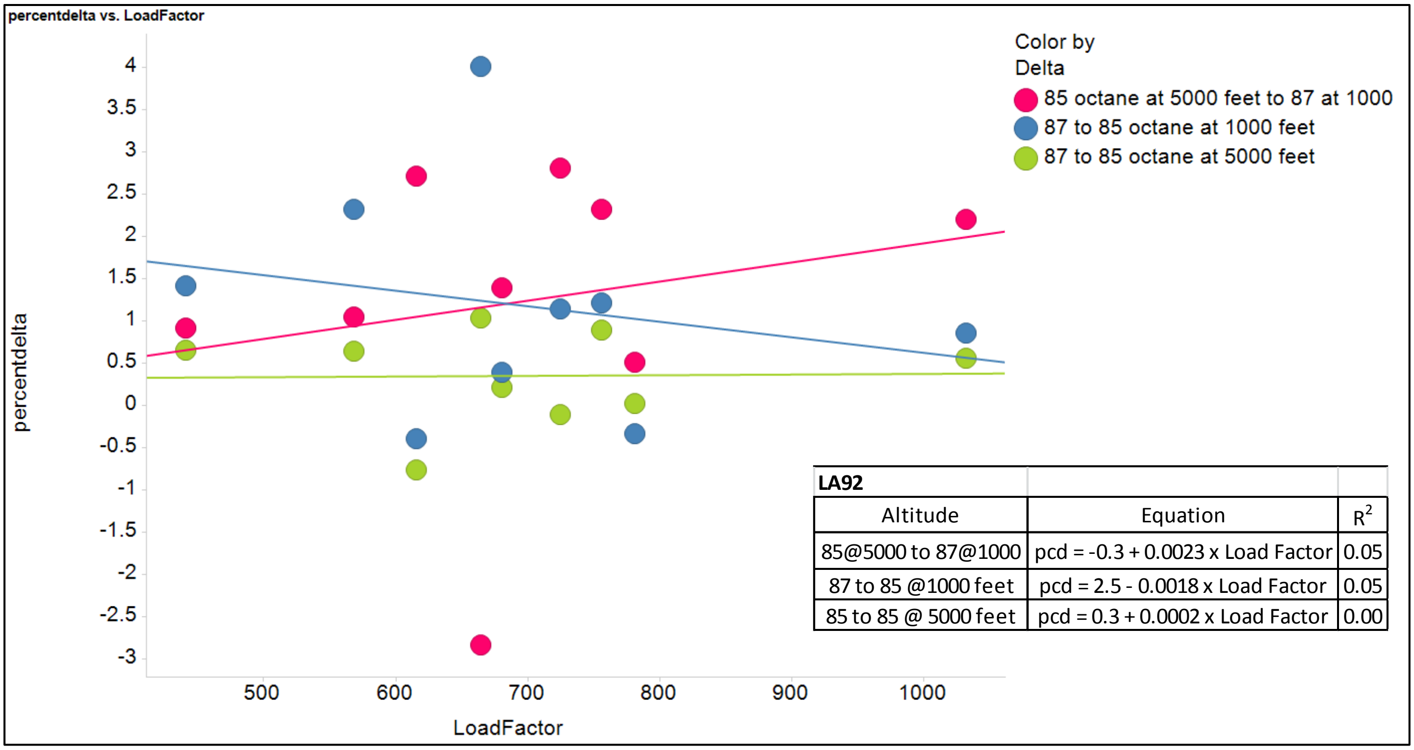
Figure 36 Correlation of Vehicle Load Factor to CO_2 Emissions for US06 Tests

Figures 38 through 40 show no correlation between the Percent Delta CO2 emissions when using 85 and 87 AKI test fuels and vehicle load factors except for a mild correlation (R^2 = 0.68) for the 87 to 85 AKI case at 5,000 ft.



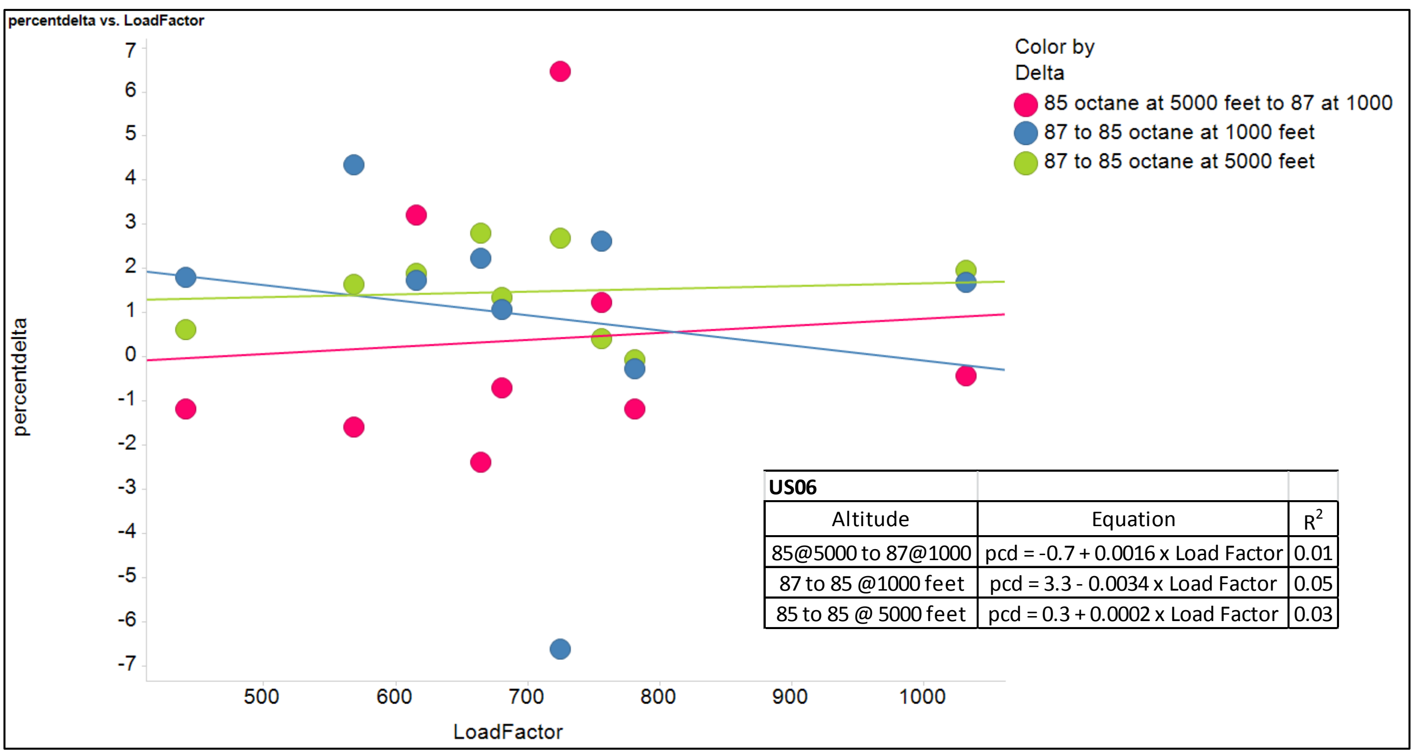
US FTP		
Delta	Equation	R^2
85@5000 to 87@1000	pcd = 3.2 - 0.0001 x Load Factor	0.01
87 to 85 @1000 feet	pcd = 0.9 - 0.0014 x Load Factor	0.03
85 to 85 @ 5000 feet	pcd = -2.7 + 0.0044 x Load Factor	0.68

Figure 37 Correlation of Vehicle Load Factor to CO_2 Percent Deltas for the US FTP-75 Tests



LA92		
Altitude	Equation	R^2
85@5000 to 87@1000	pcd = -0.3 + 0.0023 x Load Factor	0.05
87 to 85 @1000 feet	pcd = 2.5 - 0.0018 x Load Factor	0.05
85 to 85 @ 5000 feet	pcd = 0.3 + 0.0002 x Load Factor	0.00

Figure 38 Correlation of Vehicle Load Factor to CO_2 Percent Deltas for the LA92 Tests



US06		
Altitude	Equation	R^2
85@5000 to 87@1000	pcd = -0.7 + 0.0016 x Load Factor	0.01
87 to 85 @1000 feet	pcd = 3.3 - 0.0034 x Load Factor	0.05
85 to 85 @ 5000 feet	pcd = 0.3 + 0.0002 x Load Factor	0.03

Figure 39 Correlation of Vehicle Load Factor to CO_2 Percent Deltas for the US06 Tests

h. Vehicle Attributes Analyses – Individual Vehicle Results

i. Fuel Economy

Figure 41 shows the mean FE for each vehicle with respect to the altitude, and octane number. Each of the three emissions test cycles (driver styles) show a series of data (incremental effects of octane rating) that are either vertical or leaning to the right from bottom to the top indicating a neutral or increasing fuel economy for the 87 AKI test fuel compared to the 85 AKI test fuel.

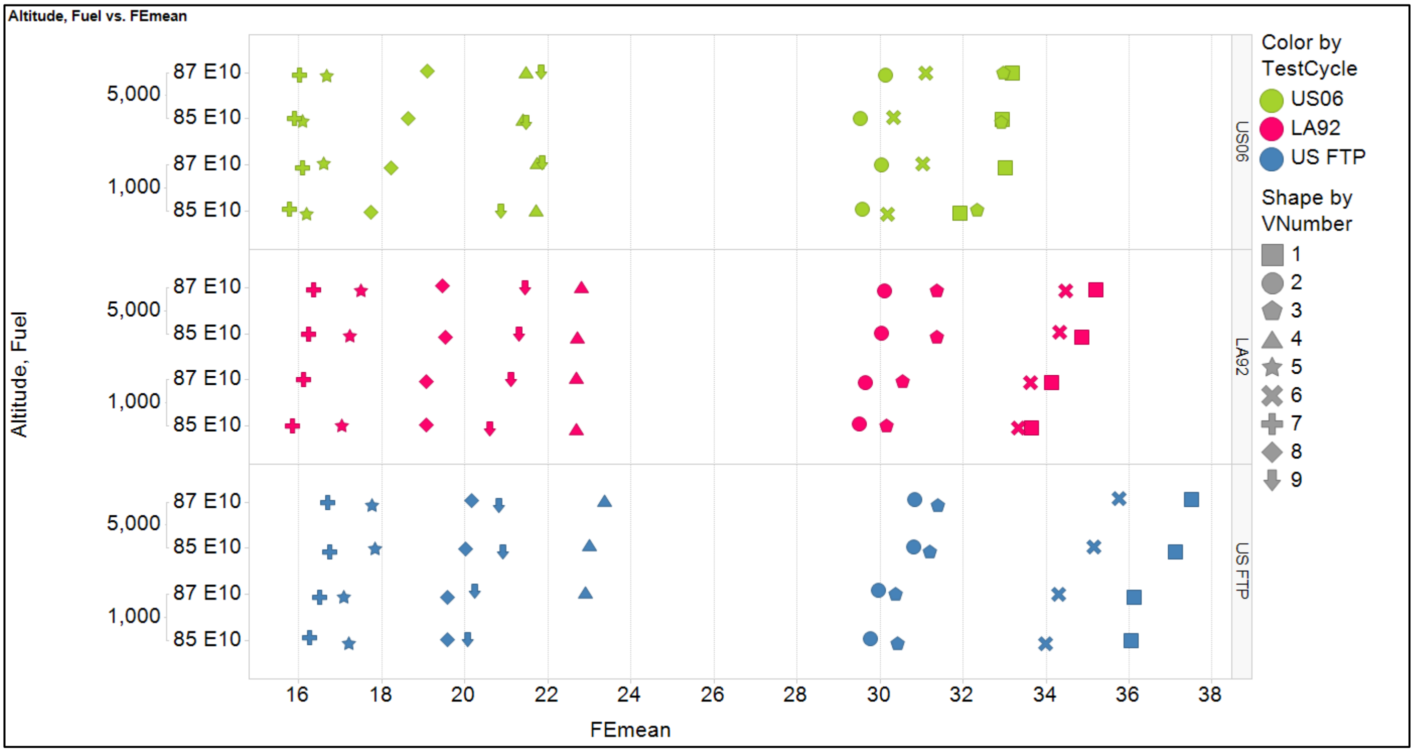


Figure 40 Vehicle Fuel Economy with Respect to Octane Number and Altitude

ii. Carbon Dioxide

Figure 42 shows the CO_2 trends for each vehicle and are essentially the inverse of FE trends; lower CO2 with 87 AKI relative to 85 AKI fuel.

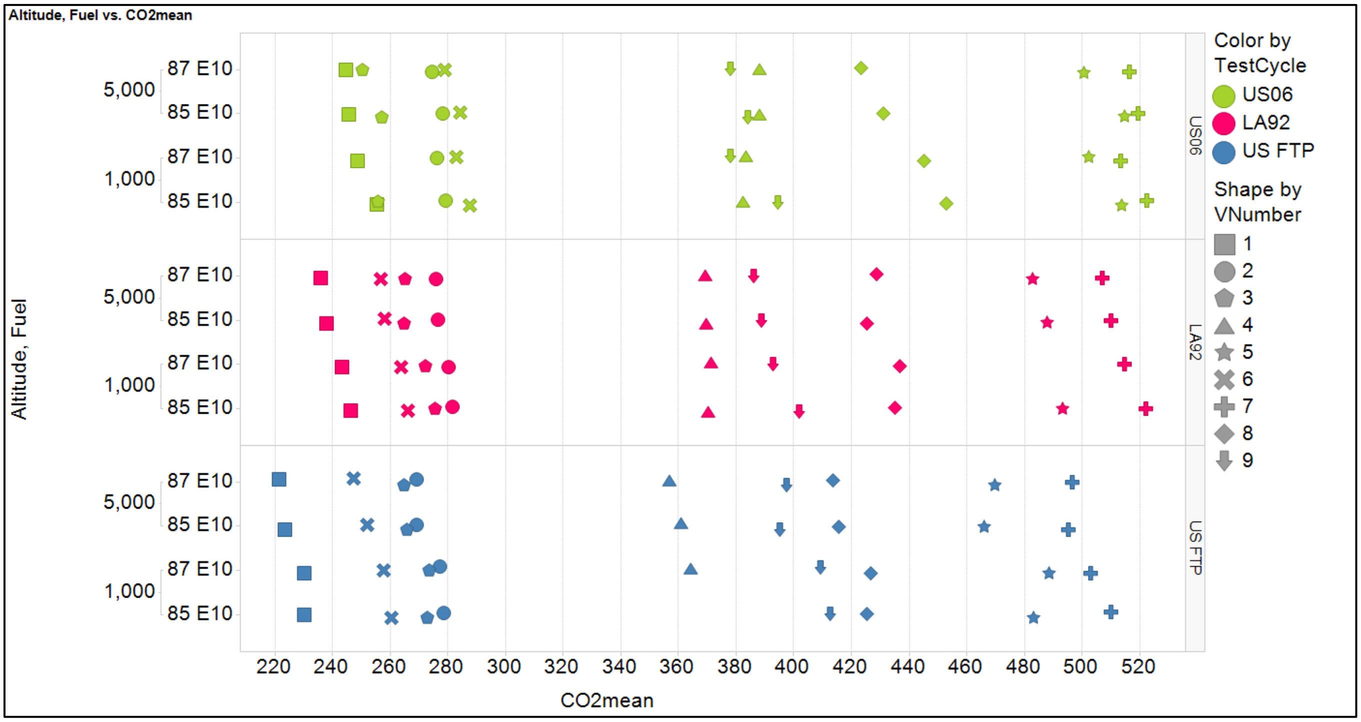


Figure 41 Vehicle CO_2 (gpm) with Respect to Octane Number and Altitude

iii. Carbon Monoxide

Figure 43 shows the CO emissions clustered tightly together for the USFTP-75 and LA92 cycles and much more varied for the US06 cycle. CO emission levels are usually lower for the 87 AKI fuel in each pair.

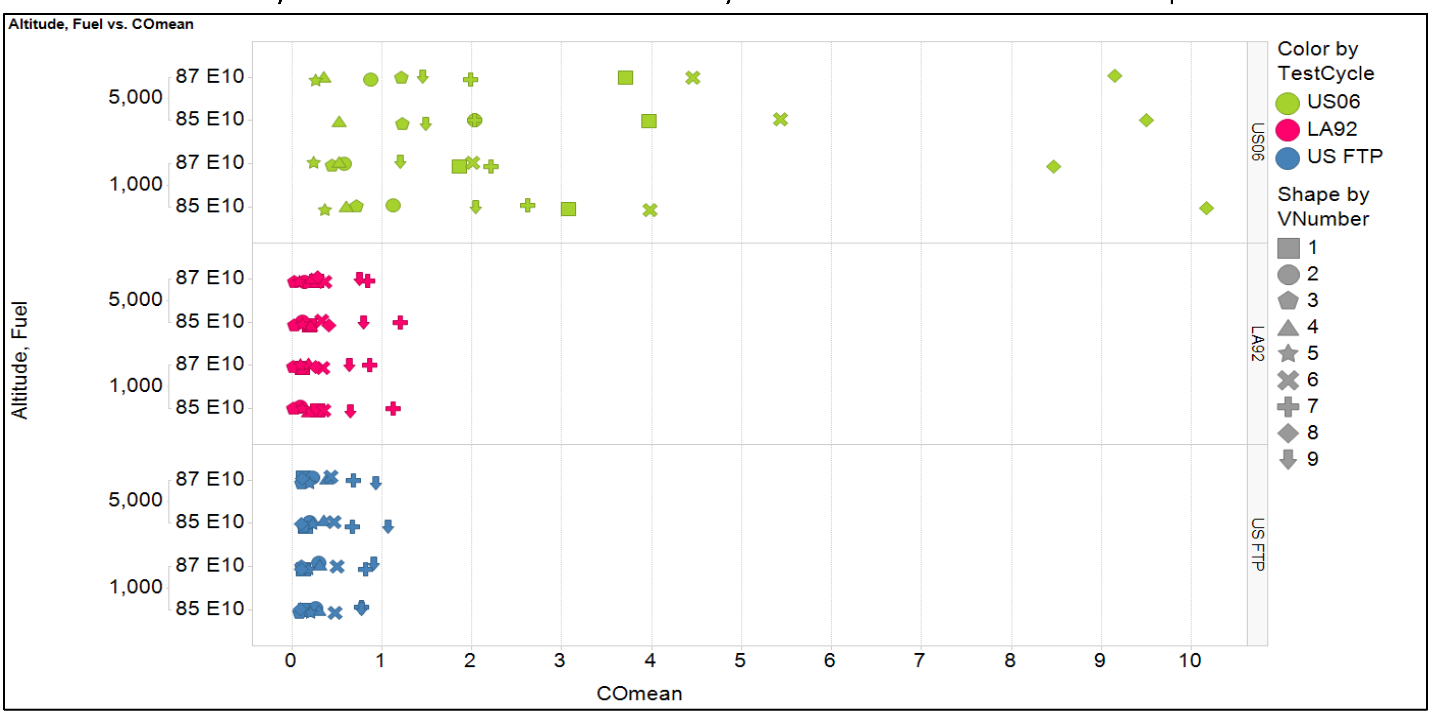


Figure 42 Vehicle CO (gpm) with Respect to Octane Number and Altitude

iv. Engine Speed

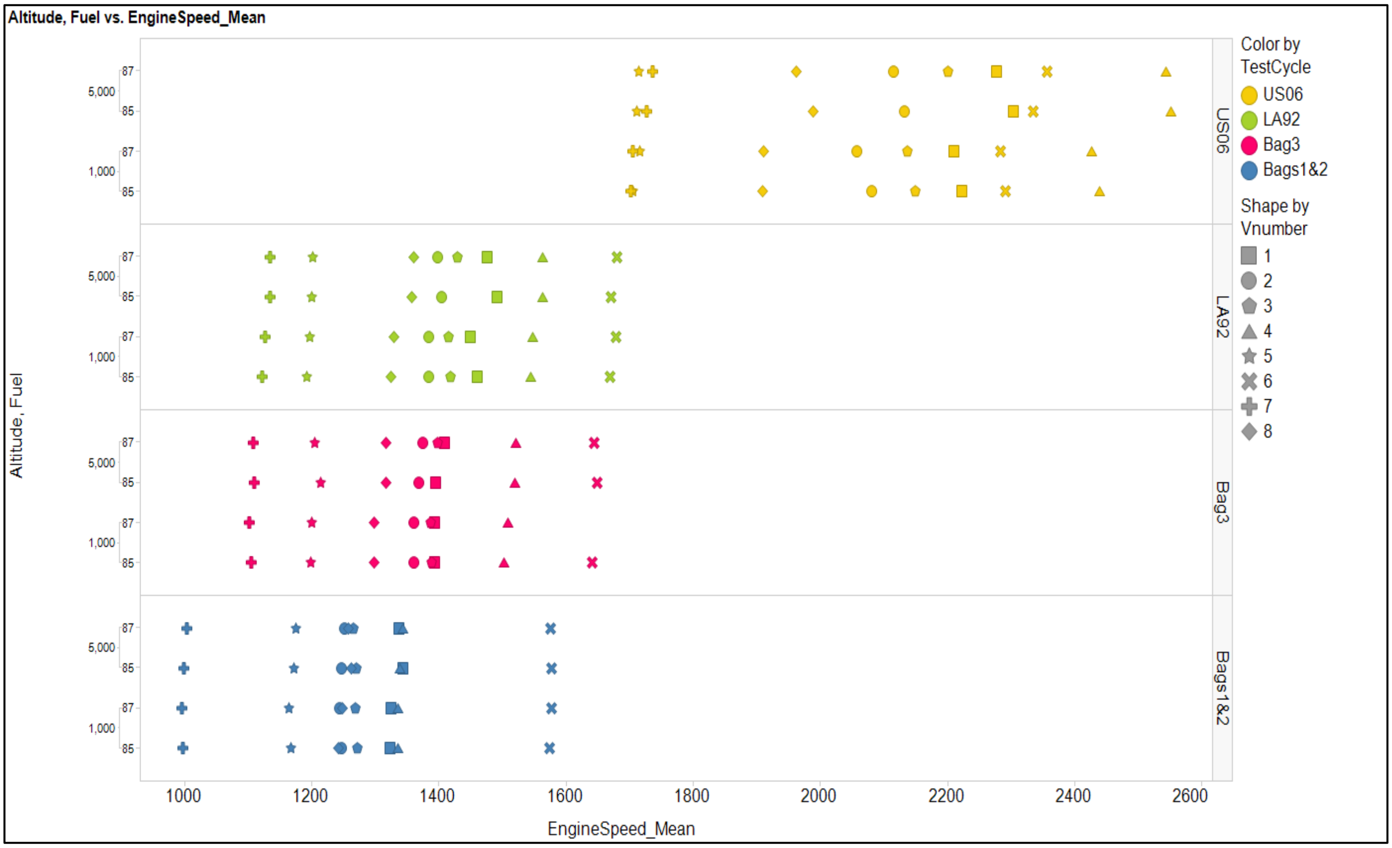


Figure 43 Engine Speed (rpm) with Respect to Octane Number and Altitude

v. Engine Load (Percent)

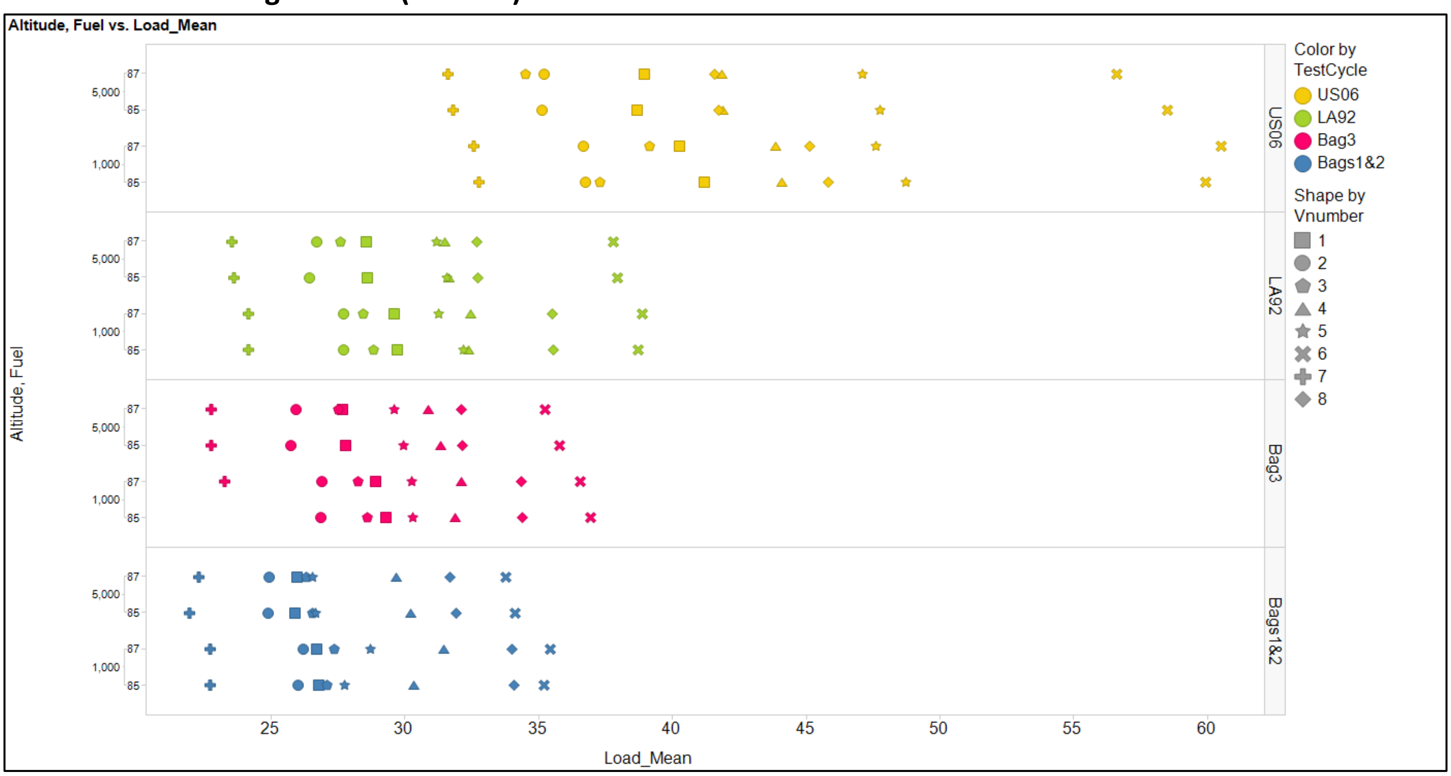


Figure 44 Engine Load (%) with Respect to Octane Number and Altitude

vi. Ignition Timing

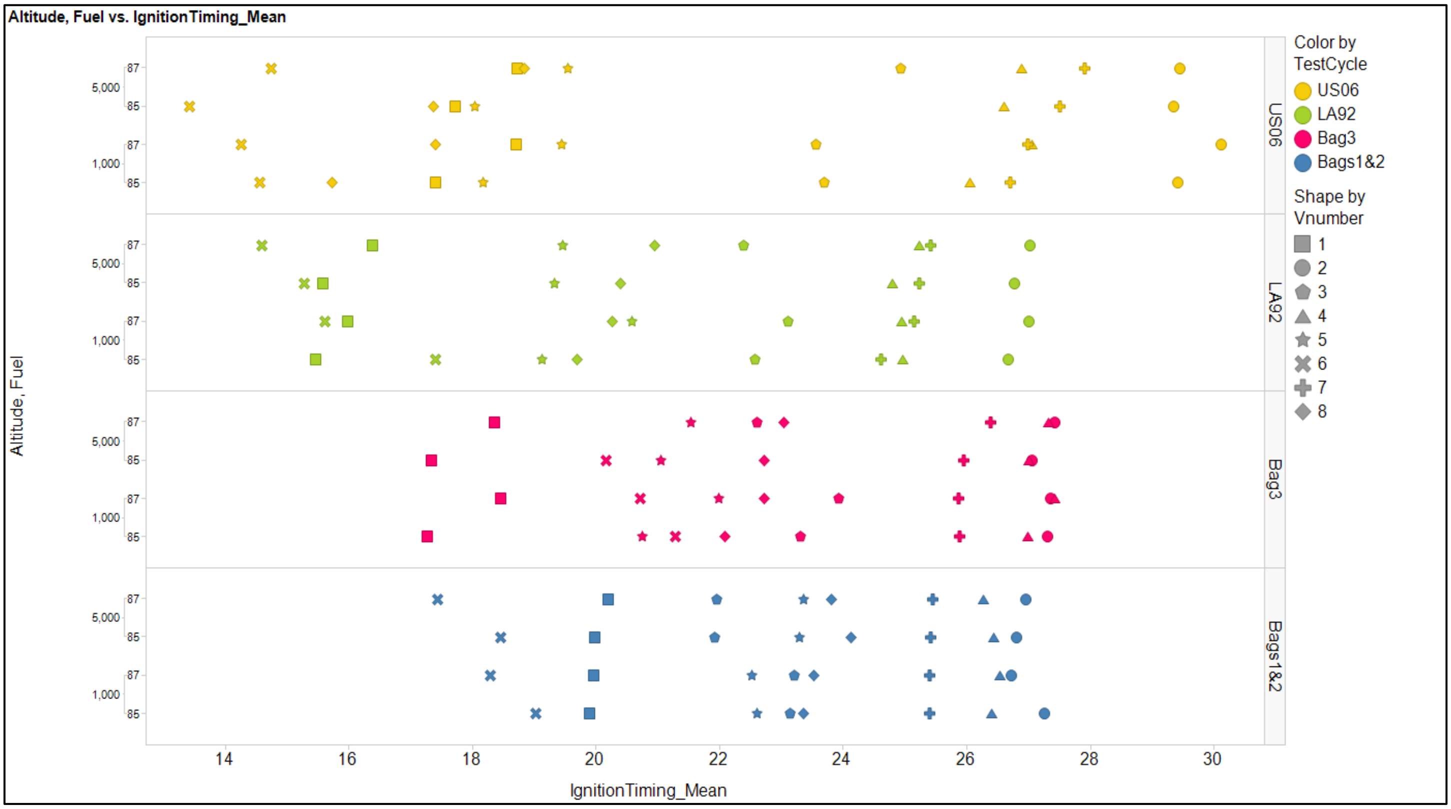


Figure 45 Engine Ignition Timing (°BTDC) with Respect to Octane Number and Altitude

vii. Pre-Catalyst Temperature

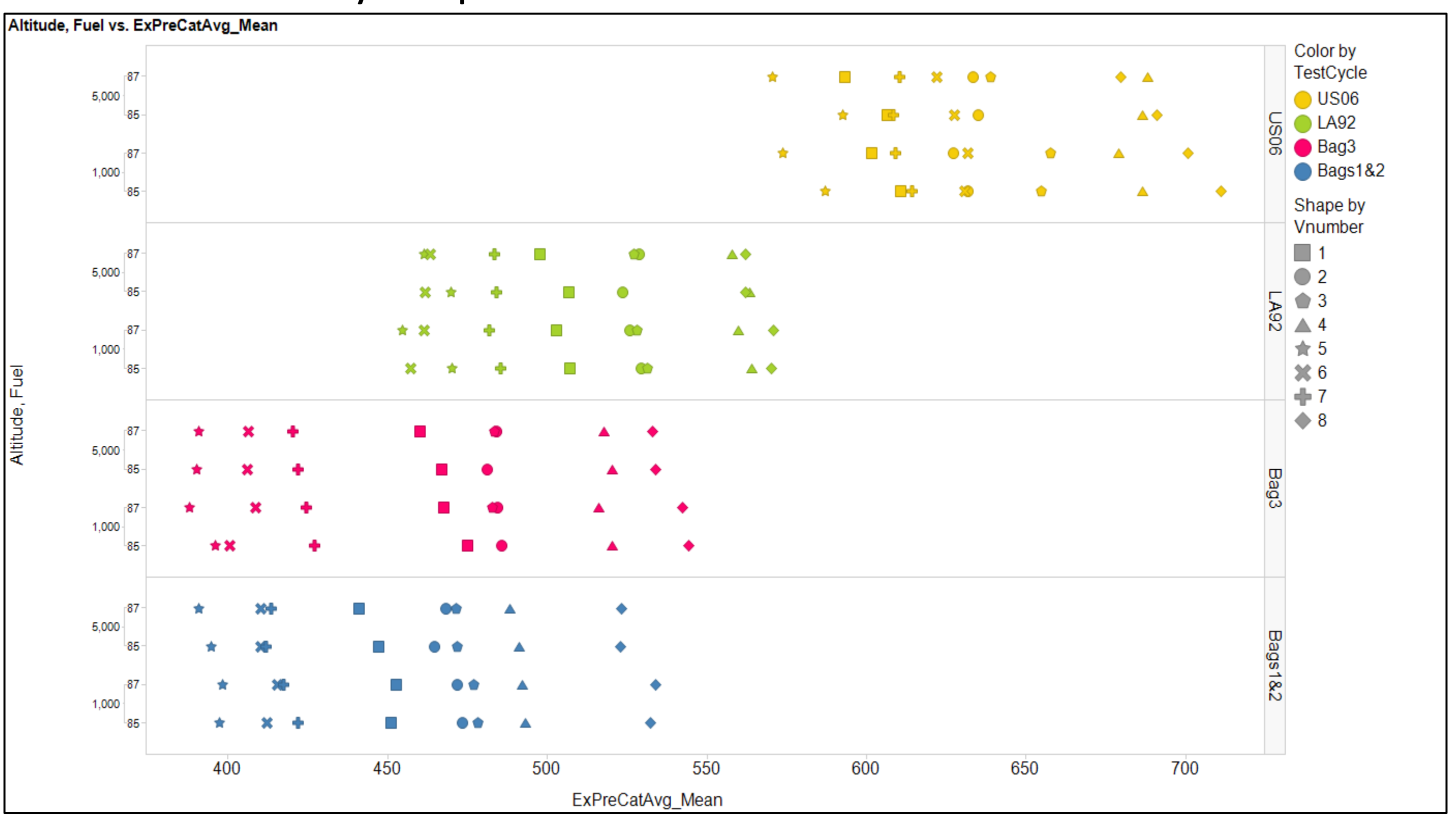


Figure 46 Exhaust Pre-Catalyst Temperature (°C) with Respect to Octane Number and Altitude

viii. Mid-Catalyst Temperatures

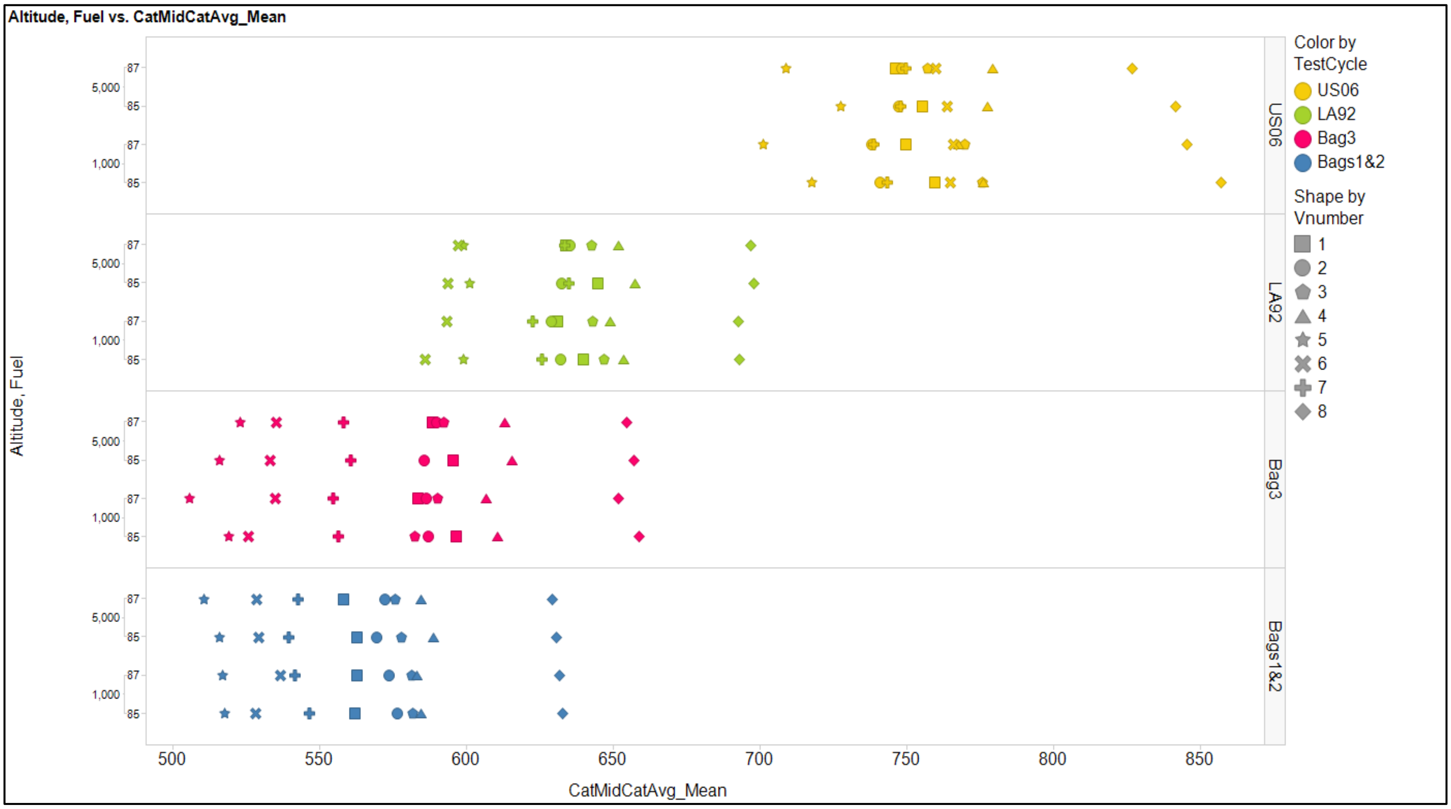


Figure 47 Exhaust Mid-Catalyst Temperature (°C) with Respect to Octane Number and Altitude

X. Recommendations

Next tests (future programs) should include both HC only and ethanol gasoline blends to understand the influence of ethanol or future renewable fuels on the magnitude of octane effects. Once the vehicle is designed for an “E10 blend” what are the implications of removing the ethanol for a given octane level?

To look for effects within individual vehicles using paired t-test statistics, the next programs should include multiple vehicles of the same model and replicate tests should be truly randomized in test sequence, i.e. flush and re-conditioning should be included along with each repeat.

More aggressive cycles like US06 only require fewer vehicles, while less aggressive cycles require more test vehicles. Also, consider increasing the number of tests on the less severe cycles while maintaining the number of more aggressive cycle tests.

If the research goal is to understand the impacts of two similar fuel octane number values on a fleet of vehicles then future programs should include additional fuels just outside these ranges, e.g. 83 and 89 AKI to improve the understanding of the two octane numbers of interest. In this study, the octane numbers were relatively close together. Interpolation of results around the octane numbers of interest would have offered better understanding of octane number effects on vehicle performance.

Because calculated fuel economy is a function of vehicle emissions (primarily CO_2) and vehicle emission levels vary considerably based on vehicle type, consider running blocks of vehicles in the same or closely matched fuel economy ranges to improve the evaluation of the incremental octane effects on a block of more similar vehicles.

XI. Acknowledgments

The program Data Analysis Panel thanks Jim Rutherford (Chevron Oronite Statistician) for his many long hours providing a multitude of data analyses, figures and chart options to help understand the magnitude of fuel octane number effects on vehicle performance, both statistically and visually. His coaching, experience and discussions on the data statistical significance and trend analyses were very much appreciated.

The program Data Capture Team thanks Dave Gian (FEV Inc.) for his technical guidance and insights into developing robust vehicle emissions test methodologies and protocols and Sridhar Koushik (FEV Inc.) for his excellent help in identifying the web-based vehicle data loggers and ensuring their proper function. Dave and Sri were essential in helping the test program get started properly and to collect accurate data.

XII. Appendices

a. SOW

SOW: Sub-Regular Grade Octane Rating (85AKI) Study

Background: The performance of spark-ignition engines is dependent upon the antiknock rating for which the engine was designed. Modern day engines are calibrated for maximum fuel economy and performance while minimizing emissions using the grade of gasoline that the manufacturer requires for use in the vehicle's operating manual. The use of fuel that is below the recommended AKI rating may result in the vehicle or engine being operated outside of conditions for which it was designed and calibrated, creating the possibility for voiding the vehicle's warranty.

The specifications for gasoline used in spark-ignition engines in the United States are found under ASTM D4814. Although the ASTM standard does not explicitly list specifications for antiknock/ octane ratings, it does provide non-mandatory information in its appendix. In the Appendix of ASTM D4814, the effect of altitude on vehicle antiknock requirement is listed for vehicles that are pre-1984 vintage. These vehicles lack the sophisticated control systems found in today's vehicles and may require fuels with different antiknock ratings upon changing altitude. The ASTM standard lists five areas in the western United States where reduced antiknock requirements for pre-1984 vehicles are applicable based on the altitude of the area. However, the ASTM standard also notes that "new vehicles have sensors to measure and engine management computers, which take into account such conditions as air charge temperature and barometric pressure. These vehicles are designed to have the same antiknock requirement at all altitudes."

Based on recent regulatory changes in some western states that allow the use of 85 AKI for newer vehicles, the importance of maintaining AKI levels in market fuels at levels that meet the engine manufacturer's requirements was made clear. As stated above, modern day vehicles do not experience any decreases in octane requirements as altitude increases. Currently, there are no publically available studies that show the degradation of performance and/or increased exhaust emissions due to the use of sub-regular grade 85 AKI fuel. Thus, a study is needed to evaluate the potential for decreased performance or increased emissions when using 85 AKI fuel versus the manufacturer's recommended "regular grade" 87 AKI fuel.

Program Proposal (General): The proposed study may consist of engine dynamometer and/or vehicle tests evaluating the impacts on fuel economy and emissions (criteria pollutants and CO2) when an 85 AKI fuel is used versus 87 AKI fuel. Higher load conditions, such as during towing performance tests or a high load emissions test may be considered. Vehicle selection should include vehicles that are expected to come to the market such as those equipped with engines that are downsized and exhibit a lower ratio of engine displacement size to vehicle weight. Likewise, vehicles that can tow heavy trailers relative to their engine size are also candidates for evaluation and testing. The study should include the use of fuels that are representative of fuels available in the high altitude market place where the 85 AKI and equivalent fuels are found, this would include E10 85 AKI and E10 87 AKI fuels, it is possible that an 85AKI E0 fuel could be included for comparison while the fuel recommended by the manufacturer (87 AKI) would serve as baseline fuel.

Program Proposal (Specific):
The request for CRC Funds is for fuel blending, vehicle transport from SwRI to Michigan, and ECM data acquisition instrumentation in a program structure as outlined below. The vehicles will come from OEM fleets and the current EPAct fleet at SwRI.

- **Program Objective**
    - Evaluate vehicle performance and emissions effects of 85 AKI gasoline relative to 87 AKI gasoline at two elevations.

- **Test Locations**
  - Variable Altitude Chassis Dynamometer Emissions Chambers (GM, Ford, Chrysler)
  - Two test elevations: Low = 1,000 ft and High 5,000 ft
  - No other contract lab with variable altitude emissions capability located

- **Metrics for evaluation**
  - Fuel economy
  - Emissions (CO_2, CO, NO_x, THC, NMOG)
  - Pre-cat inlet temperature
  - Spark Advance
  - Stoichiometry

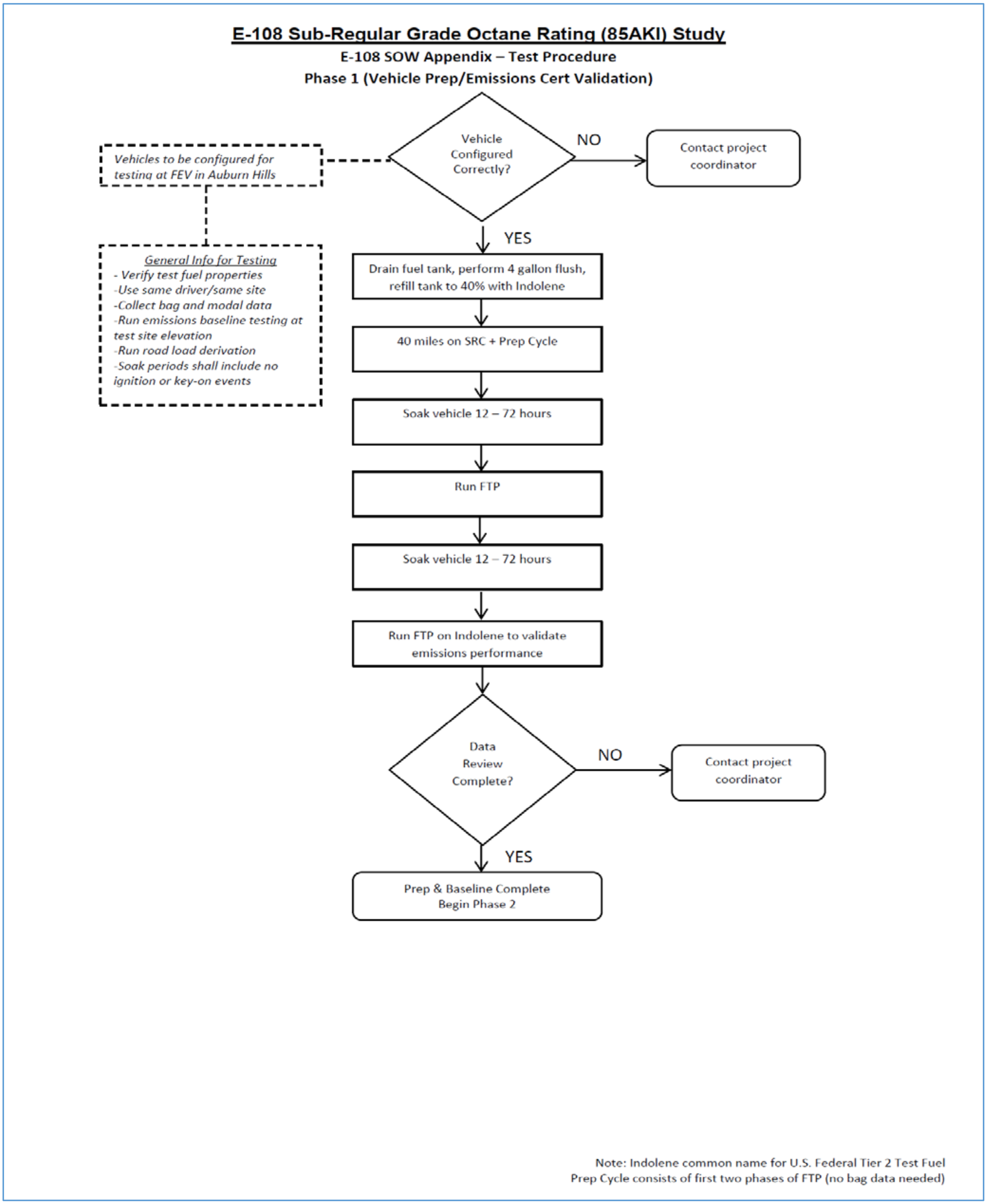
- **Vehicle selection criteria**
  - 9 Test vehicles – Purposely varied engine architectures, load factors, model years, manufacturers, and passenger cars and trucks.
  - Vehicle load factors have been increasing for some time in the US marketplace as a result of a push for higher vehicle FE and lower GHG emissions.

Vehicle	Model Year	Odometer	Fuel System	Induction System	Eng. Disp. (L)
Toyota Corolla	2008	13,248	PFI	Nat. Asp.	1.8
Honda Odyssey	2008	13,248	PFI	Nat. Asp.	3.5
Honda Fit	2012	19,378	PFI	Nat. Asp.	1.5
Ford Transit Connect	2010	11,860	PFI	Nat. Asp.	2.0
Ford Focus	2008	12,563	PFI	Nat. Asp.	2.0
Ford F-150 Ecoboost	2011	5,200	DI	Turbo	3.5
Ford F-150	2008	15,487	PFI	Nat. Asp.	5.4
Dodge Dart	2013	14,403	PFI	Turbo	1.4
Chevy Equinox	2010	37,396	DI	Nat. Asp.	3.0

- **Test Fuels**
  - Matched E10 blends of 85 and 87 AKI fuel pair
  - Equivalent properties including heating value, composition, (aromatics, olefins and sulfur), RVP, distillation (T50 and T90) and H/C ratio
  - Octane tolerance - 85.0-85.4 and 87.0-87.4; Sensitivity tolerance - 6-8
  - Fuel supplier can meet targets except Octane Sensitivity for 85 AKI, currently 4.9
  - Lab inspections: 3 or 4 lab validation. BP, Flint Hills, Chevron confirmatory labs
  - Fuel Volume: 4 gal flush +12 gal fill.   (20 mile conditioning and 2 repeat tests)

- **Test cycles**
  - Preliminary: Each vehicle will receive a USFTP-75 on Tier 2 to validate emissions performance
  - Test cycles: 1×USFTP-75 (cold) + 1×LA92 (hot) + 1×US06 (hot)
    - Repeat – 2 consecutive days – no fuel change between
  - Test order:
    - Five cars will start with 87 AKI and switch to 85 AKI (A →B)
    - Five cars will start with 85 AKI and switch to 87 AKI (B →A)
  - Number of tests:
    - 9 vehicles x 2 fuels x 2 repeats x 2 altitudes = 72 observations
    - 2 observations / day = 40 work days
    - Additional 20 days for fuel switching, initial data analysis, extra tests

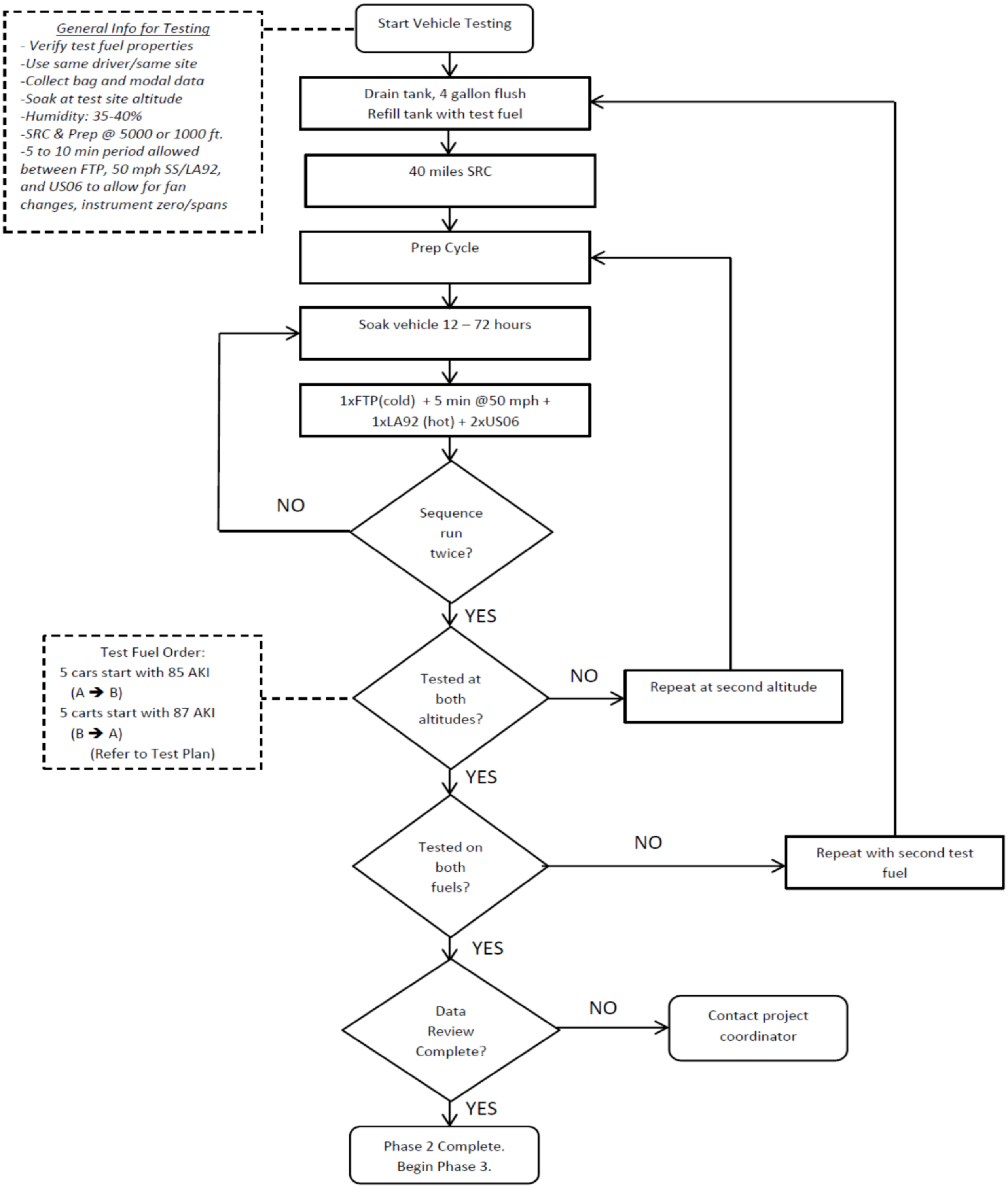
b. Flow Charts – Vehicle preps, ECM and Catalyst conditioning, Emissions Test Cycles



E-108 Sub-Regular Grade Octane Rating (85AKI) Study

E-108 SOW Appendix – Test Procedure

Phase 2 (Vehicle Testing @ 5000 ft. and 1000 ft. in Altitude Chamber)



Note: Indolene common name for U.S. Federal Tier 2 Test Fuel
Prep Cycle consists of first two phases of FTP (no bag data needed)

c. Test Vehicle Matrix – Detailed

	CRC E-108 Program Test Vehicles								
Year	2012	2008	2008	2010	2011	2013	2008	2008	2010
Make	Honda	Ford	Toyota	Ford	Ford	Dodge	Ford	Honda	Chevrolet
Model	Fit	Focus	Corolla CE	Transit Connect	F-150	Dart SXT	F150 XL 5.4 4x2	Odyssey LX	Equinox
VIN	JHMGE8H3XCC005253	1FAHP32N58W15120(	1NXBR32E88Z050881	NMOKS9BN5AT000010	1FTFX1ET8BKD00021	1C3CDFBH5DD576113	1FTPF12V98KB22903	5FNRL38288B017848	2CNFLDEY0A6200484
Odometer		12563	13248	11860	5,200	14403	15487	13248	37396
Engine	1.5L I4 Nat Asp	2.0L I4	1.8L I4	2.0L I4	3.5L V6	1.4L Turbo	5.4L Nat Asp	3.5L Nat.Asp	1706
Displacement	1.5	2.0	1.8	2.0	3.5	1.4	5.4	3.5	3.0
Transmission	5-spd A/T - 6T40	4-spd A/T - 4F27E	5-spd A/T	4-spd A/T	6-speed A/T - 6R80	6-speed DDCT - C635	4-SPD - 4R75E	5-spd A/T	6-spd A/T - 6T70
1st gear	2.996	2.81	3.166	2.82	4.17 : 1	4.15	2.84	2.7	4.48
2nd gear	1.679	1.49	1.904	1.5	2.34 : 1	2.26	1.95	1.61	2.87
3rd gear	1.067	1	1.31	1	1.52 : 1	1.44	1.00	1.07	1.84
4th gear	0.761	0.73	0.885	0.73	1.14 : 1	0.97	0.70	0.77	1.41
5th gear	0.552		0.725		0.86 : 1	0.75		0.58	1
6th gear	-				0.69 : 1	0.62		-	0.74
Reverse	1.957			2.65	3.40 : 1	4		1.89	2.88
Final Drive	4.563	3.34	2.96	4.2	3.55	4.43	3.55	4.312	2.77
Fuel System	PFI	PFI	PFI	PFI	GDI	PFI	PFI - FFV	PFI	GDI
Recommended fuel (R+M)/2	87	87	87	87	87	93 prefered, 87 accepted	87	87	87
Aspiration	NA	NA	NA	NA	Turbocharged	Turbocharged	NA	NA	Nat. Asp.
Curb Weight (FEV measured)	2,553	2,588	2,520	3492	5,289	3,261	4,844	4,311	3900
ETW in lbs	2,875	3,000	2,875	3750	5,500	3,500	5,250	4,750	4500
Curb Weight (kg)	1158	1174	1143	1584	2399	1479	2197	1955	1769
Load Factor (kg/L)	772	587	635	792	685	1057	407	559	590
Emission Control Information									
U.S.EPA	T2B5	T2B4	T2B5	T2B4	T2B4	T2B5	T2B8	T2B5	T2B4
Emission Cert Group	LDV	LDV	LDV	LDT1	LDT2	LDV	LDT2	LDT2	LDT2
California	Lev II ULEV PC	ULEV II	ULEV II	not certified		LEV II PC		ULEV II	ULEV Qual.
OBD	CA OBD II	CA II	OBD II	OBD II	OBD II	CA OBD II	F II	CA OBD II	CA OBD II
Fuel	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Test Group	CHNXV01.5HB2	8FMXV02.0VD4	8TYXV01.8BEA	AFMXT2.01DV	BFMXT03.54EP	DCRXV01.44P1	8FMXT05.44HF	8HNXT03.54KR	AGMXJ03.0157
Evaporative Family	CHNXROO96VEA	8FMXR0125KAK	8TYXR0115P12	AFMXR0125NBB	BFMXR0265NBV	DCRXR0100PKO	8FMXR0240NBR	8HNXR0163BBA	AGMXR0138813

d. Octane Test Fuels – Detailed

Name			Test Methods	Test Method Used?	Test Method Used?	Test Method Used?	Test	85 AKI E10	85 AKI E10	85 AKI E10	85 AKI E10				87 AKI E10	87 AKI E10	87 AKI E10	87 AKI E10	87 AKI E10			
		Requested	GAGE	Lab 2	Lab 3	Lab 4		GAGE	Lab 2	Lab 3	Lab 4	Average	Std	% CoV	GAGE	Lab 2	Lab 2	Lab 3	Lab 4	Average	Std	% CoV
RON		D2699	D2699	D2699	D2699	D2699	RON	88.0	88.4	87.4	87.6	87.9	0.4	0.5%	91.0	91.0	90.8	90.5	90.2	90.7	0.3	0.4%
MON		D2700	D2700	D2700	D2700	D2700	MON	82.0	81.7	82.0	82.4	82.0	0.3	0.4%	83.2	84.7	84.0	83.6	84.0	83.9	0.6	0.7%
AKI		---	(R+M)/2	(R+M)/2	(R+M)/2	(R+M)/2	AKI	85.0	85.1	84.7	85.0	84.9	0.2	0.2%	87.1	87.9	87.4	87.1	87.1	87.3	0.3	0.4%
Sensitivity		Calc.	R-M	R-M	R-M	R-M	Sensitivity	6.0	6.7	5.4	5.2	5.8	0.7	11.6%	7.8	6.3	6.8	6.9	6.2	6.8	0.6	9.4%
Relative Density	S.G. 60/60F	D1298	D4052	D4052	D4052	D4052	Relative Density	0.7357	0.7359	0.7357	0.7365	0.7360	0.0	0.1%	0.7367	0.7368		0.7365	0.7364	0.7366	0.0	0.0%
DVPE	psi @ 100F	D5191	D5191	D5191	D5191	D5191	DVPE	8.32	8.18	8.59	8.48	8.39	0.2	2.1%	8.57	8.62		8.89	8.77	8.71	0.1	1.7%
Distillation	deg. F	D86	D86	D86	D86	D86	Distillation															
IBP							IBP	100.0	100.4	98.2	104.4	100.8	2.6	2.6%	105.8	96.2		96.3	102.9	100.3	4.8	4.8%
T5							T5	125.2	128.7	126.6	126.6	126.8	1.4	1.1%	123.3	122.9		126.6	124.4	124.3	1.7	1.3%
T10							T10	133.0	134.9	134.0	133.5	133.8	0.8	0.6%	130.6	130.3		132.7	131.5	131.3	1.1	0.8%
T20							T20	142.5	144.0	142.8	142.5	143.0	0.7	0.5%	140.7	140.7		141.3	141.4	141.0	0.4	0.3%
T30							T30	149.2	151.2	149.2	149.3	149.7	1.0	0.7%	147.7	147.8		147.4	148.3	147.8	0.4	0.3%
T40							T40	162.0	166.1	159.7	162.0	162.4	2.7	1.6%	153.1	155.3		154.3	154.5	154.3	0.9	0.6%
T50							T50	214.7	220.0	214.3	215.2	216.1	2.7	1.2%	213.3	212.2		208.8	211.3	211.4	1.9	0.9%
T60							T60	240.8	241.5	239.4	240.0	240.4	0.9	0.4%	240.6	243.0		242.8	243.8	242.6	1.4	0.6%
T70							T70	260.1	264.4	261.2	261.2	261.7	1.9	0.7%	264.4	265.1		265.3	265.5	265.1	0.5	0.2%
T80							T80	285.3	288.7	284.9	285.5	286.1	1.8	0.6%	287.1	286.5		285.5	287.9	286.7	1.0	0.4%
T90							T90	313.3	315.0	313.2	313.2	313.7	0.9	0.3%	314.8	313.5		312.1	314.0	313.6	1.1	0.4%
T95							T95	333.7	341.8	334.1	---	336.5	4.6	1.4%	337.5	340.9		332.5	---	337.0	4.2	1.3%
FBP							FBP	360.3	361.1	358.3	359.7	359.9	1.2	0.3%	360.1	363.0		359.2	361.5	361.0	1.7	0.5%
Residue							Residue	1.0	1.0	1.0	1.0	1.0	0.0	0.0%	1.2	1.0		1.0	1.0	1.1	0.1	9.5%
DI							DI	1180	1203	1179	1182	1186.1	11.1	0.9%	1174	1172		1160	1168	1168.5	6.0	0.5%
Aromatics	v%	D1319	D1319	D1319	D1319	---	Aromatics	10.5	14.0	10.4	---	11.6	2.1	17.6%	11.1	13.1		10.5	---	11.6	1.4	11.8%
Olefins					D1319		Olefins	6.7	9.6	8.2	---	8.2	1.5	17.8%	7.0	10.3		8.7	---	8.7	1.7	19.0%
Paraffins					D1319		Paraffins	73.0	65.8	72.1	---	70.3	3.9	5.6%	72.0	65.7		71.3	---	69.7	3.5	5.0%
Ethanol				D4815	D4815		Ethanol	9.80	10.6	9.3	9.4	9.9	0.6	6.3%	9.86	10.9		9.5	9.5	10.1	0.7	6.9%
Sum							Sum	100.0	100.0	100.0	---				100.0	100.0		100.0	---			
Sulfur	ppm	D7039	D5453	D2622	D5453	D5453	Sulfur	<0.0001	<5	<1	0.25	0.3	#DIV/0!	#DIV/0!	<0.0001	<5		<1	0.22	0.2	#DIV/0!	#DIV/0!
Carbon	wt%	D3343	D5291		5291		Carbon	81.68		81.51		81.6	0.1	0.1%	81.90			81.62		81.8	0.2	0.2%
Hydrogen	wt%	D3343	D5291		5291	D3343	Hydrogen	14.57		14.50	14.56	14.5	0.0	0.3%	14.22			14.49	14.51	14.4	0.2	1.1%
H/C Ratio		Calc.	Calc.				H/C Ratio	2.120		2.12		2.1	0.0	0.0%	2.068			2.12		2.1	0.0	1.8%
NHV*	btu/lb	D240	D240		D4809		NHV*	18,181.3	---	19,312	---	18746.7	799.5	4.3%	18,129.8			19,331		18730.4	849.4	4.5%
Existent Gum	mg/100ml	D381	D381	D381	D381	D381	Existent Gum								<0.5							
- Unwashed			200 ppm PEA Added				- Unwashed	14.6	5.0	9.8	16.6	11.5	5.2	45.1%	5.8	6.0		11.8	17.8	10.4	5.7	55.0%
- Washed							- Washed	<0.5	0.0	0.0	0.4	0.1	0.2	173.2%		0.0		0.0	0.4	0.1	0.2	173.2%

(*) Note: Wide variation in NHV from two labs. Chrysler re-analyzed the 87 AKI test fuel. NHV = 41.52 MJ/kg (17,894 BTU/lb). Used D240 test method. Lab 3 appears to have reported HHV, not NHV.
Confirmed that each of the 3 OEM Emissions Sites used the Average NHV from this spreadsheet. FE numbers should not be compared to those reported to EPA (plus these are not Tier 2 Cert Fuels.)

e. Standardized Vehicle Emissions Drive Cycles - Detailed

Reference: https://www.dieselnet.com/standards/cycles/#us-ld

i. US-FTP-75

The FTP-75-75 (Federal Test Procedure) has been used for emission certification and fuel economy testing of light-duty vehicles in the United States since 1978. The test is often referred to as simply 'FTP-75' (this should not be confused with the FTP-75 test for heavy-duty engines).

The FTP-75-75 and the FTP-75-72 are two variants of the EPA Urban Dynamometer Driving Schedule (UDDS). The FTP-75-75 cycle is derived from the FTP-75-72 by adding a third phase of 505 s, identical to the first phase of FTP-75-72 but with a hot start. The third phase starts after the engine is stopped for 10 minutes. Thus, the entire FTP-75-75 cycle consists of the following segments:

1. Cold start transient phase (ambient temperature 20-30°C), 0-505 s
2. Stabilized phase, 506-1372 s
3. Hot soak (min 540 s, max 660 s)
4. Hot start transient phase, 0-505 s

Emissions from each phase are collected in a separate teflon bag, analyzed and expressed in g/mile (g/km). The weighting factors are 0.43 for the cold start phase, 1.0 for the 'stabilized' phase and 0.57 for the hot start phase.

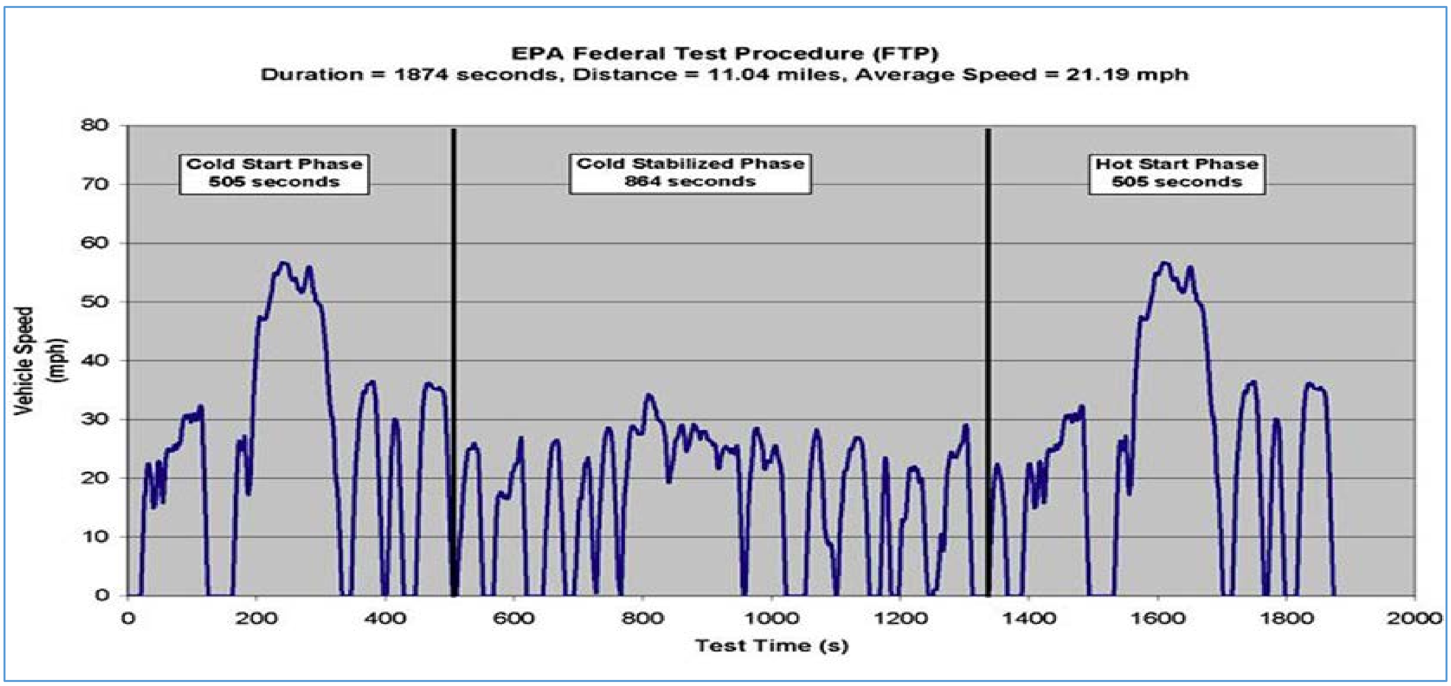


Figure 48 Vehicle Speed Trace of US FTP-75 Emissions Test Cycle

ii. LA92

The California Unified Cycle (UC), Figure 1, is a dynamometer driving schedule for light-duty vehicles developed by the California Air Resources Board. The test is also referred to as the Unified Cycle Driving Schedule (UCDS). The UC test was referred to in the past as the LA92 test. It was often called the "Unified LA92", to distinguish it from a "short LA92"; test, which included the first 969 seconds of the Unified LA92.

The UC test has a similar three-bag structure to the US FTP-75, but is a more aggressive driving cycle than the federal FTP-75-75; it has higher speed, higher acceleration, fewer stops per mile, and less idle time. The UC test is run in the following manner: Bags 1 and 2 are run consecutively, followed by a ten minute hot soak, then Bag 3 which is a duplicate of Bag 1. Overall cycle emissions are calculated in the same manner as the weighted, overall FTP-75-75 formula, taking actual mileage from the UC into account.

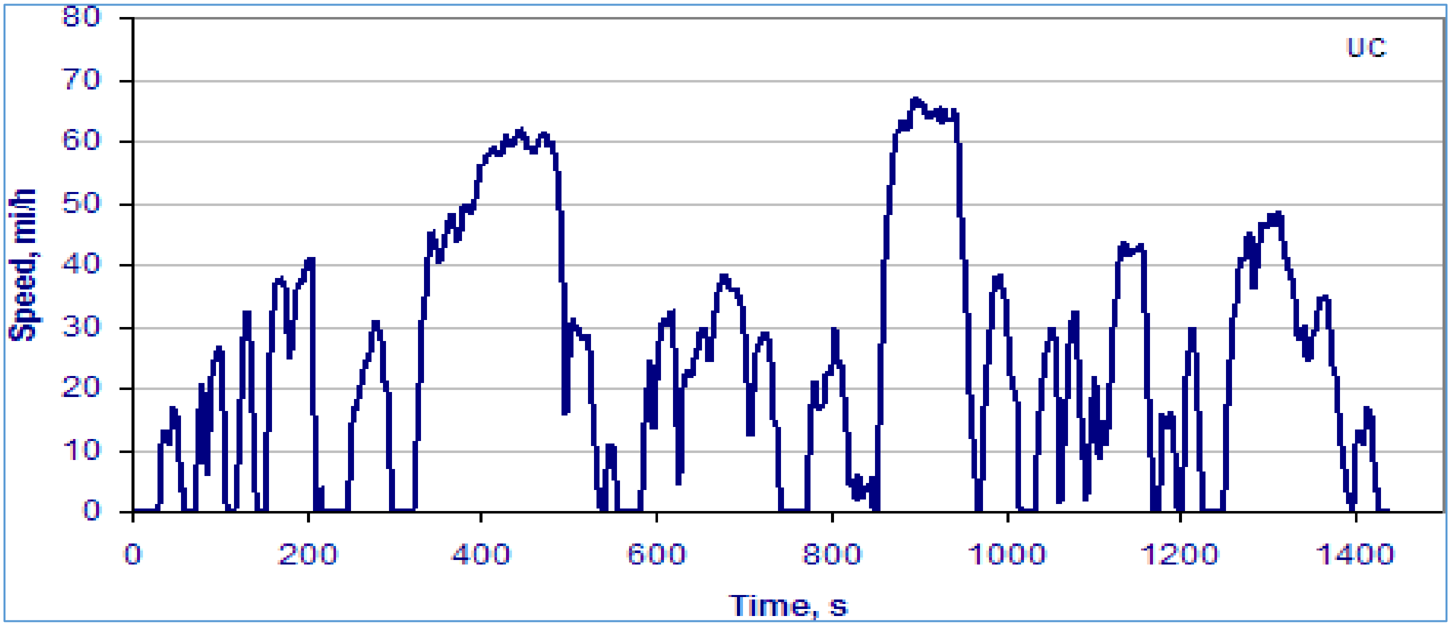


Figure 49 Vehicle Speed Trace of LA92 Emissions Test Cycle

iii. US06

The US06 Supplemental Federal Test Procedure (SFTP-75) was developed to address the shortcomings with the FTP-75-75 test cycle in the representation of aggressive, high speed and/or high acceleration driving behavior, rapid speed fluctuations, and driving behavior following startup.

Since model year 2008, the US06 results are also used for the determination of the EPA on-road fuel economy ratings using the EPA 5-cycle method.

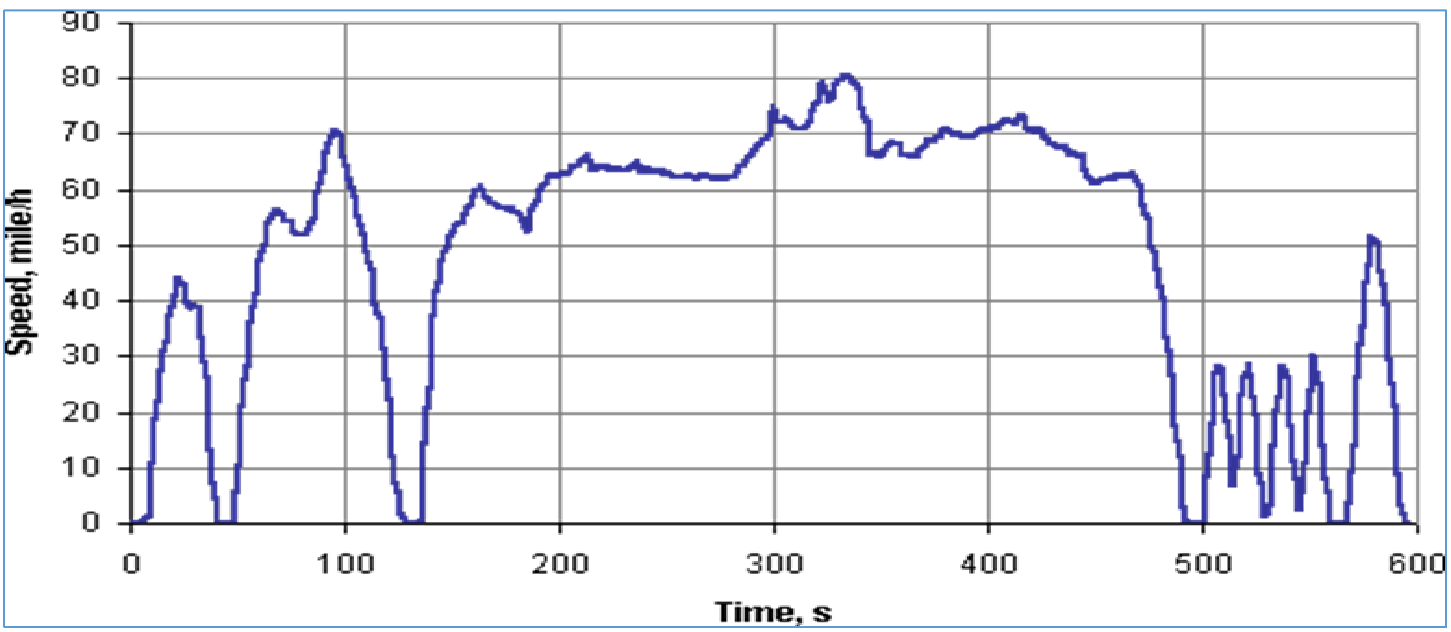


Figure 50 Vehicle Speed Trace of US06 Emissions Test Cycle

g. Significance of Vehicle Driver Behavior on Real World Fuel Economy and Results of This Program

Reference: U.S. EPA, Final Technical Support Document, "Fuel Economy Labeling of Motor Vehicles: Revisions to Improve Calculation of Fuel Economy Estimates," EPA420-R-06-01, December 2006.

There is a general recognition that the original US FTP-75 emissions test cycle and fuel economy (FE) vehicle label calculations did not adequately represent enough consumer driving habits to ensure consumer real world fuel economy matched their vehicle's FE label estimates. The 2006 U.S. EPA Technical Support Document describes the new 5-cycle calculation of vehicle FE and significance of understanding a range of driver behaviors on this program's measurement of fuel octane rating effects on vehicle performance.

"A fundamental issue with today's fuel economy estimates is that the underlying test procedures do not fully represent real-world driving conditions. Some of the key limitations are that the highway test has a top speed of only 60 miles per hour, both the city and highway tests are run at mild climatic conditions (75°F), both tests have mild acceleration rates, and neither test is run with the use of accessories, such as air conditioning. However, since the time of the last fuel economy labeling revisions in the mid-1980's, EPA has established several additional test procedures, used for emissions compliance purposes, which capture a much broader range of real-world driving conditions. Specifically, these emissions test cycles capture the effects of higher speeds, more aggressive driving (i.e., higher acceleration rates), the use of air conditioning at higher ambient temperatures, and colder temperature operation. Our analysis indicates that these factors can have a significant impact on fuel economy, and that the impacts can vary widely across different vehicles."

EPA's Technical Support document goes on to state, "Our final rule revises the test methods by which the city and highway fuel economy estimates are calculated. We are replacing the current method of adjusting the city (FTP-75) test result downward by 10% and the highway (HFET) test result downward by 22%. Instead, we are finalizing a new approach that incorporates additional test methods that address factors that impact fuel economy, but are missing from today's tests – specifically, higher speeds, more aggressive driving (higher acceleration rates), the use of air conditioning, and the effect of cold temperature. The new test methods will bring into the fuel economy estimates the test results from the five emissions tests in place today: FTP-75, HFET, US06, SC03, and Cold FTP-75.[a]

[a] The US06 test is designed to represent high speed highway driving and aggressive (i.e., rapid accelerations and decelerations) urban driving. The SC03 test is designed to represent the impact of air conditioner operation at high temperatures. The Cold FTP-75, which is conducted at 20°F, is designed to reflect the impact of cold temperatures. "

h. Potential Data Outlier Tables

Core Emissions Data Repeatability Potential Outliers

	LA92	US FTP	US06
InCO	1 (2, 5000, 87 E10)	1 (3, 1000, 87 E10)	2 (2, 1000, 87E 10) (2, 1000, 87 E10)
InCO2	0	0	1 (3, 1000, 85 E10)
FC	0	0	2 (3, 1000, 85 E10) (3, 5000, 85 E10)
InNMOG	3 (2, 1000, 85 E10) (2, 5000, 85 E10) (2, 5000, 85 E10)	3 (2, 1000, 87 E10) (2, 5000, 85 E10) (3, 5000, 85 E10)	0
(vehicle, altitude, fuel)			

Core Emissions Data Means Potential Outliers

	LA92	US FTP	US06
InCO	1 (8, 1000, 85 E10)	0	1 (5, 5000, 85 E10)
InCO2	1 (5, 1000, 87 E10)	1 (4, 1000, 85 E10)	1 (3, 1000, 87 E10)
FC	1 (5, 1000, 87 E10)	1 (4, 1000, 85 E10)	1 (3, 1000, 87 E10)
InNMOG	1 (3, 5000, 85 E10)	1 (2, 1000, 85 E10)	1 (4, 5000, 85 E10)
(vehicle, altitude, fuel)			

Performance Data Potential Outliers

	Bag3	Bags1&2	LA92	US06
Engine Speed	1 (6, 1000, 87 E10)	0	0	0
Load	1 (7, 1000, 85 E10)	0	0	0
Ignition Timing	1 (6, 5000, 87 E10)	0	0	0
ExPreCatAvg	1 (3, 1000, 85 E 10)	0	0	0
CatMidAvg	0	0	1 (5, 1000, 87 E10)	0
(vehicle, altitude, fuel)				

i. Test Program Vehicle Response Drift

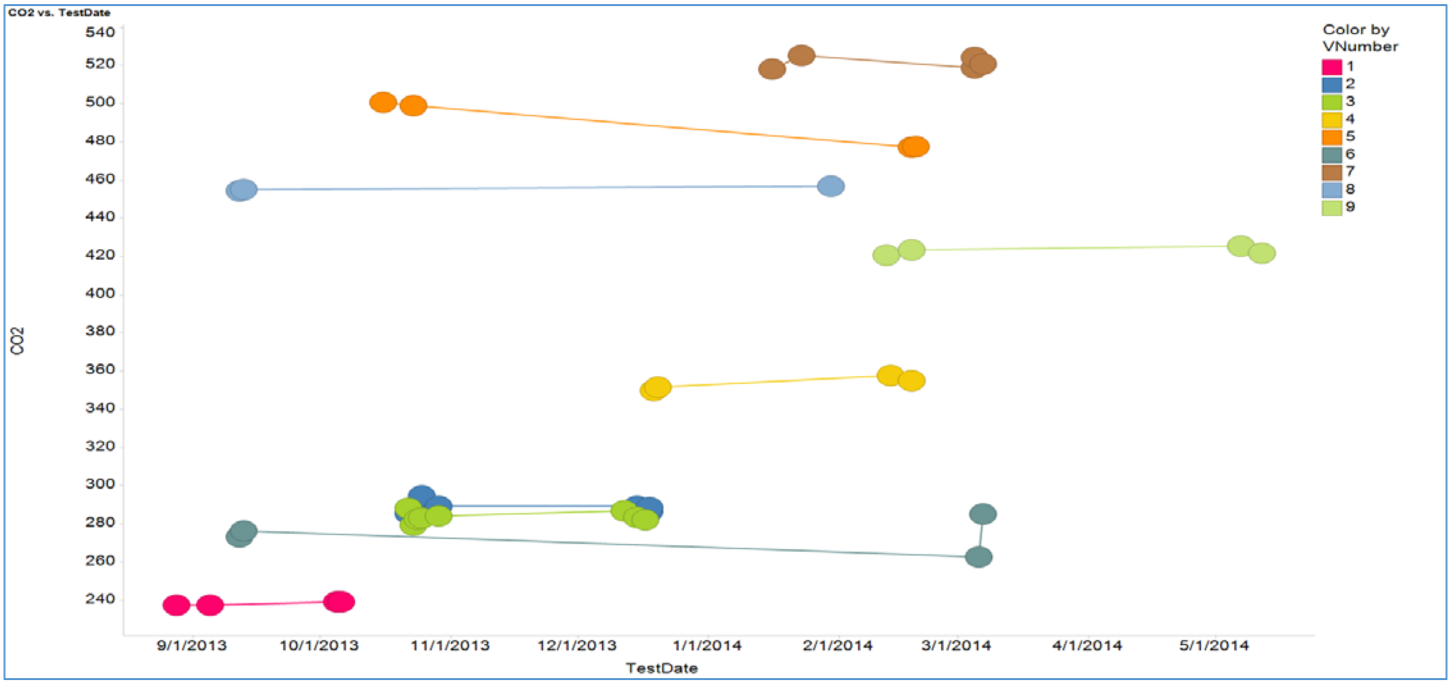


Figure 51 CO2 Emissions from SOT to EOT Measured on Tier2 Emissions Certification Fuel

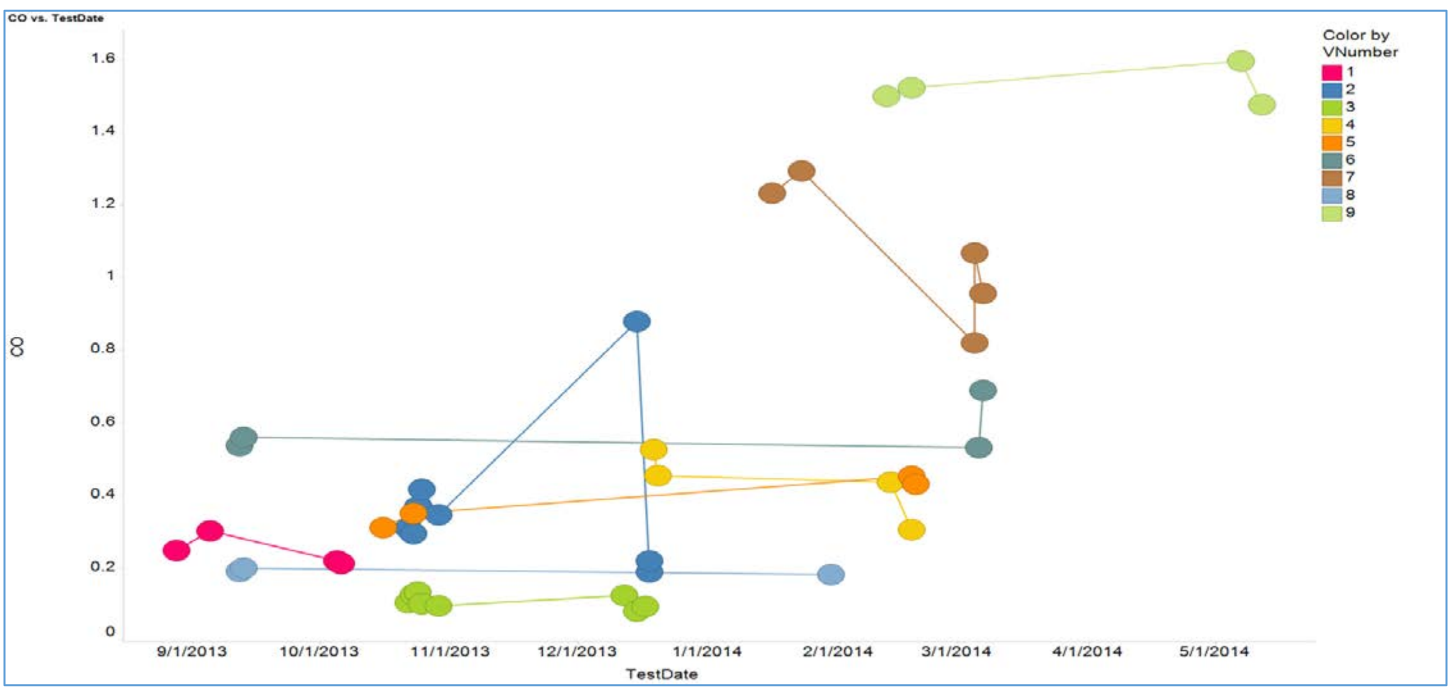


Figure 52 CO Drift SOT to EOT

Analysis of Vehicle Response Drift: SOT → EOT Emissions and FE Data

US FTP Tests; Tier 2 Emissions Cert Fuel

- Significant ($p<0.05$) drift for CO_2 and FE for vehicle 1.
- Significant ($p<0.05$) drift for CO, CO_2 and FE for vehicle 5.
- Significant drift for CO for vehicle 7.

	p-values for drift								
Vehicle Number	1	2	3	4	5	6	7	8	9
CO	0.164	0.749	0.419	0.252	0.004	0.522	0.045	0.324	0.722
CO_2	0.000	0.826	0.754	0.073	0.001	0.944	0.906	0.127	0.521
FE	0.002	0.889	0.753	0.087	0.001	0.955	0.802	0.225	0.926
NMOG	0.706	0.540	0.385	0.173	0.955	0.870	0.167	0.220	0.211

Emissions Data Sheet Inspection

- Vehicle 1: CO2 / FE Data – Tight Precision. Small change in magnitude.
- Vehicle 5: Change in response over time.
  - SOT FE Avg. = 17.80 mpg EOT FE Avg. = 18.55 (+4.2% Inc.)
- Vehicle 7: CO Change in Response over time.
  - SOT CO Avg. = 1.26 g/mile EOT CO Avg. = 0.95 (-24.6% Dec.)

Figure 53 Analysis of Emissions Drift

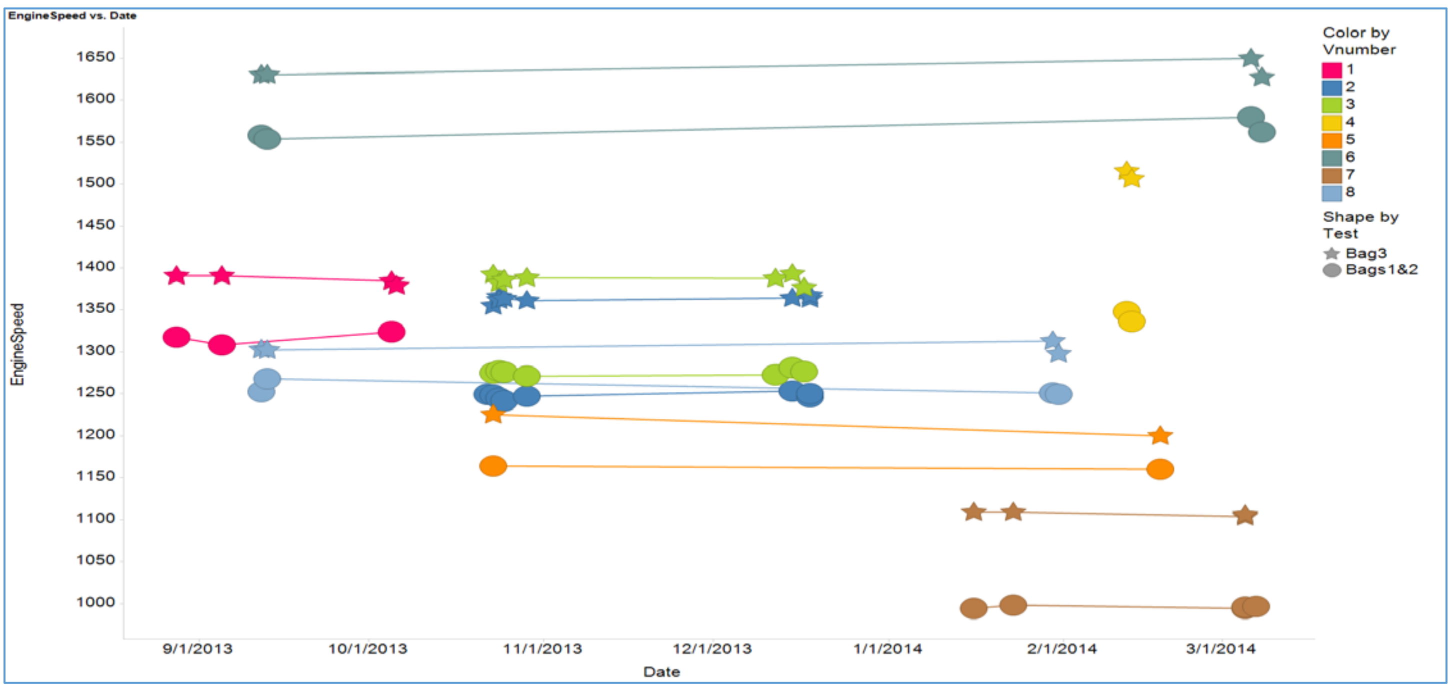


Figure 54 Engine Speed Response Drift

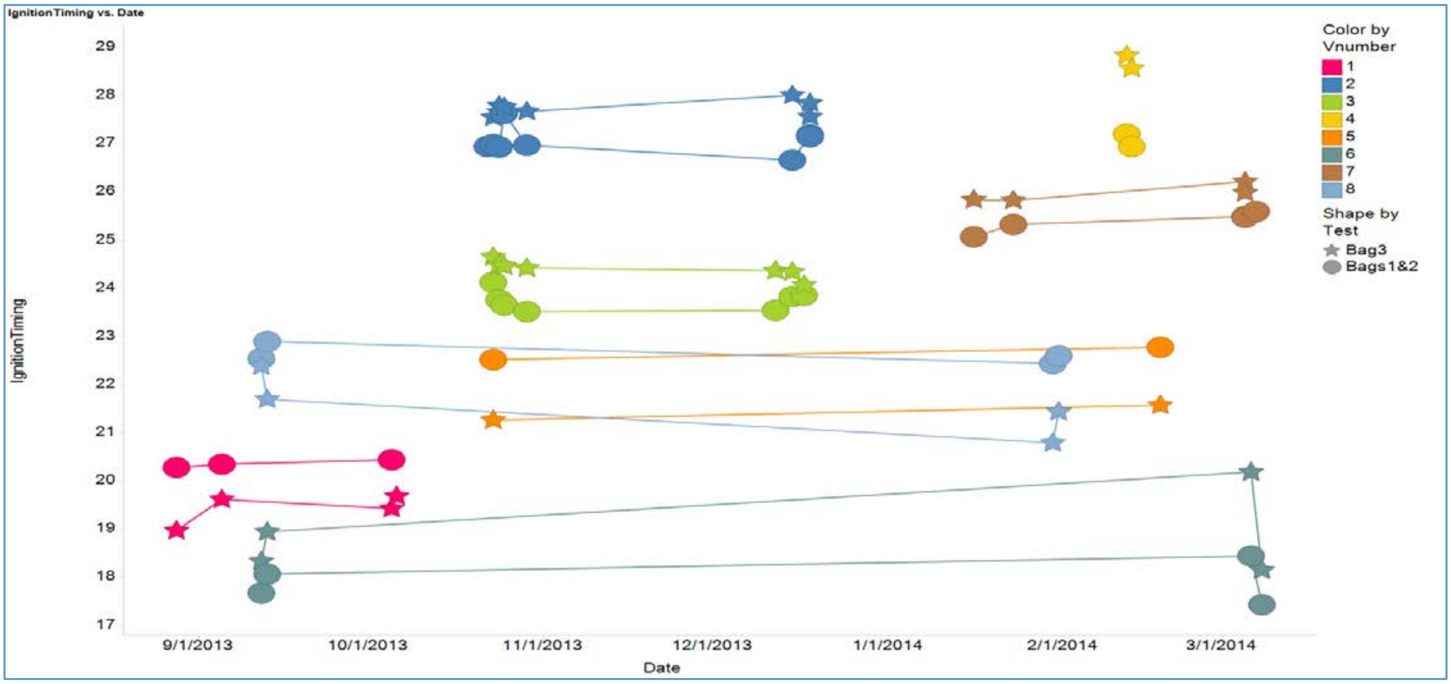


Figure 55 Ignition Timing Response Drift

Analysis of Vehicle Response Drift: SOT → EOT Performance Data
US FTP Tests; Tier 2 Emissions Cert Fuel

- Significant ($p<0.05$) drift for each vehicle with testable data for at least one performance result.

		p-values for drift								
	Vehicle Number	1	2	3	4	5	6	7	8	9
Bag3	Vehice Speed	0.172	0.272	0.780	na	na	0.203	0.160	0.615	na
Bag3	Load	0.015	0.509	0.690	na	na	0.904	0.632	0.873	na
Bag3	Ignition Timing	0.527	0.353	0.058	na	na	0.669	0.130	0.187	na
Bag3	ExPreCatAvg	0.210	0.016	0.451	na	na	0.049	0.077	na	na
Bag3	CatMidCatAvg	0.815	0.021	0.071	na	na	0.117	0.569	na	na
Bags1&2	Vehice Speed	0.814	0.639	0.233	na	na	0.731	0.018	0.012	na
Bags1&2	Load	0.207	0.238	0.508	na	na	0.863	0.886	0.962	na
Bags1&2	Ignition Timing	0.279	0.675	0.913	na	na	0.914	0.054	0.395	na
Bags1&2	ExPreCatAvg	0.114	0.844	0.230	na	na	0.071	0.014	na	na
Bags1&2	CatMidCatAvg	0.432	0.963	0.035	na	na	0.160	0.227	na	na

Figure 56 Vehicle Performance Testing Analysis of Drift from SOT to EOT

j. Individual Vehicle FE, CO_2, and CO Percent Change Data

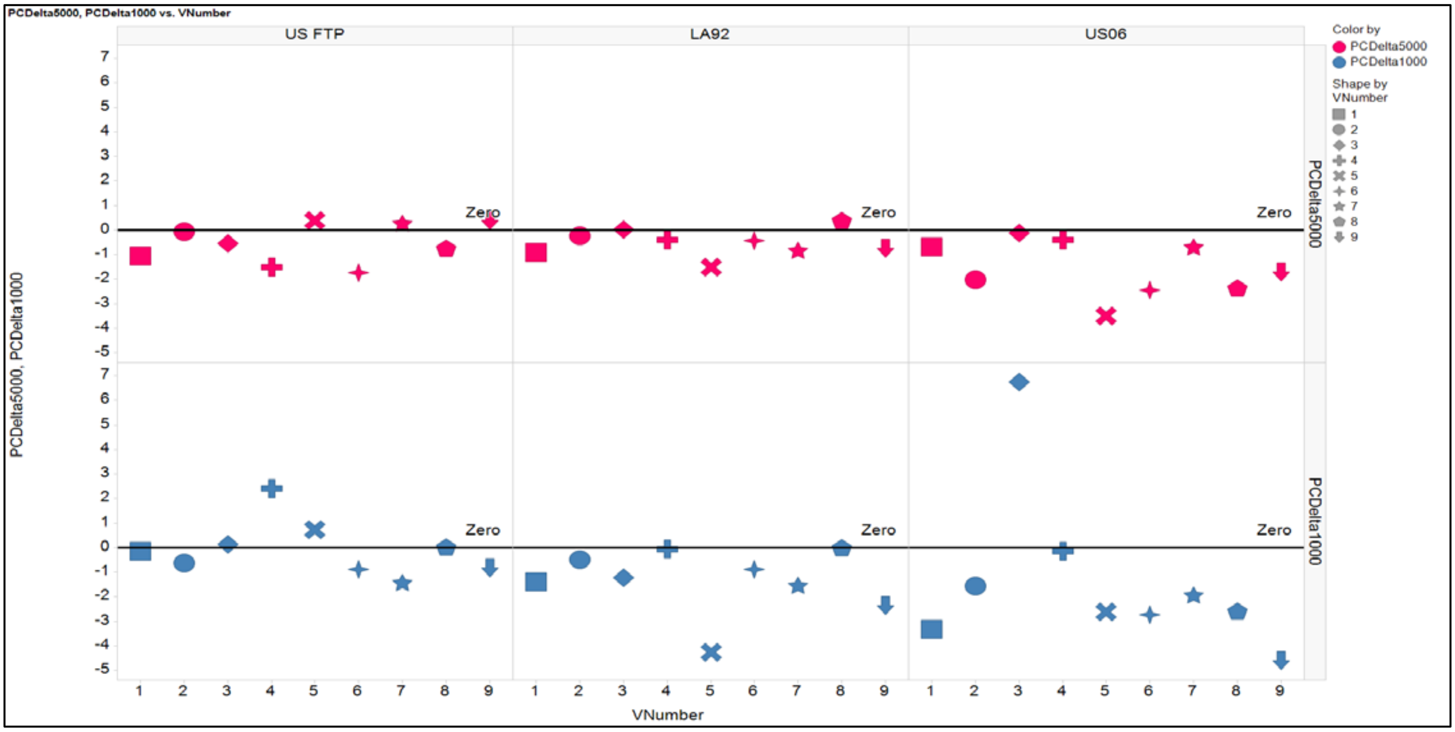


Figure 57 Individual Vehicle Fuel Economy Percent Change when moving from 87 to 85 AKI Fuel

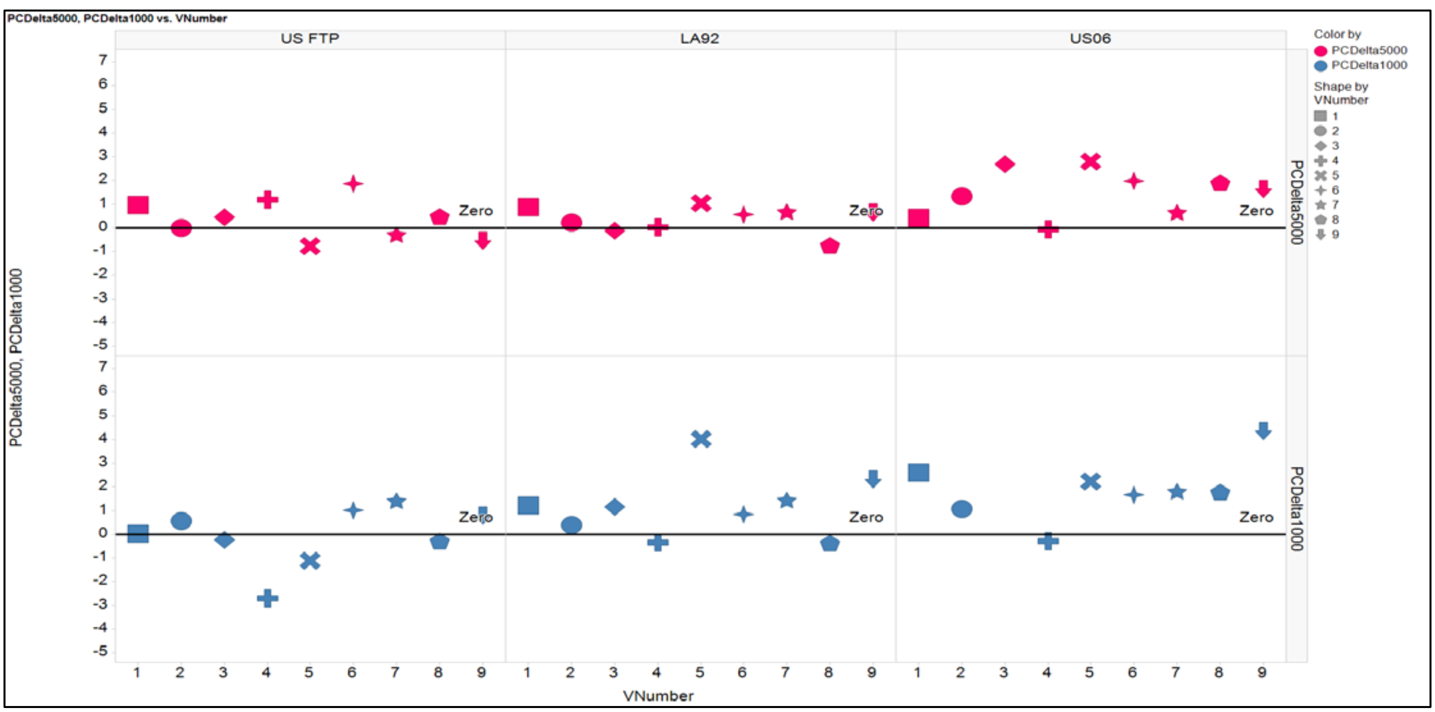


Figure 58 Individual Vehicle CO_2 Percent Change when moving from 87 to 85 AKI Fuel

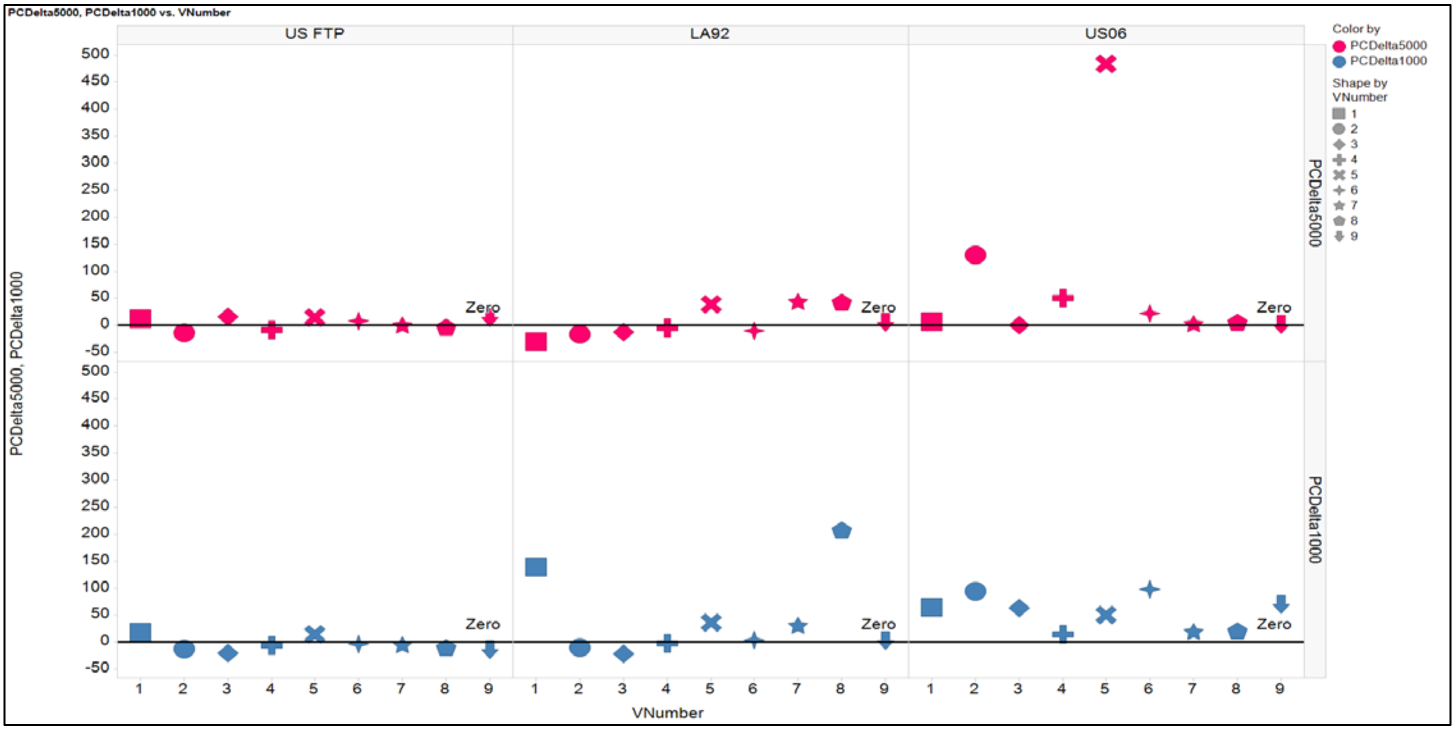


Figure 59 Individual Vehicle CO Percent Change when moving from 87 to 85 AKI Fuel

k. Vehicle Emissions Data – Core Data (85 and 87 AKI)

VNumber	Altitude	Fuel	TestCycle	TestID	TestDate	THC	CH4	NonMethane	CO	Nox	CO2	FE	NMOG
	(ft)					(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(mpg)	(g/mile)
1	5,000	87 E10	US FTP	MS34008535	9/11/2013	0.0230	0.0028	0.0204	0.1090	0.0047	219.8340	37.7864	0.0212
1	5,000	87 E10	LA92	MS34008536	9/11/2013	0.0044	0.0017	0.0028	0.4300	0.0010	235.6490	35.1861	0.0029
1	5,000	87 E10	US06	MS34008537	9/11/2013	0.0199	0.0054	0.0148	3.6782	0.0185	245.5540	33.0789	0.0154
1	5,000	87 E10	US FTP	MS34008541	9/12/2013	0.0260	0.0031	0.2312	0.1552	0.0052	223.0740	37.2246	0.0284
1	5,000	87 E10	LA92	MS34008542	9/12/2013	0.0039	0.0016	0.0024	0.1797	0.0023	235.9480	35.2005	0.0025
1	5,000	87 E10	US06	MS34008543	9/12/2013	0.0179	0.0047	0.0135	3.7308	0.0180	244.0100	33.2731	0.0141
1	1,000	87 E10	US FTP	MS34008565	9/18/2013	0.0218	0.0031	0.0189	0.1385	0.0051	230.1060	36.0947	0.0197
1	1,000	87 E10	LA92	MS340008566	9/18/2013	0.0034	0.0015	0.0020	0.0881	0.0015	243.6930	34.1034	0.0021
1	1,000	87 E10	US06	MS340008567	9/18/2013	0.0130	0.0032	0.0100	2.0111	0.0128	250.7260	32.7491	0.0103
1	1,000	87 E10	US FTP	MS34008574	9/19/2013	0.0214	0.0030	0.0186	0.1233	0.0056	229.9390	36.1249	0.0193
1	1,000	87 E10	LA92	MS34008575	9/19/2013	0.0036	0.0015	0.0022	0.1586	0.0021	243.1560	34.1631	0.0023
1	1,000	87 E10	US06	MS34008576	9/19/2013	0.0118	0.0028	0.0092	1.7285	0.0120	246.9140	33.3079	0.0096
1	5,000	85 E10	US FTP	MS34008583	9/23/2013	0.0240	0.0025	0.0217	0.1386	0.0065	223.3590	37.1511	0.0226
1	5,000	85 E10	LA92	MS34008584	9/23/2013	0.0035	0.0015	0.0021	0.3704	0.0019	237.3920	34.9131	0.0022
1	5,000	85 E10	US06	MS34008585	9/23/2013	0.0134	0.0042	0.0095	3.4323	0.0078	244.5620	33.2357	0.0099
1	5,000	85 E10	US FTP	MS34008590	9/24/2013	0.0263	0.0034	0.0232	0.1521	0.0056	223.8560	37.0640	0.0241
1	5,000	85 E10	LA92	MS34008591	9/24/2013	0.0032	0.0012	0.0021	0.1006	0.0005	238.3950	34.8285	0.0022
1	5,000	85 E10	US06	MS34008592	9/24/2013	0.0160	0.0048	0.0116	4.5957	0.0080	247.0240	32.6739	0.0120
1	1,000	85 E10	US FTP	MS34008653	10/1/2013	0.0234	0.0033	0.0203	0.1248	0.0051	228.9860	36.2429	0.0211
1	1,000	85 E10	LA92	MS34008654	10/1/2013	0.0032	0.0015	0.0019	0.3251	0.0020	244.7850	33.8712	0.0020
1	1,000	85 E10	US06	MS34008655	10/1/2013	0.0127	0.0037	0.0092	3.3260	0.0102	255.0090	31.9233	0.0096
1	1,000	85 E10	US FTP	MS34008668	10/3/2013	0.0340	0.0042	0.0301	0.1915	0.0047	231.2180	35.8723	0.0313
1	1,000	85 E10	LA92	MS34008669	10/3/2013	0.0161	0.0017	0.0145	0.2466	0.0025	248.0040	33.4439	0.0151
1	1,000	85 E10	US06	MS34008670	10/3/2013	0.0201	0.0034	0.0169	2.8367	0.0081	255.6410	31.9373	0.0176
2	5,000	87 E10	US FTP	MS34008825	11/5/2013	0.0162	0.0029	0.0137	0.2773	0.0035	271.5260	30.5718	0.0142
2	5,000	87 E10	LA92	MS34008826	11/5/2013	0.0005	0.0006	0.0000	0.1390	0.0003	277.2410	29.9712	0.0000
2	5,000	87 E10	US06	MS34008827	11/5/2013	0.0046	0.0015	0.0033	1.3737	0.0089	276.4490	29.8463	0.0034
2	5,000	87 E10	US FTP	MS34008839	11/7/2013	0.0145	0.0026	0.0126	0.2183	0.0086	266.9410	31.1073	0.0131
2	5,000	87 E10	LA92	MS34008840	11/7/2013	0.0008	0.0008	0.0001	0.4594	0.0002	276.8800	29.9622	0.0001
2	5,000	87 E10	US06	MS34008841	11/7/2013	0.0045	0.0012	0.0034	0.8442	0.0078	273.1100	30.3000	0.0035
2	5,000	87 E10	US FTP	MS34008849	11/8/2013	0.0129	0.0023	0.0110	0.1932	0.0027	269.2880	30.8416	0.0115
2	5,000	87 E10	LA92	MS34008850	11/8/2013	0.0005	0.0005	0.0001	0.1424	0.0000	273.5200	30.3780	0.0001
2	5,000	87 E10	US06	MS34008851	11/8/2013	0.0033	0.0010	0.0024	0.5907	0.0061	273.9240	30.2546	0.0025
2	1,000	87 E10	US FTP	MS34008868	11/10/2013	0.0162	0.0033	0.0135	0.3038	0.0013	276.0650	30.0719	0.0148
2	1,000	87 E10	LA92	MS34008869	11/10/2013	0.0003	0.0003	0.0001	0.0931	0.0012	280.0420	29.6793	0.0001
2	1,000	87 E10	US06	MS34008870	11/10/2013	0.0031	0.0010	0.0022	0.6593	0.0038	275.9040	30.0265	0.0023
2	1,000	87 E10	LA92	MS34008878	11/12/2013	0.0003	0.0007	0.0000	0.1188	0.0007	281.2040	29.5526	0.0000
2	1,000	87 E10	US06	MS34008879	11/12/2013	0.0033	0.0012	0.0022	0.5813	0.0072	278.1930	29.7934	0.0023
2	1,000	87 E10	US FTP	MS34008894	11/14/2013	0.0334	0.0048	0.0294	0.3670	0.0048	277.7280	29.8695	0.0305
2	1,000	87 E10	US FTP	MS34008911	11/18/2013	0.0152	0.0030	0.0126	0.2498	0.0008	277.5540	29.9139	0.0131
2	1,000	87 E10	LA92	MS34008912	11/19/2013	0.0003	0.0005	0.0000	0.1005	0.0016	279.6820	29.7163	0.0000
2	1,000	87 E10	US06	MS34008913	11/19/2013	0.0022	0.0008	0.0015	0.1076	0.0118	274.5750	30.2669	0.0015
2	5,000	85 E10	US FTP	MS34008930	11/21/2013	0.0136	0.0027	0.0115	0.2451	0.0037	266.6900	31.1055	0.0119
2	5,000	85 E10	LA92	MS34008931	11/21/2013	0.0006	0.0004	0.0002	0.1059	0.0028	274.3200	30.2701	0.0002
2	5,000	85 E10	US06	MS34008932	11/21/2013	0.0044	0.0016	0.0029	2.4528	0.0052	273.6760	29.9369	0.0030
2	5,000	85 E10	US FTP	MS34008941	11/22/2013	0.0106	0.0022	0.0085	0.1680	0.0024	267.5020	31.0263	0.0089
2	5,000	85 E10	LA92	MS34008942	11/22/2013	0.0005	0.0007	0.0000	0.1260	0.0015	276.1220	30.0693	0.0000
2	5,000	85 E10	US06	MS34008943	11/22/2013	0.0051	0.0016	0.0036	2.0738	0.0054	276.2780	29.7218	0.0038
2	5,000	85 E10	US FTP	MS35004518	11/26/2013	0.0249	0.0030	0.0221	0.1824	0.0039	273.5700	30.3317	0.0230
2	5,000	85 E10	LA92	MS35004519	11/26/2013	0.0119	0.0007	0.0112	0.1211	0.0023	278.9880	29.7578	0.0117
2	5,000	85 E10	US06	MS35004520	11/26/2013	0.0086	0.0016	0.0071	1.6365	0.0084	284.6480	28.9257	0.0074
2	1,000	85 E10	US FTP	MS35004534	11/27/2013	0.0186	0.0033	0.0156	0.1952	0.0014	279.0010	29.7418	0.0162
2	1,000	85 E10	LA92	MS35004535	11/27/2013	0.0063	0.0008	0.0056	0.0895	0.0005	281.1800	29.5329	0.0058
2	1,000	85 E10	US06	MS35004536	11/27/2013	0.0060	0.0014	0.0047	1.2280	0.0063	283.3950	29.1186	0.0049
2	1,000	85 E10	US FTP	MS34008988	12/5/2013	0.0329	0.0045	0.0288	0.3333	0.0033	278.0580	29.8148	0.0300
2	1,000	85 E10	LA92	MS34008989	12/5/2013	0.0005	0.0005	0.0002	0.0976	0.0004	280.9870	29.5537	0.0002
2	1,000	85 E10	US06	MS34008990	12/5/2013	0.0030	0.0010	0.0021	0.8033	0.0020	277.3190	29.8244	0.0021
2	1,000	85 E10	US FTP	MS34008998	12/6/2013	0.0229	0.0038	0.0198	0.2908	0.0017	278.8810	29.7372	0.0206
2	1,000	85 E10	LA92	MS34008999	12/6/2013	0.0004	0.0005	0.0001	0.0923	0.0012	282.0840	29.4398	0.0001
2	1,000	85 E10	US06	MS34009000	12/6/2013	0.0040	0.0017	0.0024	1.4598	0.0082	276.9410	29.7543	0.0025

VNumber	Altitude	Fuel	TestCycle	TestID	TestDate	THC	CH4	NonMethane	CO	Nox	CO2	FE	NMOG
	(ft)					(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(mpg)	(g/mile)
3	5,000	85 E10	US FTP	MS34008822	11/5/2013	0.0249	0.0022	0.0228	0.1074	0.0154	266.7820	31.1161	0.0237
3	5,000	85 E10	LA92	MS34008823	11/5/2013	0.0012	0.0009	0.0004	0.0289	0.0031	264.3100	31.4299	0.0004
3	5,000	85 E10	US06	MS34008824	11/5/2013	0.0031	0.0013	0.0019	1.2255	0.0047	270.9720	30.4455	0.0020
3	5,000	85 E10	US FTP	MS34008836	11/6/2013	0.0337	0.0026	0.0315	0.1243	0.0130	266.7700	31.1113	0.0328
3	5,000	85 E10	LA92	MS34008837	11/6/2013	0.0012	0.0006	0.0006	0.0261	0.0007	265.1180	31.3346	0.0006
3	5,000	85 E10	US06	MS34008838	11/6/2013	0.0037	0.0014	0.0024	1.2231	0.0041	251.5190	32.7824	0.0025
3	5,000	85 E10	US FTP	MS34008842	11/7/2013	0.0641	0.0031	0.0612	0.1489	0.0133	264.1800	31.4005	0.0637
3	5,000	85 E10	LA92	MS34008843	11/7/2013	0.0019	0.0008	0.0012	0.0248	0.0015	265.2110	31.3237	0.0013
3	5,000	85 E10	US06	MS34008844	11/7/2013	0.0037	0.0012	0.0026	1.2174	0.0025	249.3850	33.0620	0.0027
3	1,000	85 E10	US FTP	MS34008865	11/10/2013	0.0148	0.0018	0.0132	0.0611	0.0109	270.9730	30.6469	0.0137
3	1,000	85 E10	LA92	MS34008866	11/10/2013	0.0004	0.0006	0.0000	0.0084	0.0019	275.2650	30.1831	0.0000
3	1,000	85 E10	US06	MS34008867	11/10/2013	0.0019	0.0009	0.0011	0.6162	0.0027	277.7700	29.8079	0.0011
3	1,000	85 E10	US FTP	MS34008874	11/11/2013	0.0177	0.0020	0.0161	0.0978	0.0095	272.5620	30.4609	0.0168
3	1,000	85 E10	LA92	MS34008875	11/12/2013	0.0005	0.0007	0.0000	0.0159	0.0009	275.4050	30.1664	0.0000
3	1,000	85 E10	US06	MS34008876	11/12/2013	0.0022	0.0010	0.0012	0.8821	0.0051	257.5740	32.0844	0.0013
3	1,000	85 E10	US FTP	MS34008891	11/14/2013	0.0194	0.0024	0.0177	0.0988	0.0071	275.3010	30.1574	0.0184
3	1,000	85 E10	LA92	MS34008892	11/14/2013	0.0007	0.0006	0.0002	0.0240	0.0016	275.6460	30.1386	0.0002
3	1,000	85 E10	US06	MS34008893	11/14/2013	0.0019	0.0009	0.0011	0.6897	0.0058	253.6950	32.6111	0.0011
3	5,000	87 E10	US FTP	MS34008927	11/21/2013	0.0235	0.0020	0.0217	0.1031	0.0172	263.6080	31.5184	0.0226
3	5,000	87 E10	LA92	MS34008928	11/21/2013	0.0004	0.0006	0.0000	0.0334	0.0007	265.6120	31.3019	0.0000
3	5,000	87 E10	US06	MS34008929	11/21/2013	0.0034	0.0013	0.0022	1.2743	0.0048	251.8550	32.7566	0.0023
3	5,000	87 E10	US FTP	MS34008938	11/21/2013	0.0305	0.0025	0.0285	0.1330	0.0206	262.8520	31.6008	0.0296
3	5,000	87 E10	LA92	MS34008939	11/22/2013	0.0009	0.0005	0.0004	0.0279	0.0048	263.9740	31.4969	0.0004
3	5,000	87 E10	US06	MS34008940	11/22/2013	0.0041	0.0014	0.0028	1.5110	0.0035	251.6700	32.7322	0.0029
3	1,000	87 E10	US FTP	MS34008969	12/3/2013	0.0164	0.0020	0.0146	0.0362	0.0155	273.0000	30.4491	0.0152
3	1,000	87 E10	LA92	MS34008971	12/3/2013	0.0007	0.0009	0.0000	0.0146	0.0017	271.1610	30.6647	0.0000
3	1,000	87 E10	US FTP	MS34008991	12/5/2013	0.0274	0.0024	0.0255	0.0993	0.0116	273.5980	30.3679	0.0265
3	1,000	87 E10	LA92	MS34008992	12/5/2013	0.0001	0.0006	0.0001	0.0258	0.0007	274.0960	30.3344	0.0001
3	1,000	87 E10	US06	MS34008993	12/5/2013	0.0017	0.0007	0.0011	0.3898	0.0028	272.0780	30.4950	0.0011
3	1,000	87 E10	US FTP	MS34009001	12/6/2013	0.0237	0.0024	0.0219	0.1117	0.0123	274.0820	30.3134	0.0228
3	1,000	87 E10	LA92	MS34009002	12/6/2013	0.0005	0.0006	0.0000	0.0181	0.0010	271.6840	30.6051	0.0000
3	1,000	87 E10	US06	MS34009003	12/6/2013	0.0018	0.0007	0.0011	0.4997	0.0021	275.4100	30.1080	0.0012
3	5,000	87 E10	US FTP	MS34009009	12/9/2013	0.0268	0.0021	0.0252	0.0930	0.0151	267.7470	31.0322	0.0262
3	5,000	87 E10	LA92	MS34009010	12/9/2013	0.0008	0.0007	0.0002	0.0304	0.0026	265.8820	31.2705	0.0002
3	5,000	87 E10	US06	MS34009011	12/9/2013	0.0035	0.0013	0.0023	0.9259	0.0026	247.5680	33.3925	0.0024
4	5,000	85 E10	US FTP	7632502	1/14/2014	0.0600	0.0056	0.0543	0.3925	0.0076	359.3406	23.1131	0.0565
4	5,000	85 E10	LA92	7632502	1/14/2014	0.0026	0.0005	0.0021	0.2223	0.0015	372.2304	22.5577	0.0022
4	5,000	85 E10	US06	7632502	1/14/2014	0.0048	0.0008	0.0040	0.5857	0.0029	391.5742	21.1968	0.0042
4	5,000	85 E10	US FTP	7632515	1/15/2014	0.0533	0.0055	0.0482	0.3210	0.0118	362.6174	22.9108	0.0501
4	5,000	85 E10	LA92	7632515	1/15/2014	0.0024	0.0023	0.0001	0.1964	0.0014	366.7183	22.8737	0.0001
4	5,000	85 E10	US06	7632515	1/15/2014	0.0047	0.0028	0.0018	0.4750	0.0001	384.3272	21.6053	0.0019
4	1,000	85 E10	US FTP	7632525	1/16/2014	0.0410	0.0062	0.0369	0.3005	0.0039	354.7072	23.4233	0.0384
4	1,000	85 E10	LA92	7632525	1/16/2014	0.0001	0.0005	0.0001	0.2051	0.0012	371.6965	22.5780	0.0001
4	1,000	85 E10	US06	7632525	1/16/2014	0.0002	0.0009	0.0002	0.6176	0.0027	382.4781	21.6968	0.0002
4	1,000	85 E10	US FTP	7632541	1/17/2014	0.0417	0.0089	0.0367	0.2855	0.0050	354.0904	23.4662	0.0382
4	1,000	85 E10	LA92	7632541	1/17/2014	0.0002	0.0032	0.0002	0.1660	0.0028	368.5639	22.7791	0.0003
4	1,000	85 E10	US06	7632541	1/17/2014	0.0022	0.0026	0.0003	0.5837	0.0027	382.0868	21.7220	0.0003
4	5,000	87 E10	US FTP	7632641	1/28/2014	0.0583	0.0059	0.0529	0.3998	0.0033	350.1681	23.8073	0.0550
4	5,000	87 E10	LA92	7632641	1/28/2014	0.0002	0.0000	0.0002	0.2128	0.0014	368.6685	22.8404	0.0002
4	5,000	87 E10	US06	7632641	1/28/2014	0.0002	0.0004	0.0002	0.3065	0.0053	387.9717	21.4990	0.0002
4	5,000	87 E10	US FTP	7632656	1/29/2014	0.0781	0.0058	0.0727	0.3770	0.0111	363.4949	22.9384	0.0756
4	5,000	87 E10	LA92	7632656	1/29/2014	0.0001	0.0000	0.0001	0.2280	0.0010	370.0977	22.7691	0.0001
4	5,000	87 E10	US06	7632656	1/29/2014	0.0001	0.0006	0.0001	0.4040	0.0033	388.3606	21.4690	0.0001
4	1,000	87 E10	US FTP	7632669	1/30/2014	0.0458	0.0046	0.0415	0.2844	0.0072	362.2882	23.0232	0.0432
4	1,000	87 E10	LA92	7632669	1/30/2014	0.0000	0.0000	0.0000	0.1965	0.0016	375.5836	22.4265	0.0000
4	1,000	87 E10	US06	7632669	1/30/2014	0.0000	0.0010	0.0000	0.5255	0.0012	385.7737	21.6021	0.0000
4	1,000	87 E10	US FTP	7632681	1/31/2014	0.0435	0.0094	0.0387	0.3466	0.0079	366.2294	22.7697	0.0402
4	1,000	87 E10	LA92	7632681	1/31/2014	0.0001	0.0000	0.0001	0.1829	0.0025	367.1877	22.9616	0.0001
4	1,000	87 E10	US06	7632681	1/31/2014	0.0001	0.0004	0.0001	0.5198	0.0037	380.9072	21.8780	0.0001

VNumber	Altitude	Fuel	TestCycle	TestID	TestDate	THC	CH4	NonMethane	CO	Nox	CO2	FE	NMOG
	(ft)					(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(mpg)	(g/mile)
5	5,000	85 E10	LA92	7631985	11/5/2013	0.0001	0.0024	0.0001	0.0917	0.0050	495.4226	16.9511	0.0001
5	5,000	85 E10	US06	7631985	11/5/2013	0.0364	0.0148	0.0216	1.4709	0.0518	521.8467	15.8724	0.0225
5	5,000	85 E10	US FTP	7631996	11/6/2013	0.0224	0.0086	0.0157	0.2183	0.0108	467.5383	17.7812	0.0163
5	5,000	85 E10	LA92	7631996	11/6/2013	0.0001	0.0018	0.0000	0.1228	0.0195	490.5300	17.1383	0.0000
5	5,000	85 E10	US06	7631996	11/6/2013	0.0367	0.0139	0.0227	2.2769	0.0148	513.3744	16.0936	0.0236
5	1,000	85 E10	US FTP	7632108	11/19/2013	0.0280	0.0079	0.0209	0.1787	0.0126	482.2586	17.2414	0.0217
5	1,000	85 E10	LA92	7632108	11/19/2013	0.0001	0.0021	0.0001	0.0851	0.0055	490.4208	17.1415	0.0001
5	1,000	85 E10	US06	7632108	11/19/2013	0.0170	0.0073	0.0097	0.4639	0.0170	517.1492	16.0648	0.0101
5	1,000	85 E10	US FTP	7632126	11/21/2013	0.0226	0.0074	0.0153	0.2181	0.0087	484.5152	17.1610	0.0159
5	1,000	85 E10	LA92	7632126	11/21/2013	0.0001	0.0002	0.0001	0.1275	0.0053	486.2131	17.2861	0.0001
5	1,000	85 E10	US06	7632126	11/21/2013	0.0115	0.0044	0.0072	0.3031	0.0189	509.3711	16.3179	0.0075
5	1,000	85 E10	US FTP	7632427	1/8/2014	0.0250	0.0107	0.0178	0.2291	0.0056	482.5647	17.2279	0.0185
5	1,000	85 E10	LA92	7632427	1/8/2014	0.0000	0.0021	0.0000	0.1690	0.0059	502.8789	16.7046	0.0000
5	1,000	85 E10	US06	7632427	1/8/2014	0.0134	0.0068	0.0066	0.3447	0.0126	514.4750	16.1541	0.0069
5	5,000	85 E10	US FTP	7632456	1/10/2014	0.0267	0.0078	0.0192	0.2360	0.0041	464.2759	17.9053	0.0200
5	5,000	85 E10	LA92	7632456	1/10/2014	0.0001	0.0009	0.0001	0.1413	0.0139	478.0007	17.6097	0.0001
5	5,000	85 E10	US06	7632456	1/10/2014	0.0211	0.0084	0.0126	1.0920	0.0127	508.8532	16.2948	0.0131
5	5,000	87 E10	US FTP	7632579	1/22/2014	0.0240	0.0075	0.0178	0.1757	0.0089	461.2572	18.0933	0.0185
5	5,000	87 E10	LA92	7632579	1/22/2014	0.0001	0.0001	0.0001	0.0840	0.0102	472.0427	17.9033	0.0001
5	5,000	87 E10	US06	7632579	1/22/2014	0.0079	0.0034	0.0045	0.2464	0.0105	494.7013	16.8684	0.0047
5	5,000	87 E10	US FTP	7632589	1/23/2014	0.0311	0.0121	0.0198	0.2249	0.0184	478.0128	17.4584	0.0206
5	5,000	87 E10	LA92	7632589	1/23/2014	0.0037	0.0029	0.0008	0.0837	0.0285	494.0525	17.0950	0.0008
5	5,000	87 E10	US06	7632589	1/23/2014	0.0148	0.0054	0.0093	0.2824	0.0308	506.7147	16.4669	0.0097
5	1,000	87 E10	US FTP	7632625	1/27/2014	0.0255	0.0083	0.0172	0.2236	0.0062	489.7637	17.0399	0.0179
5	1,000	87 E10	LA92	7632625	1/27/2014	0.0001	0.0000	0.0001	0.1059	0.0083	481.4894	17.5253	0.0001
5	1,000	87 E10	US06	7632625	1/27/2014	0.0093	0.0038	0.0055	0.2590	0.0107	502.7363	16.5984	0.0057
5	1,000	87 E10	US FTP	7632778	2/10/2014	0.0267	0.0094	0.0206	0.1458	0.0127	487.3117	17.1286	0.0214
5	1,000	87 E10	LA92	7632778	2/10/2014	0.0001	0.0021	0.0001	0.0762	0.0075	466.8019	18.0804	0.0001
5	1,000	87 E10	US06	7632778	2/10/2014	0.0072	0.0048	0.0024	0.2247	0.0118	502.0875	16.6216	0.0025
6	5,000	85 E10	US FTP	782012140006–8	1/30/2014	0.0371	0.0051	0.0322	0.4570	0.0459	252.8000	35.0041	0.0335
6	5,000	85 E10	LA92	782012140006–10	1/30/2014	0.0021	0.0017	0.0005	0.2847	0.0182	256.2000	34.6483	0.0005
6	5,000	85 E10	US06	782012140006–11	1/30/2014	0.0175	0.0092	0.0086	5.4455	0.0238	279.7000	30.7861	0.0090
6	1,000	85 E10	US FTP	782012140006–13	2/4/2014	0.0298	0.0053	0.0247	0.4695	0.0330	261.2000	33.9354	0.0257
6	1,000	85 E10	LA92	782012140006–15	2/4/2014	0.0031	0.0025	0.0007	0.4139	0.0178	267.9000	33.0739	0.0007
6	1,000	85 E10	US06	782012140006–16	2/4/2014	0.0124	0.0062	0.0065	3.3692	0.0110	288.8000	30.1883	0.0067
6	1,000	85 E10	US FTP	782012140006–17	2/4/2014	0.0330	0.0051	0.0281	0.4849	0.0387	259.7000	34.0623	0.0292
6	1,000	85 E10	LA92	782012140006–19	2/5/2014	0.0030	0.0021	0.0010	0.3073	0.0184	264.3000	33.5938	0.0010
6	1,000	85 E10	US06	782012140006–20	2/5/2014	0.0127	0.0063	0.0066	4.6993	0.0209	286.7000	30.1788	0.0069
6	5,000	85 E10	US FTP	782012140009–2	2/7/2014	0.0382	0.0051	0.0333	0.5118	0.0409	251.1000	35.2706	0.0346
6	5,000	85 E10	LA92	782012140009–4	2/7/2014	0.0027	0.0019	0.0009	0.4308	0.0205	261.5000	33.8254	0.0009
6	5,000	85 E10	US06	782012140009–5	2/7/2014	0.0162	0.0086	0.0080	5.4425	0.0296	288.2000	29.9577	0.0083
6	5,000	85 E10	US FTP	782012140009–6	2/9/2014	0.0371	0.0049	0.0324	0.4415	0.0373	252.2000	35.1469	0.0337
6	5,000	85 E10	LA92	782012140009–8	2/10/2014	0.0021	0.0016	0.0005	0.2972	0.0130	256.8000	34.5095	0.0005
6	5,000	85 E10	US06	782012140009–9	2/10/2014	0.0147	0.0078	0.0071	5.4079	0.0396	284.9000	30.2690	0.0074
6	5,000	87 E10	US FTP	782012140010–4	2/24/2014	0.0396	0.0053	0.0349	0.4388	0.0347	244.0000	36.2710	0.0363
6	5,000	87 E10	LA92	782012140010–6	2/25/2014	0.0030	0.0022	0.0011	0.3523	0.0143	253.5000	34.8830	0.0012
6	5,000	87 E10	US FTP	782012140010–8	2/25/2014	0.0417	0.0051	0.0371	0.4277	0.0394	250.9000	35.2641	0.0386
6	5,000	87 E10	LA92	782012140010–10	2/25/2014	0.0026	0.0020	0.0008	0.3821	0.0189	260.0000	34.0736	0.0009
6	5,000	87 E10	US06	782012140010–11	2/26/2014	0.0144	0.0072	0.0080	3.9369	0.0088	278.2000	31.2410	0.0083
6	5,000	87 E10	US06	782012140012–1	2/26/2014	0.0135	0.0072	0.0071	5.0403	0.0162	279.3000	30.9443	0.0074
6	1,000	87 E10	US FTP	782012140010–13	2/26/2014	0.0358	0.0057	0.0308	0.5007	0.0343	254.2000	34.8364	0.0320
6	1,000	87 E10	LA92	782012140010–15	2/26/2014	0.0046	0.0029	0.0020	0.3233	0.0194	261.4000	33.9547	0.0021
6	1,000	87 E10	US FTP	782012140010–17	2/28/2014	0.0363	0.0055	0.0314	0.4924	0.0361	261.5000	33.7784	0.0326
6	1,000	87 E10	LA92	782012140010–19	2/28/2014	0.0024	0.0020	0.0006	0.3641	0.0142	266.3000	33.3111	0.0007
6	1,000	87 E10	US06	782012140010–20	2/28/2014	0.0100	0.0050	0.0055	1.9907	0.0086	281.9000	31.1398	0.0057
6	1,000	87 E10	US06	782012140013–1	2/28/2014	0.0067	0.0031	0.0039	2.0384	0.0115	284.1000	30.9155	0.0041

VNumber	Altitude	Fuel	TestCycle	TestID	TestDate	THC	CH4	NonMethane	CO	Nox	CO2	FE	NMOG
	(ft)					(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(mpg)	(g/mile)
7	5,000	85 E10	US06	MS34009190	1/24/2014	0.0529	0.0309	0.0240	1.8788	0.0231	519.9720	15.8843	0.0249
7	5,000	85 E10	US FTP	MS34009188	1/29/2014	0.0534	0.0178	0.0367	0.7347	0.0215	494.6590	16.7525	0.0382
7	5,000	85 E10	LA92	MS34009189	1/29/2014	0.0376	0.0219	0.0172	1.3141	0.0109	510.3080	16.2127	0.0178
7	5,000	85 E10	US FTP	MS34009199	1/30/2014	0.0424	0.0145	0.0289	0.6162	0.0140	495.5290	16.7305	0.0300
7	5,000	85 E10	LA92	MS34009200	1/30/2014	0.0259	0.0164	0.0106	1.0972	0.0084	510.0560	16.2326	0.0110
7	5,000	85 E10	US06	MS34009201	1/30/2014	0.0564	0.0318	0.0266	2.1881	0.0254	518.8330	15.9038	0.0277
7	1,000	85 E10	LA92	MS34009228	2/4/2014	0.0184	0.0135	0.0059	1.0913	0.0061	523.5000	15.8181	0.0061
7	1,000	85 E10	US06	MS34009229	2/4/2014	0.0593	0.0338	0.0278	2.6355	0.0317	524.0010	15.7268	0.0289
7	1,000	85 E10	US FTP	MS34009230	2/5/2014	0.0593	0.0196	0.0410	0.8459	0.0125	512.7910	16.1556	0.0426
7	1,000	85 E10	LA92	MS34009231	2/5/2014	0.0249	0.0175	0.0085	1.1570	0.0040	520.8750	15.8938	0.0089
7	1,000	85 E10	US06	MS34009232	2/5/2014	0.0575	0.0340	0.0257	2.6134	0.0261	520.9050	15.8207	0.0267
7	1,000	85 E10	US FTP	MS34009247	2/7/2014	0.0552	0.0189	0.0376	0.7048	0.0137	506.9760	16.3478	0.0391
7	5,000	87 E10	US FTP	MS34009342	2/18/2014	0.0931	0.0199	0.0746	0.8079	0.0123	499.0140	16.6130	0.0775
7	5,000	87 E10	LA92	MS34009343	2/18/2014	0.0157	0.0122	0.0044	0.8584	0.0061	508.6550	16.3039	0.0045
7	5,000	87 E10	US06	MS34009344	2/18/2014	0.0492	0.0293	0.0218	2.0795	0.0173	518.7150	15.9267	0.0227
7	5,000	87 E10	US FTP	MS34009353	2/19/2014	0.0576	0.0157	0.0432	0.5761	0.0138	494.4010	16.7834	0.0449
7	5,000	87 E10	LA92	MS34009354	2/19/2014	0.0143	0.0103	0.0046	0.8261	0.0018	505.1240	16.4194	0.0048
7	5,000	87 E10	US06	MS34009355	2/19/2014	0.0450	0.0280	0.0188	1.8982	0.0139	513.8060	16.0872	0.0196
7	1,000	87 E10	LA92	MS34009417	2/25/2014	0.0113	0.0089	0.0030	0.8797	0.0004	516.0290	16.0709	0.0031
7	1,000	87 E10	US06	MS34009418	2/25/2014	0.0531	0.0305	0.0246	2.3869	0.0259	513.6580	16.0671	0.0256
7	1,000	87 E10	US FTP	MS34009428	2/27/2014	0.0529	0.0185	0.0356	0.7650	0.0120	502.2330	16.5130	0.0370
7	1,000	87 E10	LA92	MS34009429	2/27/2014	0.0161	0.0124	0.0045	0.8438	0.0007	513.7360	16.1438	0.0047
7	1,000	87 E10	US06	MS34009430	2/27/2014	0.0480	0.0282	0.0217	2.0485	0.0200	512.8320	16.1099	0.0226
7	1,000	87 E10	US FTP	MS34009434	2/28/2014	0.0601	0.0202	0.0413	0.8736	0.0115	503.4200	16.4679	0.0429
8	5,000	87 E10	US FTP	782012130059-4	12/10/2013	0.0152	0.0026	0.0127	0.1066	0.0105	415.4000	20.0718	0.0140
8	5,000	87 E10	LA92	782012130059-6	12/10/2013	0.0023	0.0020	0.0005	0.2941	0.0083	429.6030	19.4077	0.0005
8	5,000	87 E10	US06	782012130059-7	12/10/2013	0.0067	0.0031	0.0037	8.8330	0.0088	424.3000	19.0713	0.0038
8	5,000	87 E10	US FTP	782012130059-8	12/10/2013	0.0166	0.0028	0.0145	0.1224	0.0087	411.7431	20.2655	0.0159
8	5,000	87 E10	LA92	782012130059-10	12/10/2013	0.0017	0.0018	0.0001	0.2796	0.0134	427.6722	19.4989	0.0001
8	5,000	87 E10	US06	782012130059-11	12/10/2013	0.0059	0.0034	0.0026	9.4689	0.0100	422.2000	19.1149	0.0027
8	1,000	87 E10	US FTP	782012130059-13	12/11/2013	0.0122	0.0029	0.0100	0.0993	0.0079	427.1895	19.5561	0.0109
8	1,000	87 E10	LA92	782012130059-15	12/11/2013	0.0023	0.0022	0.0005	0.1698	0.0071	438.4525	19.0183	0.0005
8	1,000	87 E10	US06	782012130059-16	12/11/2013	0.0042	0.0024	0.0019	9.9875	0.0214	445.6000	18.0877	0.0019
8	1,000	87 E10	US FTP	782012130059-17	12/12/2013	0.0130	0.0029	0.0106	0.1199	0.0124	428.9594	19.4634	0.0117
8	1,000	87 E10	LA92	782012130059-19	12/12/2013	0.0019	0.0022	0.0001	0.3111	0.0158	436.8435	19.0958	0.0002
8	1,000	87 E10	US06	782012130059-20	12/12/2013	0.0033	0.0019	0.0015	6.9615	0.0487	444.4000	18.3566	0.0015
8	1,000	87 E10	US FTP	782012130062-1	12/16/2013	0.0163	0.0033	0.0135	0.1144	0.0105	423.8106	19.6931	0.0148
8	1,000	87 E10	LA92	782012130062-3	12/16/2013	0.0032	0.0025	0.0008	0.3340	0.0161	435.5563	19.1381	0.0008
8	1,000	87 E10	US06	782012130062-4	12/16/2013	0.0047	0.0023	0.0025	8.7338	0.0147	445.1000	18.2051	0.0025
8	5,000	85 E10	US FTP	782012130061-4	12/18/2013	0.0163	0.0028	0.0136	0.1095	0.0088	413.6739	20.0921	0.0150
8	5,000	85 E10	LA92	782012130061-6	12/19/2013	0.0019	0.0021	0.0002	0.4641	0.0060	426.0632	19.5031	0.0002
8	5,000	85 E10	US06	782012130061-7	12/19/2013	0.0043	0.0023	0.0021	11.0671	0.0271	427.7000	18.6785	0.0022
8	5,000	85 E10	US FTP	782012130061-8	1/3/2014	0.0170	0.0031	0.0144	0.1048	0.0086	414.1566	20.0926	0.0159
8	5,000	85 E10	LA92	782012130061-10	1/3/2014	0.0019	0.0021	0.0002	0.5369	0.0114	429.4421	19.3162	0.0002
8	5,000	85 E10	US06	782012130061-11	1/3/2014	0.0037	0.0018	0.0019	7.7974	0.0305	427.6000	18.8965	0.0020
8	5,000	85 E10	US FTP	782012140002-1	1/8/2014	0.0178	0.0033	0.0152	0.1092	0.0101	415.0000	20.0362	0.0167
8	5,000	85 E10	LA92	782012140002-3	1/8/2014	0.0014	0.0020	0.0001	0.3629	0.0080	420.2000	19.7817	0.0001
8	5,000	85 E10	US FTP	782012140003-1	1/9/2014	0.0173	0.0034	0.0143	0.1133	0.0090	419.1000	19.8451	0.0158
8	5,000	85 E10	LA92	782012140003-3	1/9/2014	0.0016	0.0019	0.0002	0.3046	0.0071	425.9000	19.5076	0.0002
8	5,000	85 E10	US06	782012140003-4	1/9/2014	0.0034	0.0022	0.0014	11.2021	0.0305	439.4000	18.2203	0.0014
8	5,000	85 E10	US06	782012140003-5	1/9/2014	0.0031	0.0018	0.0013	8.4113	0.0266	430.3000	18.7705	0.0014
8	1,000	85 E10	US FTP	782012130061-13	1/9/2014	0.0147	0.0030	0.0120	0.0988	0.0079	425.2587	19.5730	0.0132
8	1,000	85 E10	LA92	782012130061-15	1/10/2014	0.0034	0.0027	0.0009	0.7976	0.0108	435.2345	19.0768	0.0009
8	1,000	85 E10	US06	782012130061-16	1/10/2014	0.0035	0.0021	0.0015	10.1682	0.0221	452.8000	17.7393	0.0015

VNumber	Altitude	Fuel	TestCycle	TestID	TestDate	THC	CH4	NonMethane	CO	Nox	CO2	FE	NMOG
	(ft)					(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(mpg)	(g/mile)
9	5,000	87 E10	US FTP	MS34009554	3/18/2014	0.1666	0.0774	0.0944	0.9827	0.0062	396.6650	20.8569	0.0982
9	5,000	87 E10	LA92	MS34009555	3/18/2014	0.0785	0.0523	0.0297	0.7138	0.0126	386.3810	21.4470	0.0309
9	5,000	87 E10	US06	MS34009556	3/18/2014	0.1320	0.0667	0.0699	1.4788	0.0860	377.9270	21.8466	0.0727
9	5,000	87 E10	US FTP	MS34009610	3/24/2014	0.1726	0.0846	0.0938	0.8948	0.0058	397.9980	20.7936	0.0975
9	5,000	87 E10	LA92	MS34009611	3/24/2014	0.0834	0.0529	0.0341	0.7982	0.0096	386.0090	21.4595	0.0355
9	5,000	87 E10	US06	MS34009612	3/24/2014	0.1265	0.0645	0.0663	1.4319	0.0484	378.0430	21.8451	0.0690
9	1,000	87 E10	US FTP	MS34009626	3/26/2014	0.1493	0.0781	0.0765	1.1655	0.0038	409.0740	20.2158	0.0796
9	1,000	87 E10	LA92	MS34009627	3/27/2014	0.0732	0.0465	0.0299	0.6391	0.0086	392.9030	21.0994	0.0311
9	1,000	87 E10	US06	MS34009628	3/27/2014	0.1112	0.0561	0.0589	1.2028	0.0433	382.0990	21.6376	0.0613
9	1,000	87 E10	US FTP	MS34009633	3/28/2014	0.1472	0.0813	0.0714	0.7672	0.0054	410.6380	20.1701	0.0742
9	1,000	87 E10	LA92	MS34009634	3/28/2014	0.0915	0.0519	0.0431	0.7314	0.0098	392.6400	21.1028	0.0448
9	1,000	87 E10	US06	MS34009635	3/28/2014	0.1078	0.0546	0.0569	1.1986	0.0358	374.5180	22.0740	0.0592
9	1,000	87 E10	US FTP	MS34009676	4/3/2014	0.1408	0.0743	0.0716	0.8343	0.0033	407.9530	20.2980	0.0744
9	1,000	87 E10	LA92	MS34009677	4/3/2014	0.0734	0.0437	0.0327	0.5551	0.0086	392.7200	21.1162	0.0340
9	1,000	87 E10	US06	MS34009678	4/3/2014	0.1213	0.0581	0.0671	1.2055	0.0564	377.7700	21.8822	0.0698
9	5,000	85 E10	US FTP	MS34009693	4/10/2014	0.1756	0.0761	0.1047	1.2217	0.0066	392.3220	21.0473	0.1089
9	5,000	85 E10	LA92	MS34009694	4/11/2014	0.0929	0.0540	0.0426	0.7622	0.0088	386.3550	21.4237	0.0443
9	5,000	85 E10	US06	MS34009695	4/11/2014	0.1248	0.0631	0.0660	1.4863	0.0486	383.3630	21.5212	0.0686
9	5,000	85 E10	LA92	MS35004794	4/14/2014	0.0898	0.0538	0.0391	0.8410	0.0087	391.0130	21.1633	0.0407
9	5,000	85 E10	US06	MS35004795	4/14/2014	0.1143	0.0593	0.0585	1.4867	0.0430	385.0610	21.4287	0.0608
9	5,000	85 E10	US FTP	MS35004800	4/15/2014	0.1659	0.0861	0.0849	0.9425	0.0053	398.1170	20.7670	0.0883
9	1,000	85 E10	US FTP	MS35004853	4/24/2014	0.1533	0.0774	0.0805	1.1966	0.0054	413.2000	19.9951	0.0837
9	1,000	85 E10	LA92	MS35004854	4/24/2014	0.0784	0.0476	0.0336	0.7445	0.0091	401.1310	20.6411	0.0349
9	1,000	85 E10	US06	MS35004855	4/24/2014	0.1141	0.0568	0.0606	1.5964	0.0452	393.6820	20.9536	0.0630
9	1,000	85 E10	US FTP	MS35004886	5/1/2014	0.1243	0.0722	0.0564	0.6353	0.0070	412.1880	20.0909	0.0587
9	1,000	85 E10	LA92	MS35004887	5/1/2014	0.0678	0.0439	0.0265	0.6429	0.0097	404.2530	20.4919	0.0275
9	1,000	85 E10	US06	MS35004888	5/1/2014	0.1310	0.0653	0.0696	3.1553	0.0463	397.2420	20.6382	0.0724
9	1,000	85 E10	US FTP	MS35004894	5/2/2014	0.1226	0.0732	0.0537	0.6159	0.0053	412.0990	20.0970	0.0559
9	1,000	85 E10	LA92	MS35004895	5/2/2014	0.0623	0.0427	0.0222	0.5823	0.0081	400.2250	20.7033	0.0230
9	1,000	85 E10	US06	MS35004896	5/2/2014	0.1068	0.0541	0.0559	1.7064	0.0376	392.9020	20.9868	0.0582

I. Vehicle Performance Data – Core Data (85 and 87 AKI)

Vnumber	Altitude	Fuel	Test Cycle	Date	Vehicle Speed	Engine Speed	Throttle Position	Load	Ignition Timing	Exhaust Temp - PreCat Avg.	Catalyst Temp - MidCat Avg.	Exhaust Temp - PreCat Max.	Catalyst Temp - MidCat Max.
					(mph)	(rpm)	(%)	(%)	(deg BTDC)	(deg. C)	(deg. C)	(deg. C)	(deg. C)
1	5,000	87 E10	FTP-1 (Bag 3)	9/11/2013	25.13	1413.5	18.21	27.73	18.83	461.4	587.2	675.7	744.9
1	5,000	87 E10	LA92	9/11/2013	24.93	1476.0	19.18	28.58	16.20	500.9	637.8	754.2	830.7
1	5,000	87 E10	US06 (2nd)	9/11/2013	47.98	2284.5	27.29	38.94	19.10	594.2	747.2	806.4	877.0
1	5,000	87 E10	FTP-2 (Bags 1 & 2)	9/12/2013	19.43	1337.6	17.21	25.98	20.20	441.0	558.0	694.6	752.0
1	5,000	87 E10	FTP-2 (Bag3)	9/12/2013	25.04	1403.9	18.01	27.58	17.87	458.6	589.4	665.1	737.6
1	5,000	87 E10	LA92	9/12/2013	24.90	1476.1	18.92	28.52	16.57	494.3	629.6	741.6	821.9
1	5,000	87 E10	US06 (2nd)	9/12/2013	48.15	2270.3	27.12	38.93	18.33	592.1	744.9	814.0	895.1
1	1,000	87 E10	FTP-3 (Bags 1 & 2)	9/18/2013	19.49	1322.7	16.47	26.57	19.94	451.8	562.8	690.9	754.4
1	1,000	87 E10	FTP-1 (Bag 3)	9/18/2013	25.29	1392.0	17.22	28.83	18.62	466.4	580.8	670.0	724.4
1	1,000	87 E10	LA92	9/18/2013	25.13	1452.8	17.88	29.63	16.17	503.2	630.3	764.2	847.7
1	1,000	87 E10	US06 (2nd)	9/18/2013	48.41	2209.3	24.67	40.26	18.70	601.7	749.6	862.6	942.4
1	1,000	87 E10	FTP-4 (Bags 1 & 2)	9/19/2013	19.59	1325.4	16.49	26.85	19.99	453.8	562.8	681.8	747.8
1	1,000	87 E10	FTP-2 (Bag3)	9/19/2013	25.34	1394.7	17.22	28.98	18.28	468.7	586.1	683.4	695.7
1	1,000	87 E10	LA92	9/19/2013	24.80	1445.4	18.00	29.59	15.78	502.5	631.9	782.7	860.1
1	5,000	85 E10	FTP-1 (Bags 1 & 2)	9/23/2013	19.56	1342.3	17.18	25.83	19.70	446.1	560.7	691.6	756.2
1	5,000	85 E10	FTP-1 (Bag 3)	9/23/2013	24.86	1397.7	18.18	28.02	17.30	467.0	596.0	702.4	766.9
1	5,000	85 E10	LA92	9/23/2013	25.14	1494.1	19.26	28.51	15.68	---	---	---	---
1	5,000	85 E10	US06 (2nd)	9/23/2013	48.58	2293.1	27.64	38.66	17.55	608.2	755.4	815.5	887.0
1	5,000	85 E10	FTP-2 (Bags 1 & 2)	9/24/2013	19.57	1343.0	17.16	25.92	20.26	448.4	564.9	697.4	764.9
1	5,000	85 E10	FTP-2 (Bag3)	9/24/2013	24.41	1390.6	18.12	27.52	17.38	467.0	595.0	680.2	746.4
1	5,000	85 E10	LA92	9/24/2013	25.11	1488.7	19.34	28.65	15.48	506.7	644.6	760.5	847.8
1	5,000	85 E10	US06 (2nd)	9/24/2013	48.66	2314.1	27.77	38.73	17.88	604.6	755.4	829.8	896.0
1	1,000	85 E10	FTP-3 (Bags 1 & 2)	10/1/2013	19.55	1323.6	16.48	26.76	20.20	449.5	561.9	686.1	754.9
1	1,000	85 E10	FTP-3 (Bag3)	10/1/2013	25.20	1388.9	17.38	29.28	17.30	474.3	594.5	682.2	752.3
1	1,000	85 E10	LA92	10/1/2013	24.92	1459.8	18.02	29.55	15.55	506.8	639.9	813.1	862.2
1	1,000	85 E10	US06 (2nd)	10/1/2013	48.49	2230.1	25.48	41.09	17.63	612.4	759.8	879.4	948.8
1	1,000	85 E10	FTP-4 (Bags 1 & 2)	10/3/2013	19.51	1324.0	16.53	26.82	19.59	452.3	562.1	692.2	763.6
1	1,000	85 E10	FTP-4 (Bag 3)	10/3/2013	25.36	1397.7	17.38	29.27	17.23	475.8	598.7	708.1	777.3
1	1,000	85 E10	LA92	10/3/2013	25.04	1460.7	18.12	29.90	15.38	507.1	640.0	807.3	878.5
1	1,000	85 E10	US06 (2nd)	10/3/2013	48.18	2214.5	25.30	41.30	17.17	608.7	759.2	876.1	932.5
2	5,000	87 E10	FTP-1 (Bags 1 & 2)	11/5/2013	19.22	1247.2	16.38	25.19	27.00	467.3	570.3	616.0	701.8
2	5,000	87 E10	FTP-1 (Bag 3)	11/5/2013	25.79	1378.6	17.10	26.16	28.09	484.8	591.1	640.5	722.5
2	5,000	87 E10	LA92	11/5/2013	24.58	1390.9	17.71	26.74	26.85	527.4	634.2	726.9	809.7
2	5,000	87 E10	US06 (2nd)	11/5/2013	48.34	2124.8	25.18	35.21	29.55	633.2	746.7	823.5	915.8
2	5,000	87 E10	FTP-2 (Bags 1 & 2)	11/7/2013	19.30	1250.6	16.24	24.50	26.83	470.6	574.0	618.7	713.5
2	5,000	87 E10	FTP-2 (Bag3)	11/7/2013	25.16	1373.9	17.28	25.92	26.95	487.5	591.8	641.7	739.6
2	5,000	87 E10	LA92	11/7/2013	24.80	1404.8	17.68	26.59	27.14	531.0	636.7	733.2	815.7
2	5,000	87 E10	US06 (2nd)	11/7/2013	48.25	2113.1	25.13	35.35	29.27	636.4	750.9	838.7	911.3
2	5,000	87 E10	FTP-3 (Bags 1 & 2)	11/8/2013	19.24	1254.4	16.37	25.14	27.00	467.0	572.2	616.6	713.6
2	5,000	87 E10	FTP-2 (Bag 3)	11/8/2013	25.06	1370.2	16.99	25.76	27.24	480.4	586.1	641.8	732.0
2	5,000	87 E10	LA92	11/8/2013	24.84	1399.4	17.69	26.73	27.08	528.1	634.4	726.3	818.6
2	5,000	87 E10	US06 (2nd)	11/8/2013	47.95	2108.1	25.12	35.05	29.51	630.1	747.2	807.2	880.8
2	1,000	87 E10	FTP-1 (Bags 1 & 2)	11/10/2013	19.36	1237.8	15.80	26.33	26.63	471.8	572.9	601.8	680.0
2	1,000	87 E10	FTP-1 (Bag 3)	11/10/2013	25.14	1366.6	16.33	27.02	27.16	485.2	586.4	632.0	712.4
2	1,000	87 E10	LA92	11/10/2013	24.91	1386.1	16.76	27.69	27.05	528.7	631.3	725.3	806.5
2	1,000	87 E10	US06 (2nd)	11/10/2013	48.06	2059.3	22.29	36.65	30.18	628.7	739.4	843.2	931.4
2	1,000	87 E10	FTP-3 (Bags 1 & 2)	11/14/2013	19.30	1249.0	15.83	26.25	26.95	472.3	575.0	602.8	702.5
2	1,000	87 E10	FTP-3 (Bag 3)	11/14/2013	24.97	1360.2	16.57	26.99	27.49	484.5	586.5	625.0	711.5
2	1,000	87 E10	FTP-4 (Bags 1 & 2)	11/18/2013	19.24	1246.0	15.79	26.00	26.56	471.3	572.8	607.6	693.7
2	1,000	87 E10	FTP-4 (Bag 3)	11/18/2013	24.97	1356.8	16.48	26.72	27.40	483.9	585.4	633.0	710.4
2	1,000	87 E10	LA92	11/19/2013	24.66	1382.0	16.68	27.73	26.95	523.1	626.2	719.0	803.8
2	1,000	87 E10	US06 (2nd)	11/19/2013	48.29	2055.1	22.44	36.72	30.06	625.7	736.7	789.7	875.9
2	5,000	85 E10	FTP-1 (Bags 1 & 2)	11/21/2013	19.20	1241.1	16.36	24.98	26.67	462.9	565.5	613.9	702.1
2	5,000	85 E10	FTP-1 (Bag 3)	11/21/2013	24.89	1368.2	16.98	25.56	26.99	480.5	583.0	631.3	717.4
2	5,000	85 E10	LA92	11/21/2013	24.81	1403.3	17.96	26.49	26.75	520.5	629.8	728.8	816.6
2	5,000	85 E10	US06 (2nd)	11/21/2013	48.09	2126.7	25.18	34.94	29.46	634.0	745.8	846.3	914.9
2	5,000	85 E10	FTP-2 (Bags 1 & 2)	11/22/2013	19.24	1250.7	16.36	24.73	26.70	466.1	571.5	607.6	693.9
2	5,000	85 E10	FTP-2 (Bag 3)	11/22/2013	25.00	1366.6	17.18	25.68	26.94	481.7	588.0	636.3	732.6
2	5,000	85 E10	LA92	11/22/2013	24.73	1406.9	17.87	26.30	26.63	525.9	634.7	732.9	819.7
2	5,000	85 E10	US06 (2nd)	11/22/2013	48.37	2137.2	25.64	35.08	29.35	633.3	747.5	874.0	965.7
2	5,000	85 E10	FTP-3 (Bags 1 & 2)	11/26/2013	19.33	1250.5	16.35	24.98	27.03	465.3	570.5	611.1	699.7
2	5,000	85 E10	FTP-3 (Bag 3)	11/26/2013	25.12	1371.4	17.35	25.96	27.24	481.7	585.8	641.6	733.4
2	5,000	85 E10	LA92	11/26/2013	24.78	1400.8	17.70	26.53	26.93	524.9	632.6	708.9	799.5
2	1,000	85 E10	LA92	11/26/2013	24.67	1377.7	16.87	27.56	26.78	526.4	627.6	727.9	805.4
2	5,000	85 E10	US06 (2nd)	11/26/2013	48.28	2130.7	24.99	35.36	29.22	637.6	748.7	872.2	957.1
2	1,000	85 E10	US06 (2nd)	11/26/2013	47.93	2075.7	22.59	36.46	29.43	629.4	739.4	841.4	910.4
2	1,000	85 E10	FTP-1 (Bags 1 & 2)	11/27/2013	19.31	1244.3	15.81	26.13	26.95	471.0	571.9	604.5	684.0
2	1,000	85 E10	FTP-1 (Bag 3)	11/27/2013	25.04	1361.3	16.29	26.75	27.24	485.9	586.5	623.0	706.3
2	1,000	85 E10	FTP-2 (Bags 1 & 2)	12/5/2013	19.28	1247.8	15.85	26.22	27.01	474.2	576.3	604.6	689.6
2	1,000	85 E10	FTP-2 (Bag3)	12/5/2013	25.01	1359.1	16.44	26.88	27.18	485.6	587.1	636.3	708.5
2	1,000	85 E10	LA92	12/5/2013	24.77	1387.3	16.91	27.61	26.64	532.1	635.3	733.0	816.7
2	1,000	85 E10	US06 (2nd)	12/5/2013	48.52	2103.7	22.35	36.63	30.05	635.6	742.8	864.6	924.3
2	1,000	85 E10	FTP-3 (Bags 1 & 2)	12/6/2013	19.61	1246.5	15.77	25.72	27.80	475.3	580.4	606.3	688.8
2	1,000	85 E10	FTP-3 (Bag3)	12/6/2013	24.93	1361.5	16.44	26.92	27.52	486.0	587.4	642.4	718.7
2	1,000	85 E10	LA92	12/6/2013	24.77	1387.3	17.02	27.93	26.59	530.3	633.4	749.5	839.0
2	1,000	85 E10	US06 (2nd)	12/6/2013	47.92	2059.8	22.69	37.12	28.75	630.6	740.3	875.3	968.2

Vnumber	Altitude	Fuel	Test Cycle	Date	Vehicle Speed	Engine Speed	Throttle Position	Load	Ignition Timing	Exhaust Temp - PreCat Avg.	Catalyst Temp - MidCat Avg.	Exhaust Temp - PreCat Max.	Catalyst Temp - MidCat Max.
					(mph)	(rpm)	(%)	(%)	(deg BTDC)	(deg. C)	(deg. C)	(deg. C)	(deg. C)
3	5,000	85 E10	FTP-1 (Bags 1 & 2)	11/5/2013	19.75	1282.9	18.69	26.73	22.39	477.2	581.5	651.0	726.8
3	5,000	85 E10	FTP-2 (Bags 1 & 2)	11/6/2013	19.77	1273.9	18.74	26.81	21.78	468.3	574.0	663.0	730.1
3	5,000	85 E10	FTP-3 (Bags 1 & 2)	11/7/2013	19.13	1252.7	18.62	26.08	21.58	469.5	578.1	658.7	731.6
3	1,000	85 E10	FTP-1 (Bag 3)	11/10/2013	25.58	1390.0	18.70	28.46	23.70	485.8	592.8	659.3	723.0
3	1,000	85 E10	LA92	11/10/2013	25.42	1422.8	18.98	28.88	22.74	532.4	647.5	727.4	798.8
3	1,000	85 E10	US06 (2nd)	11/10/2013	48.98	2153.2	24.39	39.01	23.14	661.8	775.8	838.0	909.0
3	1,000	85 E10	FTP-2 (Bags 1 & 2)	11/11/2013	19.68	1263.7	18.02	27.05	23.19	---	---	---	---
3	1,000	85 E10	FTP-2 (Bag3)	11/12/2013	25.59	1388.2	18.78	28.73	23.14	493.2	599.5	663.8	729.1
3	1,000	85 E10	LA92	11/12/2013	25.29	1419.7	18.90	28.85	22.65	530.0	644.4	722.4	792.4
3	1,000	85 E10	US06 (2nd)	11/12/2013	48.69	2146.1	24.08	36.93	23.21	647.4	775.7	858.4	930.4
3	1,000	85 E10	FTP-4 (Bags 1 & 2)	11/14/2013	19.68	1272.3	18.17	27.40	22.54	480.6	584.7	782.4	849.1
3	1,000	85 E10	FTP-3 (Bag 3)	11/14/2013	25.43	1386.2	18.70	28.56	23.09	373.3	554.5	373.3	554.5
3	1,000	85 E10	LA92	11/14/2013	25.18	1411.9	18.94	28.77	22.31	532.0	648.2	727.4	794.0
3	1,000	85 E10	US06 (2nd)	11/14/2013	49.19	2146.4	23.74	35.89	24.72	---	---	---	---
3	5,000	87 E10	FTP-1 (Bags 1 & 2)	11/21/2013	19.66	1264.8	18.69	26.29	22.17	470.7	574.3	649.4	722.4
3	5,000	87 E10	FTP-2 (Bags 1 & 2)	11/21/2013	19.71	1266.2	18.65	26.06	21.93	---	---	---	---
3	5,000	87 E10	FTP-1 (Bag 3)	11/21/2013	27.03	1416.0	19.58	27.81	22.78	---	---	---	---
3	5,000	87 E10	LA92	11/21/2013	25.19	1424.8	19.78	27.77	22.40	---	---	---	---
3	5,000	87 E10	US06 (2nd)	11/21/2013	48.83	2203.7	26.12	34.41	24.93	639.6	759.7	819.5	899.0
3	5,000	87 E10	FTP-2 (Bag 3)	11/22/2013	25.55	1392.6	19.49	27.18	22.61	483.4	592.1	646.1	715.5
3	5,000	87 E10	LA92	11/22/2013	25.17	1438.3	19.83	27.32	22.33	528.1	644.0	729.0	795.4
3	5,000	87 E10	US06 (2nd)	11/22/2013	48.96	2211.9	26.15	34.47	24.89	641.2	759.6	807.7	888.3
3	1,000	87 E10	FTP-1 (Bags 1 & 2)	12/3/2013	19.68	1270.0	18.06	27.26	23.21	477.6	580.2	648.8	720.6
3	1,000	87 E10	FTP-1 (Bag 3)	12/3/2013	25.30	1378.2	18.63	28.20	23.57	483.6	590.6	633.4	699.0
3	1,000	87 E10	LA92	12/3/2013	25.21	1412.9	18.88	28.59	23.09	527.0	640.9	710.9	780.5
3	1,000	87 E10	FTP-2 (Bags 1 & 2)	12/5/2013	19.71	1266.4	18.11	27.60	23.12	477.1	582.2	659.1	732.4
3	1,000	87 E10	FTP-2 (Bag 3)	12/5/2013	25.63	1390.2	18.71	28.29	24.01	482.9	592.8	636.7	707.3
3	1,000	87 E10	LA92	12/5/2013	25.29	1416.2	18.89	28.33	23.30	528.4	642.9	718.2	789.1
3	1,000	87 E10	US06 (2nd)	12/5/2013	48.85	2135.3	24.40	39.41	23.52	659.8	770.7	840.0	923.0
3	1,000	87 E10	FTP-2 (Bags 1 & 2)	12/6/2013	19.75	1267.2	18.09	27.17	23.26	476.6	581.6	661.2	730.5
3	1,000	87 E10	FTP-2 (Bag 3)	12/6/2013	25.61	1392.0	18.69	28.29	24.22	482.0	586.5	637.8	709.0
3	1,000	87 E10	LA92	12/6/2013	25.31	1415.6	18.89	28.38	22.93	529.3	644.9	725.9	797.2
3	1,000	87 E10	US06 (2nd)	12/6/2013	48.74	2137.6	24.17	38.84	23.61	655.3	768.9	849.5	912.9
3	5,000	87 E10	FTP-3 (Bags 1 & 2)	12/9/2013	19.67	1266.3	18.79	26.64	21.76	472.4	577.2	652.9	729.1
3	5,000	87 E10	FTP-3 (Bag 3)	12/9/2013	25.37	1386.7	19.60	27.52	22.43	---	---	---	---
3	5,000	87 E10	LA92	12/9/2013	25.13	1425.6	19.93	27.72	22.41	526.1	641.3	727.6	803.4
3	5,000	87 E10	US06 (2nd)	12/9/2013	48.90	2185.3	26.08	34.65	24.96	635.5	752.1	794.7	884.1
3	1,000	85 E10	FTP-1 (Bags 1 & 2)	11/10/2103	19.79	1280.3	18.02	26.85	23.71	475.7	578.7	654.4	730.0
4	5,000	85 E10	FTP-1 (Bags 1 & 2)	1/14/2014	19.99	1337.3	17.99	30.44	26.31	491.8	592.0	672.3	732.7
4	5,000	85 E10	FTP-1 (Bag 3)	1/14/2014	26.99	1525.5	20.59	31.49	27.03	522.0	617.5	745.3	800.9
4	5,000	85 E10	LA92	1/14/2014	25.42	1566.5	22.63	31.77	24.77	565.5	660.3	829.4	868.0
4	5,000	85 E10	US06 (2nd)	1/14/2014	49.67	2561.3	36.81	41.97	26.61	685.5	778.0	892.2	954.9
4	5,000	85 E10	FTP-2 (Bags 1 & 2)	1/15/2014	20.00	1340.5	17.80	30.02	26.56	490.7	585.6	689.4	742.8
4	5,000	85 E10	FTP-2 (Bag3)	1/15/2014	26.82	1511.8	20.40	31.22	26.99	518.9	613.2	720.0	779.6
4	5,000	85 E10	LA92	1/15/2014	25.44	1558.7	22.29	31.50	24.83	561.1	654.2	818.0	853.6
4	5,000	85 E10	US06 (2nd)	1/15/2014	49.77	2540.6	36.98	41.79	26.59	687.5	776.9	890.9	942.3
4	1,000	85 E10	FTP-3 (Bags 1 & 2)	1/16/2014	19.94	1333.5	16.63	30.49	26.39	492.9	584.4	668.1	725.6
4	1,000	85 E10	FTP-1 (Bag 3)	1/16/2014	26.75	1504.6	18.63	31.91	26.94	520.3	610.7	706.9	751.4
4	1,000	85 E10	LA92	1/16/2014	25.44	1541.8	19.92	32.65	24.71	565.4	656.0	852.3	881.9
4	1,000	85 E10	US06 (2nd)	1/16/2014	50.19	2447.3	32.66	44.04	25.95	688.3	777.7	907.7	949.6
4	1,000	85 E10	FTP-4 (Bags 1 & 2)	1/17/2014	20.01	1337.0	16.37	30.17	26.41	493.7	584.5	678.4	736.7
4	1,000	85 E10	FTP-2 (Bag3)	1/17/2014	26.91	1499.6	18.31	31.88	27.04	520.6	610.3	739.3	787.8
4	1,000	85 E10	LA92	1/17/2014	25.47	1546.2	18.86	32.10	25.21	562.9	651.1	809.0	855.0
4	1,000	85 E10	US06 (2nd)	1/17/2014	50.03	2430.6	31.70	44.15	26.16	684.6	774.2	903.8	936.7
4	5,000	87 E10	FTP-1 (Bags 1 & 2)	1/28/2014	19.96	1349.7	17.65	28.82	26.03	486.9	583.0	677.7	747.1
4	5,000	87 E10	FTP-1 (Bag 3)	1/28/2014	26.84	1523.7	20.60	30.66	27.32	517.5	613.5	740.7	778.0
4	5,000	87 E10	LA92	1/28/2014	25.55	1564.7	22.61	31.55	25.20	557.9	653.1	804.6	850.8
4	5,000	87 E10	US06 (2nd)	1/28/2014	50.18	2542.7	38.04	42.11	26.64	690.1	782.5	889.0	949.4
4	5,000	87 E10	FTP-2 (Bags 1 & 2)	1/29/2014	19.98	1337.9	18.01	30.50	26.50	489.9	586.2	680.8	741.3
4	5,000	87 E10	FTP-2 (Bag3)	1/29/2014	26.86	1518.8	20.44	31.08	27.33	517.7	612.2	753.5	793.5
4	5,000	87 E10	LA92	1/29/2014	25.49	1562.7	22.08	31.46	25.25	558.0	650.7	832.9	857.7
4	5,000	87 E10	US06 (2nd)	1/29/2014	49.98	2543.8	37.45	41.60	27.14	686.2	775.7	875.2	936.2
4	1,000	87 E10	FTP-1 (Bags 1 & 2)	1/30/2014	20.05	1337.7	16.54	31.34	26.57	494.8	585.9	676.9	725.9
4	1,000	87 E10	FTP-1 (Bag 3)	1/30/2014	27.06	1500.6	18.00	32.09	27.31	519.2	609.8	713.6	762.7
4	1,000	87 E10	LA92	1/30/2014	25.57	1551.4	19.05	32.49	24.82	560.8	649.5	817.5	874.0
4	1,000	87 E10	US06 (2nd)	1/30/2014	50.00	2434.0	30.86	43.94	27.04	679.4	768.5	895.6	937.9
4	1,000	87 E10	FTP-2 (Bags 1 & 2)	1/31/2014	20.06	1334.4	16.63	31.59	26.50	489.4	580.5	670.1	726.8
4	1,000	87 E10	FTP-2 (Bag3)	1/31/2014	26.91	1514.9	17.52	32.15	27.52	512.8	603.6	690.0	739.2
4	1,000	87 E10	LA92	1/31/2014	25.56	1544.7	19.06	32.43	25.09	559.2	648.5	849.9	881.4
4	1,000	87 E10	US06 (2nd)	1/31/2014	49.99	2419.4	31.40	43.77	27.05	678.5	766.7	885.8	929.7

Vnumber	Altitude	Fuel	Test Cycle	Date	Vehicle Speed	Engine Speed	Throttle Position	Load	Ignition Timing	Exhaust Temp - PreCat Avg.	Catalyst Temp - MidCat Avg.	Exhaust Temp - PreCat Max.	Catalyst Temp - MidCat Max.
					(mph)	(rpm)	(%)	(%)	(deg BTDC)	(deg. C)	(deg. C)	(deg. C)	(deg. C)
5	5,000	85 E10	FTP-1 (Bags 1 & 2)	11/6/2013	19.77	1169.2	16.73	26.50	23.41	---	---	---	---
5	5,000	85 E10	FTP-1 (Bag 3)	11/6/2013	27.94	1223.3	18.30	30.14	21.27	---	---	---	---
5	5,000	85 E10	LA92	11/6/2013	25.21	1194.7	18.70	31.56	19.16	---	---	---	---
5	5,000	85 E10	US06 (2nd)	11/6/2013	49.42	1712.6	23.79	47.34	18.18	---	---	---	---
5	1,000	85 E10	FTP-4 (Bags 1 & 2)	11/21/2013	19.82	1158.0	15.80	27.41	22.47	397.3	517.5	513.4	624.1
5	1,000	85 E10	FTP-2 (Bag3)	11/21/2013	26.76	1200.9	16.58	30.12	20.97	393.1	513.8	545.5	630.9
5	1,000	85 E10	LA92	11/21/2013	25.28	1192.2	17.13	31.94	18.97	469.2	597.7	652.2	736.1
5	1,000	85 E10	US06 (2nd)	11/21/2013	49.50	1708.3	21.67	48.37	17.91	588.4	719.3	766.6	875.4
5	1,000	85 E10	FTP-4 (Bags 1 & 2)	1/9/2014	19.69	1176.3	15.96	28.12	22.75	---	---	---	---
5	1,000	85 E10	FTP-2 (Bag3)	1/9/2014	26.91	1196.1	16.69	30.45	20.53	398.8	524.1	543.3	627.6
5	5,000	85 E10	LA92	1/9/2014	25.25	1203.7	18.63	31.60	19.50	469.7	601.0	640.8	783.7
5	1,000	85 E10	LA92	1/9/2014	25.08	1191.2	17.15	32.42	19.28	471.1	600.3	659.2	759.5
5	5,000	85 E10	US06 (2nd)	1/9/2014	49.42	1708.8	24.44	48.18	17.89	592.4	727.6	753.6	888.8
5	1,000	85 E10	US06 (2nd)	1/9/2014	49.32	1702.3	22.21	49.08	18.44	585.6	716.3	767.7	905.1
5	5,000	85 E10	FTP-2 (Bags 1 & 2)	1/10/2014	19.90	1175.1	16.90	26.81	23.17	394.8	515.6	514.3	608.6
5	5,000	85 E10	FTP-2 (Bag3)	1/10/2014	26.82	1204.5	18.19	29.76	20.84	390.2	515.8	550.4	660.3
5	5,000	87 E10	FTP-1 (Bags 1 & 2)	1/22/2014	20.02	1177.0	16.71	26.62	23.35	390.8	510.6	505.1	598.2
5	5,000	87 E10	FTP-1 (Bag 3)	1/22/2014	26.79	1203.7	17.91	29.54	21.41	390.8	518.3	530.2	641.3
5	5,000	87 E10	LA92	1/22/2014	25.34	1200.0	18.53	31.19	19.62	458.9	594.8	620.3	757.5
5	5,000	87 E10	US06 (2nd)	1/22/2014	49.56	1709.6	23.68	47.32	19.46	569.5	711.2	722.2	856.2
5	5,000	87 E10	FTP-2 (Bags 1 & 2)	1/23/2014	19.87	1172.6	16.89	26.50	23.37	---	---	---	---
5	5,000	87 E10	FTP-2 (Bag3)	1/23/2014	26.77	1207.1	18.36	29.66	21.67	391.0	527.2	548.8	687.6
5	5,000	87 E10	LA92	1/23/2014	25.25	1204.1	18.91	31.16	19.31	464.2	603.1	635.6	766.0
5	5,000	87 E10	US06 (2nd)	1/23/2014	49.66	1719.5	24.08	46.91	19.61	571.8	706.5	723.7	856.1
5	1,000	87 E10	FTP-1 (Bags 1 & 2)	1/27/2014	19.52	1166.6	16.11	29.02	22.15	399.4	518.0	522.7	668.0
5	1,000	87 E10	FTP-1 (Bag 3)	1/27/2014	26.90	1200.6	16.65	30.39	21.95	392.6	515.8	528.3	616.8
5	1,000	87 E10	LA92	1/27/2014	25.33	1201.8	16.86	31.65	20.13	462.2	590.4	643.2	737.1
5	1,000	87 E10	US06 (2nd)	1/27/2014	49.43	1715.4	21.32	47.42	19.28	575.7	703.9	724.0	831.8
5	1,000	87 E10	FTP-2 (Bags 1 & 2)	2/10/2014	19.86	1160.7	16.00	28.43	22.90	397.4	515.4	519.2	646.6
5	1,000	87 E10	FTP-2 (Bag3)	2/10/2014	26.70	1199.6	16.57	30.09	22.03	383.3	495.4	513.6	592.4
5	1,000	87 E10	LA92	2/10/2014	25.16	1191.7	16.67	30.85	21.02	447.3	569.2	623.9	704.2
5	1,000	87 E10	US06 (2nd)	2/10/2014	49.95	1716.6	21.14	47.82	19.59	571.7	698.5	717.7	851.3
6	5,000	85 E10	LA92	1/7/2014	24.59	1677.0	27.07	38.40	13.93	465.0	598.5	625.3	706.3
6	5,000	85 E10	FTP-2 (Bags 1 & 2)	1/30/2014	19.60	1573.9	21.43	34.30	18.54	411.3	531.3	525.6	623.2
6	5,000	85 E10	FTP-2 (Bag3)	1/30/2014	25.43	1639.0	23.57	35.86	20.91	405.5	531.7	523.4	605.2
6	5,000	85 E10	LA92	1/30/2014	24.49	1665.3	25.28	37.55	16.48	459.2	589.8	620.1	703.4
6	5,000	85 E10	US06 (2nd)	1/30/2014	48.02	2329.6	41.51	57.30	14.27	623.7	758.6	771.7	838.6
6	1,000	85 E10	FTP-1 (Bags 1 & 2)	2/4/2014	19.71	1576.5	19.81	35.21	19.36	412.6	527.0	531.6	616.1
6	1,000	85 E10	FTP-1 (Bag 3)	2/4/2014	25.69	1642.6	21.98	37.32	21.22	400.8	526.2	526.6	607.8
6	1,000	85 E10	LA92	2/4/2014	24.52	1676.1	23.68	39.13	17.32	461.0	589.5	628.9	709.3
6	1,000	85 E10	US06 (2nd)	2/4/2014	48.42	2293.3	36.89	59.99	14.58	632.1	768.2	790.0	844.0
6	1,000	85 E10	FTP-2 (Bags 1 & 2)	2/5/2014	19.64	1569.9	19.83	35.19	18.69	411.8	528.9	528.5	619.7
6	1,000	85 E10	FTP-2 (Bag3)	2/5/2014	25.79	1640.0	21.67	36.56	21.34	400.2	525.2	521.8	605.0
6	1,000	85 E10	LA92	2/5/2014	24.53	1663.4	23.26	38.27	17.48	453.6	582.1	616.9	699.8
6	1,000	85 E10	US06 (2nd)	2/5/2014	48.33	2286.7	36.68	59.89	14.53	629.7	761.7	756.6	823.5
6	5,000	85 E10	FTP-2 (Bags 1 & 2)	2/7/2014	19.64	1579.1	21.09	33.69	18.13	410.3	528.9	521.0	613.9
6	5,000	85 E10	FTP-2 (Bag3)	2/7/2014	25.60	1645.6	23.50	35.71	19.47	407.1	535.5	530.8	609.2
6	5,000	85 E10	US06 (2nd)	2/7/2014	48.10	2320.4	41.95	60.10	12.14	632.1	769.4	768.3	832.1
6	5,000	85 E10	FTP-2 (Bags 1 & 2)	2/10/2014	19.57	1575.9	21.20	34.39	18.71	408.9	526.8	525.4	615.8
6	5,000	85 E10	FTP-2 (Bag3)	2/10/2014	25.57	1660.2	23.33	35.76	20.10	405.5	532.4	520.2	606.7
6	5,000	85 E10	LA92	2/10/2014	24.59	1667.5	26.61	37.92	15.41	461.2	592.5	637.5	709.9
6	5,000	85 E10	US06 (2nd)	2/10/2014	48.29	2351.1	41.87	58.07	13.85	627.1	763.5	761.2	835.6
6	5,000	87 E10	FTP-1 (Bags 1 & 2)	2/25/2014	19.62	1579.0	21.22	33.51	17.82	---	---	---	---
6	5,000	87 E10	FTP-1 (Bag 3)	2/25/2014	25.64	1646.2	23.33	35.37	19.26	---	---	---	---
6	5,000	87 E10	LA92	2/25/2014	24.89	1680.6	26.90	37.87	14.48	464.6	598.1	643.5	721.1
6	5,000	87 E10	FTP-2 (Bags 1 & 2)	2/26/2014	19.58	1572.2	21.17	34.04	17.05	410.3	528.4	522.4	611.3
6	5,000	87 E10	FTP-2 (Bag3)	2/26/2014	25.44	1642.7	23.71	35.12	18.92	406.4	535.2	525.4	612.8
6	5,000	87 E10	LA92	2/26/2014	24.71	1677.6	26.38	37.73	14.70	462.3	596.4	632.9	712.5
6	5,000	87 E10	US06 (2nd)	2/26/2014	48.18	2363.7	40.94	57.01	14.11	622.3	759.5	751.0	834.0
6	5,000	87 E10	US06 (2nd)	2/26/2014	48.32	2349.7	41.28	56.21	15.38	622.1	760.1	756.5	838.4
6	1,000	87 E10	FTP-3 (Bags 1 & 2)	2/27/2014	19.61	1577.6	19.76	35.54	18.96	---	---	---	---
6	1,000	87 E10	FTP-3 (Bag 3)	2/27/2014	25.53	1667.5	21.81	36.28	20.61	---	---	---	---
6	1,000	87 E10	LA92	2/27/2014	24.73	1677.1	23.78	38.75	15.58	457.9	589.5	618.0	707.9
6	1,000	87 E10	FTP-5 (Bags 1 & 2)	2/28/2014	19.68	1575.1	19.95	35.33	17.62	415.4	536.4	535.3	625.5
6	1,000	87 E10	FTP-5 (Bag3)	2/28/2014	25.61	1655.8	22.20	36.79	20.82	408.8	534.9	529.6	615.8
6	1,000	87 E10	LA92	2/28/2014	24.69	1678.8	23.89	39.02	15.63	464.7	597.2	646.6	723.2
6	1,000	87 E10	US06 (2nd)	2/28/2014	48.31	2279.3	37.73	60.80	14.13	632.9	767.1	763.5	832.4
6	1,000	87 E10	US06 (2nd)	2/28/2014	48.47	2287.1	38.35	60.21	14.37	630.7	764.5	776.0	851.5

Vnumber	Altitude	Fuel	Test Cycle	Date	Vehicle Speed	Engine Speed	Throttle Position	Load	Ignition Timing	Exhaust Temp - PreCat Avg.	Catalyst Temp - MidCat Avg.	Exhaust Temp - PreCat Max.	Catalyst Temp - MidCat Max.
					(mph)	(rpm)	(%)	(%)	(deg BTDC)	(deg. C)	(deg. C)	(deg. C)	(deg. C)
7	5,000	85 E10	FTP-1 (Bags 1 & 2)	1/29/2014	19.30	999.1	16.78	21.92	25.61	411.1	538.1	545.6	676.6
7	5,000	85 E10	FTP-1 (Bag 3)	1/29/2014	25.21	1114.6	17.34	22.80	25.98	422.6	559.2	539.3	681.9
7	5,000	85 E10	LA92	1/29/2014	24.87	1133.5	17.72	23.55	25.29	484.1	634.9	644.1	770.9
7	5,000	85 E10	US06 (2nd)	1/29/2014	49.13	1737.3	22.53	31.97	27.57	609.1	746.7	724.7	864.1
7	5,000	85 E10	FTP-2 (Bags 1 & 2)	1/30/2014	19.26	999.3	16.73	21.98	25.23	412.8	540.9	550.4	677.4
7	5,000	85 E10	FTP-2 (Bag3)	1/30/2014	25.15	1104.3	17.38	22.76	25.92	421.5	561.6	555.3	675.8
7	5,000	85 E10	LA92	1/30/2014	25.10	1135.7	17.76	23.67	25.16	484.0	634.9	641.6	768.7
7	5,000	85 E10	US06 (2nd)	1/30/2014	48.45	1717.3	22.72	31.65	27.42	607.9	749.1	734.0	866.3
7	1,000	85 E10	FTP-1 (Bags 1 & 2)	2/4/2014	19.34	997.6	16.29	22.51	25.26	420.4	545.4	564.8	678.8
7	1,000	85 E10	FTP-1 (Bag 3)	2/4/2014	25.20	1104.0	16.85	23.35	25.89	427.0	560.6	560.2	683.8
7	1,000	85 E10	LA92	2/4/2014	24.91	1127.7	17.20	24.37	24.60	491.3	631.9	666.9	785.0
7	1,000	85 E10	US06 (2nd)	2/4/2014	48.81	1701.1	21.86	32.82	26.59	613.9	742.4	774.9	869.2
7	1,000	85 E10	FTP-2 (Bags 1 & 2)	2/5/2014	19.31	999.8	16.37	22.88	25.49	426.0	552.1	571.2	685.1
7	1,000	85 E10	FTP-2 (Bag3)	2/5/2014	25.39	1110.8	16.89	23.40	25.80	429.4	554.3	549.4	678.3
7	1,000	85 E10	LA92	2/5/2014	24.36	1117.2	17.13	23.94	24.61	479.4	619.6	647.8	778.6
7	1,000	85 E10	US06 (2nd)	2/5/2014	48.82	1701.2	21.54	32.69	26.83	614.6	744.5	780.9	859.6
7	1,000	85 E10	FTP-3 (Bags 1 & 2)	2/7/2014	19.26	995.5	16.31	22.77	25.45	419.7	542.0	561.9	679.5
7	1,000	85 E10	FTP-3 (Bag3)	2/7/2014	25.17	1101.5	16.86	18.82	25.95	424.6	554.2	554.6	671.5
7	5,000	87 E10	FTP-1 (Bags 1 & 2)	2/18/2014	19.29	1006.5	16.82	22.39	25.66	413.6	541.9	549.0	684.0
7	5,000	87 E10	FTP-1 (Bag 3)	2/18/2014	25.10	1112.6	17.37	22.80	26.71	420.3	558.2	541.8	681.9
7	5,000	87 E10	LA92	2/18/2014	24.85	1139.3	17.70	23.56	25.62	482.8	633.8	640.3	769.8
7	5,000	87 E10	US06 (2nd)	2/18/2014	48.83	1740.8	22.33	31.53	27.88	608.8	748.4	731.9	862.4
7	5,000	87 E10	FTP-2 (Bags 1 & 2)	2/19/2014	19.30	1001.3	16.83	22.21	25.25	413.4	543.3	554.7	677.7
7	5,000	87 E10	FTP-2 (Bag 3)	2/19/2014	25.21	1104.9	17.39	22.69	26.07	420.3	558.2	548.4	673.6
7	5,000	87 E10	LA92	2/19/2014	24.81	1129.1	17.68	23.50	25.21	484.2	633.4	625.2	763.0
7	5,000	87 E10	US06 (2nd)	2/19/2014	48.84	1732.2	22.45	31.65	27.92	611.8	751.1	730.3	863.6
7	1,000	87 E10	FTP-1 (Bags 1 & 2)	2/25/2014	19.30	994.9	16.34	22.74	25.29	418.4	543.3	560.4	685.6
7	1,000	87 E10	FTP-1 (Bag 3)	2/25/2014	25.16	1098.2	16.81	23.41	25.79	426.1	557.4	556.4	675.2
7	1,000	87 E10	LA92	2/25/2014	24.85	1126.8	17.06	24.12	25.20	485.2	628.1	635.4	764.6
7	1,000	87 E10	US06 (2nd)	2/25/2014	48.93	1702.5	21.36	32.65	26.90	609.1	737.9	745.2	846.5
7	1,000	87 E10	FTP-2 (Bags 1 & 2)	2/27/2014	19.35	995.7	16.31	22.81	25.52	418.4	541.6	555.1	668.6
7	1,000	87 E10	FTP-2 (Bag 3)	2/27/2014	25.17	1103.3	16.87	23.06	25.89	424.0	552.7	544.7	671.6
7	1,000	87 E10	LA92	2/27/2014	24.85	1125.3	17.16	24.20	25.10	478.7	616.9	635.4	767.5
7	1,000	87 E10	US06 (2nd)	2/27/2014	48.89	1706.1	21.19	32.52	27.09	608.8	739.6	742.5	846.8
7	1,000	87 E10	FTP-2 (Bags 1 & 2)	2/28/2014	19.34	996.9	16.27	22.67	25.36	415.1	539.9	567.0	677.3
7	1,000	87 E10	FTP-2 (Bag 3)	2/28/2014	25.17	1105.9	16.82	23.38	25.93	423.7	553.0	537.4	666.0
8	1,000	87 E10	FTP-4 (Bag3)	12/13/2012	25.51	1297.2	17.15	34.26	22.29	---	---	---	---
8	1,000	85 E10	US06 (2nd)	1/10/2013	48.50	1909.1	23.96	45.83	15.73	711.1	857.1	901.5	975.0
8	5,000	87 E10	FTP-1 (Bags 1 & 2)	12/10/2013	19.64	1259.0	17.17	31.66	23.84	524.8	632.2	710.0	822.9
8	5,000	87 E10	FTP-1 (Bag 3)	12/10/2013	25.47	1319.8	17.88	32.15	22.52	532.6	656.5	705.5	817.2
8	5,000	87 E10	LA92	12/10/2013	24.65	1358.5	18.58	32.85	21.00	560.0	694.6	797.2	924.1
8	5,000	87 E10	US06 (2nd)	12/10/2013	48.59	1959.3	25.28	41.74	19.10	676.6	824.1	854.7	935.4
8	5,000	87 E10	FTP-2 (Bags 1 & 2)	12/11/2013	19.64	1257.2	17.16	31.75	23.77	521.6	626.3	704.4	814.0
8	5,000	87 E10	FTP-2 (Bag3)	12/11/2013	25.40	1314.4	17.79	32.07	23.56	533.3	653.0	701.8	812.4
8	5,000	87 E10	LA92	12/11/2013	24.63	1362.5	18.64	32.56	20.91	564.1	699.2	798.6	924.6
8	5,000	87 E10	US06 (2nd)	12/11/2013	48.53	1966.0	25.15	41.45	18.58	682.7	829.4	891.2	937.1
8	1,000	87 E10	FTP-3 (Bags 1 & 2)	12/12/2013	19.61	1240.4	16.58	33.88	23.41	---	---	---	---
8	1,000	87 E10	FTP-3 (Bag 3)	12/12/2013	25.48	1299.4	17.14	34.25	22.95	542.7	651.9	717.6	814.3
8	1,000	87 E10	LA92	12/12/2013	24.68	1331.5	17.67	35.47	20.32	571.1	690.1	829.7	945.7
8	1,000	87 E10	US06 (2nd)	12/12/2013	48.45	1902.8	23.64	45.17	17.20	697.7	841.7	906.6	966.4
8	1,000	87 E10	FTP-4 (Bags 1 & 2)	12/13/2013	19.71	1254.3	16.59	33.95	23.74	535.8	632.0	707.4	810.3
8	1,000	87 E10	LA92	12/13/2013	24.76	1329.7	17.70	35.49	20.18	571.6	693.8	831.9	947.0
8	1,000	87 E10	US06 (2nd)	12/13/2013	48.50	1917.7	23.44	45.12	18.04	---	---	---	---
8	1,000	87 E10	FTP-5 (Bags 1 & 2)	12/17/2013	19.68	1250.4	16.62	34.20	23.40	532.3	631.6	701.8	805.8
8	1,000	87 E10	FTP-5 (Bag3)	12/17/2013	25.52	1296.5	17.10	34.49	22.94	541.8	651.6	708.5	810.6
8	1,000	87 E10	LA92	12/17/2013	24.74	1325.2	17.69	35.56	20.31	570.3	694.2	826.0	940.2
8	1,000	87 E10	US06 (2nd)	12/17/2013	48.51	1913.1	23.70	45.12	16.96	704.0	849.4	890.2	967.6
8	5,000	85 E10	FTP-1 (Bags 1 & 2)	12/19/2013	19.61	1260.6	17.22	31.55	24.07	522.5	629.3	700.3	815.1
8	5,000	85 E10	FTP-1 (Bag 3)	12/19/2013	25.43	1318.3	17.90	31.89	23.15	536.5	658.3	703.8	814.1
8	5,000	85 E10	LA92	12/19/2013	24.64	1361.2	18.58	32.67	20.31	563.4	699.4	811.8	925.9
8	5,000	85 E10	US06 (2nd)	12/19/2013	48.51	1976.4	25.70	41.60	17.57	689.1	839.0	881.9	939.2
8	5,000	85 E10	FTP-2 (Bags 1 & 2)	1/3/2014	19.62	1264.4	17.20	32.02	24.27	523.4	631.8	702.6	820.7
8	5,000	85 E10	FTP-2 (Bag3)	1/3/2014	25.51	1319.4	17.77	32.20	23.35	534.4	655.3	701.0	813.7
8	5,000	85 E10	LA92	1/3/2014	24.60	1361.3	18.60	32.88	20.34	564.3	703.5	809.5	933.2
8	5,000	85 E10	US06 (2nd)	1/3/2014	48.43	1978.3	25.61	41.96	17.85	688.0	838.1	881.3	939.9
8	5,000	85 E10	FTP-1 (Bags 1 & 2)	1/8/2014	19.56	1262.3	17.20	32.05	24.25	523.2	631.1	703.4	815.3
8	5,000	85 E10	FTP-1 (Bag 3)	1/8/2014	25.42	1315.5	17.83	32.05	22.07	531.0	655.7	717.6	827.2
8	5,000	85 E10	LA92	1/8/2014	24.52	1350.5	18.47	32.80	20.67	559.7	693.2	820.6	929.1
8	5,000	85 E10	FTP-2 (Bags 1 & 2)	1/9/2014	19.55	1262.0	17.23	32.09	23.90	523.3	630.9	723.5	840.1
8	5,000	85 E10	FTP-2 (Bag3)	1/9/2014	25.35	1313.7	17.89	32.42	22.32	534.4	658.6	715.3	834.1
8	5,000	85 E10	LA92	1/9/2014	24.51	1356.6	18.55	32.61	20.23	560.6	695.9	802.1	918.7
8	5,000	85 E10	US06 (2nd)	1/9/2014	48.44	1982.6	25.62	41.35	17.37	690.0	839.8	859.1	935.6
8	5,000	85 E10	US06 (2nd)	1/9/2014	48.31	2014.6	26.15	41.99	16.65	696.6	849.4	871.4	938.5
8	1,000	85 E10	FTP-1 (Bags 1 & 2)	1/10/2014	19.59	1241.3	16.58	34.08	23.36	532.4	632.7	716.1	815.8
8	1,000	85 E10	FTP-1 (Bag 3)	1/10/2014	25.44	1297.6	17.15	34.39	22.08	544.4	659.0	710.0	805.1
8	1,000	85 E10	LA92	1/10/2014	24.62	1324.9	17.72	35.54	19.69	570.1	693.0	859.7	961.6

m. Vehicle Emissions Data – Response Drift Data (Tier 2 Emissions Test Fuel)

VNumber	Altitude	Fuel	TestCycle	TestID	TestDate	THC	CH4	NonMethane	CO	Nox	CO2	FE	NMOG
	(ft)					(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(g/mile)	(mpg)	(g/mile)
1	Site Elevation	Tier 2	US FTP	MS34008520	8/28/2013	0.0288	0.0051	0.02407	0.2474	0.0121	237.5300	37.3996	0.0250
1	Site Elevation	Tier 2	US FTP	MS35004296	9/5/2013	0.0302	0.0045	0.02595	0.3012	0.0113	237.4640	37.4235	0.0270
1	Site Elevation	Tier 2	US FTP	MS35004355	10/5/2013	0.0333	0.0038	0.0297	0.2195	0.0114	239.2380	37.1650	0.0309
1	Site Elevation	Tier 2	US FTP	MS35004362	10/6/2013	0.0271	0.0041	0.0232	0.2118	0.0075	239.2620	37.1662	0.0242
2	Site Elevation	Tier 2	US FTP	MS34008749	10/22/2013	0.0099	0.0022	0.0081	0.3080	0.0008	285.4260	31.1533	0.0085
2	Site Elevation	Tier 2	US FTP	MS34008755	10/23/2013	0.0108	0.0023	0.0088	0.2942	0.0011	287.6000	30.9203	0.0092
2	Site Elevation	Tier 2	US FTP	MS34008761	10/24/2013	0.0137	0.0030	0.0109	0.3687	0.0014	286.5500	31.0197	0.0113
2	Site Elevation	Tier 2	US FTP	MS34008767	10/25/2013	0.0260	0.0042	0.0221	0.4157	0.0020	294.5060	30.1720	0.0230
2	Site Elevation	Tier 2	US FTP	MS34008788	10/29/2013	0.0221	0.0048	0.0176	0.3460	0.0026	289.0940	30.7483	0.0183
2	Site Elevation	Tier 2	US FTP	MS35004581	12/15/2013	0.0424	0.0054	0.0374	0.8782	0.0071	289.2470	30.6369	0.0389
2	Site Elevation	Tier 2	US FTP	MS34009057	12/18/2013	0.0109	0.0022	0.0091	0.1891	0.0014	286.4870	31.0581	0.0095
2	Site Elevation	Tier 2	US FTP	MS34009065	12/18/2013	0.0115	0.0026	0.0092	0.2200	0.0012	288.6490	30.8204	0.0095
3	Site Elevation	Tier 2	US FTP	MS34008748	10/22/2013	0.0185	0.0028	0.0162	0.1038	0.0105	288.0750	30.8988	0.0168
3	Site Elevation	Tier 2	US FTP	MS34008754	10/23/2013	0.0188	0.0034	0.0156	0.1268	0.0172	279.4540	31.8470	0.0163
3	Site Elevation	Tier 2	US FTP	MS34008760	10/24/2013	0.0189	0.0027	0.0164	0.1326	0.0130	282.2470	31.5311	0.0171
3	Site Elevation	Tier 2	US FTP	MS34008766	10/25/2013	0.0187	0.0027	0.0162	0.1007	0.0145	283.2170	31.4289	0.0168
3	Site Elevation	Tier 2	US FTP	MS34008787	10/29/2013	0.0184	0.0032	0.0154	0.0954	0.0134	283.9690	31.3468	0.0161
3	Site Elevation	Tier 2	US FTP	MS35004569	12/12/2013	0.0231	0.0030	0.0208	0.1246	0.0108	286.7010	31.0416	0.0216
3	Site Elevation	Tier 2	US FTP	MS35004580	12/15/2013	0.0182	0.0025	0.0159	0.0812	0.0148	283.6020	31.3898	0.0166
3	Site Elevation	Tier 2	US FTP	MS34009056	12/17/2013	0.0189	0.0028	0.0164	0.0940	0.0151	281.9670	31.5692	0.0170
4	Site Elevation	Tier 2	US FTP	7230770	12/19/2013	0.0484	0.0053	0.0430	0.5265	0.0051	349.8270	25.2852	0.0447
4	Site Elevation	Tier 2	US FTP	7230781	12/20/2013	0.0489	0.0048	0.0441	0.4543	0.0076	351.4745	25.1750	0.0459
4	Site Elevation	Tier 2	US FTP	8343813	2/13/2014	0.0392	0.0047	0.0345	0.4367	0.0041	357.6537	24.7447	0.0359
4	Site Elevation	Tier 2	US FTP	8343875	2/18/2014	0.0214	0.0037	0.0178	0.3055	0.0029	354.8835	24.9567	0.0185
5	Site Elevation	Tier 2	US FTP	4843735	10/16/2013	0.0225	0.0066	0.0163	0.3106	0.0072	500.6258	17.7673	0.0170
5	Site Elevation	Tier 2	US FTP	3239554	10/23/2013	0.0243	0.0064	0.0178	0.3509	0.0080	498.9165	17.8260	0.0185
6	Site Elevation	Tier 2	US FTP	782012130047-3	9/12/2013	0.0365	0.0043	0.0327	0.5369	0.0368	273.3000	32.4272	0.0340
6	Site Elevation	Tier 2	US FTP	782012130047-4	9/13/2013	0.0376	0.0042	0.0339	0.5599	0.0380	276.4000	32.0716	0.0352
6	Site Elevation	Tier 2	US FTP	782012140016-4	3/6/2014	0.0356	0.0045	0.0314	0.5307	0.0357	262.6000	33.6424	0.0327
6	Site Elevation	Tier 2	US FTP	782012140016-5	3/7/2014	0.0406	0.0052	0.0360	0.6896	0.0388	285.3000	31.0250	0.0374
7	Site Elevation	Tier 2	US FTP	MS34009141	1/16/2014	0.0639	0.0223	0.0431	1.2326	0.0186	517.9910	17.0237	0.0448
7	Site Elevation	Tier 2	US FTP	MS34009167	1/23/2014	0.0765	0.0233	0.0548	1.2920	0.0188	525.2120	16.7863	0.0570
7	Site Elevation	Tier 2	US FTP	MS34009468	3/5/2014	0.0477	0.0172	0.0317	0.8203	0.0118	518.7340	17.0222	0.0329
7	Site Elevation	Tier 2	US FTP	MS34009480	3/5/2014	0.0618	0.0194	0.0439	1.0676	0.0123	524.0750	16.8353	0.0456
7	Site Elevation	Tier 2	US FTP	MS34009495	3/7/2014	0.0557	0.0200	0.0370	0.9562	0.0155	520.7020	16.9503	0.0385
8	Site Elevation	Tier 2	US FTP	782012130032-5	9/12/2013	0.0150	0.0030	0.0128	0.1908	0.0192	454.4000	19.5530	0.0133
8	Site Elevation	Tier 2	US FTP	782012130032-6	9/13/2013	0.0145	0.0017	0.0130	0.1995	0.0161	454.9000	19.5094	0.0135
8	Site Elevation	Tier 2	US FTP	782012140008-2	1/30/2014	0.0158	0.0034	0.0134	0.1817	0.0161	456.8000	19.4288	0.0139
9	Site Elevation	Tier 2	US FTP	MS34009289	2/12/2014	0.1386	0.0676	0.0755	1.4995	0.0074	420.5780	20.9142	0.0785
9	Site Elevation	Tier 2	US FTP	MS34009341	2/18/2014	0.1494	0.0708	0.0832	1.5224	0.0064	423.2250	20.7809	0.0865
9	Site Elevation	Tier 2	US FTP	MS35004934	5/7/2014	0.1786	0.0820	0.1014	1.5956	0.0082	425.4140	20.7415	0.1055
9	Site Elevation	Tier 2	US FTP	MS35004963	5/12/2014	0.1552	0.0724	0.0870	1.4761	0.0062	421.8280	20.9295	0.0905

n. Vehicle Performance Data – Response Drift Data (Tier 2 Emissions Test Fuel)

Vnumber	Altitude	Fuel	Test	Date	Vehicle Speed	Engine Speed	Throttle Position	Load	Ignition Timing	Exhaust Temp - PreCat Avg.	Catalyst Temp - MidCat Avg.	Exhaust Temp - PreCat Max.	Catalyst Temp - MidCat Max.
					(mph)	(rpm)	(%)	(%)	(deg BTDC)	(deg. C)	(deg. C)	(deg. C)	(deg. C)
1	Site	Tier 2	FTP-3 (Bags 1 & 2)	8/28/2013	19.54	1317.4	16.49	26.88	20.29	452.6	565.2	666.5	719.1
1	Site	Tier 2	FTP-3 (Bag 3)	8/28/2013	25.41	1390.5	17.32	29.05	18.98	468.4	587.6	666.1	734.3
1	Site	Tier 2	FTP-4 (Bags 1 & 2)	9/5/2013	19.64	1308.2	16.45	26.82	20.36	453.3	563.7	651.5	721.1
1	Site	Tier 2	FTP-4 (Bag3)	9/5/2013	25.47	1390.5	17.26	29.03	19.62	467.9	582.3	664.2	718.2
1	Site	Tier 2	FTP-1 (Bags 1 & 2)	10/5/2013	19.56	1323.8	16.51	27.00	20.45	456.4	566.1	674.4	751.6
1	Site	Tier 2	FTP-1 (Bag 3)	10/5/2013	25.38	1384.1	17.34	29.21	19.43	466.8	583.6	651.8	722.1
1	Site	Tier 2	FTP-2 (Bag3)	10/6/2013	25.36	1378.7	17.38	29.17	19.69	---	---	---	---
2	Site	Tier 2	FTP-1 (Bags 1 & 2)	10/22/2013	19.28	1249.1	15.84	25.70	26.96	477.6	579.6	610.7	691.9
2	Site	Tier 2	FTP-2 (Bags 1 & 2)	10/23/2013	19.27	1248.4	15.81	25.61	27.00	476.8	577.2	613.5	696.4
2	Site	Tier 2	FTP-2 (Bag3)	10/23/2013	24.96	1354.7	16.35	26.54	27.55	488.7	589.7	636.3	718.7
2	Site	Tier 2	FTP-3 (Bags 1 & 2)	10/24/2013	19.31	1245.0	15.83	25.75	26.93	476.0	577.5	605.1	689.2
2	Site	Tier 2	FTP-1 (Bag 3)	10/24/2013	25.06	1365.9	16.37	26.49	27.66	489.8	591.7	653.2	726.9
2	Site	Tier 2	FTP-3 (Bag 3)	10/24/2013	25.12	1362.1	16.38	26.54	27.81	488.0	589.9	629.7	712.5
2	Site	Tier 2	FTP-4 (Bags 1 & 2)	10/25/2013	19.58	1241.4	15.91	26.69	27.64	480.9	583.8	623.3	704.0
2	Site	Tier 2	FTP-4 (Bag3)	10/25/2013	25.04	1363.2	16.46	27.16	27.77	490.2	591.7	635.8	701.5
2	Site	Tier 2	FTP-5 (Bags 1 & 2)	10/29/2013	19.29	1247.1	15.79	25.89	26.98	478.1	578.7	615.3	695.9
2	Site	Tier 2	FTP-4 (Bag3)	10/29/2013	25.00	1361.5	16.33	26.65	27.68	490.9	592.1	638.8	713.0
2	Site	Tier 2	FTP-2 (Bags 1 & 2)	12/15/2013	19.28	1253.3	15.91	27.14	26.67	478.5	579.1	616.4	686.7
2	Site	Tier 2	FTP-2 (Bag3)	12/15/2013	25.49	1364.1	16.45	26.84	28.01	492.2	594.7	638.4	718.8
2	Site	Tier 2	FTP-3 (Bags 1 & 2)	12/18/2013	19.33	1246.6	15.90	26.24	27.19	478.7	579.8	611.7	692.1
2	Site	Tier 2	FTP-4 (Bags 1 & 2)	12/18/2013	19.32	1249.9	15.86	25.89	27.15	477.2	578.9	608.4	687.7
2	Site	Tier 2	FTP-3 (Bag 3)	12/18/2013	25.08	1363.8	16.43	26.84	27.57	492.1	593.2	627.0	707.8
2	Site	Tier 2	FTP-4 (Bag 3)	12/18/2013	25.12	1367.4	16.40	26.70	27.85	491.4	592.6	621.1	707.9
3	Site	Tier 2	FTP-2 (Bags 1 & 2)	10/23/2013	19.81	1274.7	17.89	25.80	24.13	---	---	---	---
3	Site	Tier 2	FTP-2 (Bag3)	10/23/2013	25.47	1391.9	18.74	28.63	24.66	486.7	596.0	639.6	710.7
3	Site	Tier 2	FTP-3 (Bags 1 & 2)	10/24/2013	19.78	1277.7	18.13	27.64	23.77	481.2	584.4	657.4	729.9
3	Site	Tier 2	FTP-3 (Bag 3)	10/24/2013	25.41	1381.9	18.66	28.57	24.49	487.9	596.6	641.0	708.7
3	Site	Tier 2	FTP-4 (Bags 1 & 2)	10/25/2013	19.79	1275.7	18.09	27.48	23.65	481.1	584.7	667.2	738.7
3	Site	Tier 2	FTP-4 (Bag3)	10/25/2013	25.54	1386.3	18.67	28.74	24.47	---	---	---	---
3	Site	Tier 2	FTP-5 (Bags 1 & 2)	10/29/2013	19.66	1271.3	18.04	27.51	23.52	479.9	582.6	664.4	737.3
3	Site	Tier 2	FTP-5 (Bag3)	10/29/2013	25.38	1388.2	18.64	28.46	24.43	486.7	594.7	634.8	708.9
3	Site	Tier 2	FTP-1 (Bags 1 & 2)	12/12/2013	19.81	1272.6	18.17	27.55	23.55	480.4	581.5	655.6	726.5
3	Site	Tier 2	FTP-1 (Bag 3)	12/12/2013	25.48	1387.9	18.81	28.73	24.37	487.7	594.3	630.3	701.6
3	Site	Tier 2	FTP-2 (Bags 1 & 2)	12/15/2013	19.93	1281.3	18.17	27.42	23.84	479.6	580.3	653.9	730.2
3	Site	Tier 2	FTP-2 (Bag3)	12/15/2013	25.64	1392.7	18.79	28.88	24.35	485.9	594.1	631.8	707.2
3	Site	Tier 2	FTP-3 (Bags 1 & 2)	12/17/2013	19.77	1276.3	18.13	27.34	23.86	480.1	582.0	655.6	728.7
3	Site	Tier 2	FTP-3 (Bag 3)	12/17/2013	25.07	1376.4	18.70	28.38	24.08	486.1	594.6	630.5	704.0
4	Site	Tier 2	FTP-3 (Bags 1 & 2)	2/12/2014	19.94	1347.7	16.21	30.96	27.20	492.6	581.6	655.4	731.8
4	Site	Tier 2	FTP-3 (Bag 3)	2/12/2014	26.89	1515.4	17.48	31.70	28.84	515.2	608.8	682.4	727.1
4	Site	Tier 2	FTP-4 (Bags 1 & 2)	2/13/2014	19.99	1336.3	16.35	31.25	26.95	492.7	582.4	668.6	722.1
4	Site	Tier 2	FTP-4 (Bag3)	2/13/2014	26.77	1506.3	17.38	31.49	28.57	512.1	606.4	684.7	734.3
5	Site	Tier 2	FTP-3 (Bags 1 & 2)	10/23/2013	19.94	1164.4	16.00	28.44	22.53	---	---	---	---
5	Site	Tier 2	FTP-3 (Bag 3)	10/23/2013	29.72	1225.1	16.14	27.01	21.27	---	---	---	---
5	Site	Tier 2	FTP-4 (Bags 1 & 2)	2/18/2014	19.81	1160.1	15.82	27.41	22.78	403.3	525.3	513.9	608.7
5	Site	Tier 2	FTP-4 (Bag3)	2/18/2014	26.70	1199.6	16.69	30.06	21.58	402.6	531.0	514.8	623.9
6	Site	Tier 2	FTP-1 (Bags 1 & 2)	9/12/2013	19.59	1558.3	20.06	35.58	17.69	424.5	552.0	551.6	642.4
6	Site	Tier 2	FTP-1 (Bag 3)	9/12/2013	25.68	1630.5	22.51	37.07	18.34	418.6	556.3	544.3	638.5
6	Site	Tier 2	FTP-2 (Bags 1 & 2)	9/13/2013	19.51	1553.6	20.18	35.57	18.07	422.9	547.5	550.1	641.0
6	Site	Tier 2	FTP-2 (Bag3)	9/13/2013	25.74	1630.2	21.92	37.35	18.95	417.7	552.1	541.9	642.0
6	Site	Tier 2	FTP-1 (Bags 1 & 2)	3/6/2014	19.55	1579.8	19.57	34.41	18.45	411.4	534.5	529.9	617.9
6	Site	Tier 2	FTP-1 (Bag 3)	3/6/2014	25.63	1649.9	21.04	36.44	20.19	407.3	534.3	527.5	615.2
6	Site	Tier 2	FTP-2 (Bags 1 & 2)	3/8/2014	19.58	1562.5	20.37	37.39	17.44	---	---	---	---
6	Site	Tier 2	FTP-2 (Bag3)	3/8/2014	25.48	1627.3	22.21	38.23	18.16	---	---	---	---
7	Site	Tier 2	FTP-1 (Bags 1 & 2)	1/16/2014	19.36	994.2	16.28	22.42	25.07	423.8	544.2	563.3	661.4
7	Site	Tier 2	FTP-1 (Bag 3)	1/16/2014	25.26	1109.1	16.89	23.33	25.84	432.4	559.2	548.3	678.3
7	Site	Tier 2	LA92	1/16/2014	24.85	1125.2	17.20	24.08	25.01	494.0	632.5	639.0	766.5
7	Site	Tier 2	US06 (2nd)	1/16/2014	49.32	1717.1	20.85	32.33	27.85	611.5	740.6	718.2	834.7
7	Site	Tier 2	FTP-2 (Bags 1 & 2)	1/23/2014	19.39	998.1	16.37	22.76	25.33	423.7	546.1	575.0	680.6
7	Site	Tier 2	FTP-2 (Bag3)	1/23/2014	25.21	1109.2	16.91	23.11	25.83	429.6	556.9	549.2	679.8
7	Site	Tier 2	LA92	1/23/2014	24.95	1128.6	17.19	24.04	25.06	490.2	628.3	636.5	762.6
7	Site	Tier 2	US06 (2nd)	1/23/2014	48.90	1710.6	20.81	31.79	28.20	609.1	739.5	723.5	838.5
7	Site	Tier 2	FTP-1 (Bags 1 & 2)	3/5/2014	19.28	994.3	16.29	22.53	25.50	419.6	543.6	557.0	668.6
7	Site	Tier 2	FTP-2 (Bags 1 & 2)	3/5/2014	19.31	995.9	16.30	22.50	25.48	421.2	543.6	549.7	670.0
7	Site	Tier 2	FTP-1 (Bag 3)	3/5/2014	25.19	1103.5	16.89	23.06	26.22	426.4	558.3	540.4	671.9
7	Site	Tier 2	FTP-2 (Bag3)	3/5/2014	25.17	1105.6	16.88	23.22	26.00	425.7	555.1	540.3	670.6
7	Site	Tier 2	FTP-3 (Bags 1 & 2)	3/7/2014	19.31	996.5	16.31	22.68	25.60	420.7	544.5	553.8	663.2
8	Site	Tier 2	FTP-1 (Bags 1 & 2)	9/12/2013	19.68	1252.8	16.85	34.20	22.56	---	---	---	---
8	Site	Tier 2	FTP-1 (Bag 3)	9/12/2013	25.26	1302.7	17.37	34.53	22.39	---	---	---	---
8	Site	Tier 2	FTP-2 (Bags 1 & 2)	9/13/2013	19.71	1268.1	16.85	34.21	22.90	---	---	---	---
8	Site	Tier 2	FTP-2 (Bag3)	9/13/2013	25.32	1302.6	17.27	34.53	21.70	---	---	---	---
8	Site	Tier 2	FTP-2 (Bags 1 & 2)	1/30/2014	19.56	1251.1	16.69	34.49	22.44	540.7	646.0	703.8	808.6
8	Site	Tier 2	FTP-2 (Bag3)	1/30/2014	25.34	1312.9	17.25	34.75	20.80	546.1	667.2	720.5	822.6
8	Site	Tier 2	FTP-2 (Bags 1 & 2)	1/31/2014	19.55	1249.4	16.66	33.95	22.61	---	---	---	---
8	Site	Tier 2	FTP-2 (Bag3)	1/31/2014	25.09	1297.5	17.15	34.20	21.44	542.2	659.9	707.4	659.9