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EFFECTS OF RVP ON EMISSIONS AT 20°F AMBIENT TEMPERATURE

by

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NOTICE

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This report, "Effect of RVP on Emissions at 20°F Ambient Temperature" is a data only report and therefore has not been peer reviewed. It is being provided for general information.

Concurrence

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INTRODUCTION

The Environmental Protection Agency is currently proposing rules that will establish cold carbon monoxide (CO) emission standards. The vehicle emission certification testing will be performed using the Federal Test Procedure (FTP) driving cycle at 20°F ambient temperature. Questions have arisen as to whether the Reid Vapor Pressure (RVP) of the fuel used for the FTP test will have an impact on cold temperature CO emissions.

PURPOSE

The purpose of this test program was to determine whether the RVP of fuel could affect the CO exhaust emissions of recent technology vehicles FTP tested at 20°F ambient temperature. Since EPA had procured a number of recent technology light-duty trucks (LDT's) for a different test program, these LDT's were also used in the test program described in this report.

SUMMARY

In most cases, an increase in RVP of the test fuel did not significantly influence the weighted FTP emission values at 20°F ambient temperature of 15 recent technology LDT's from the four engine families tested.

In the LDT engine families tested, increasing fuel RVP from 9.1 psi to 15 psi appeared to affect some of the individual bag emissions of carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NOx). We observed that the decrease in average bag 1 CO emissions was significant, but was offset by increases in average CO emissions in bags 2 and 3, effectively offsetting the bag 1 influence on the weighted CO emission value. In the same families, we observed a consistent decrease in average bag 1 HC emissions but this was not sufficient to influence the weighted HC emission value. The higher RVP fuel appeared to increase NOx emissions.

BACKGROUND

Motor vehicle emissions have been demonstrated to be dependent on ambient temperature. As temperature decreases, carbon monoxide emissions increase[1,2]. The current regulations for certification of motor vehicles state that the ambient temperature levels encountered by the test vehicle while testing shall not be less than 68°F nor more than 86°F[3].

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1 F. Strump, S. Tejada, W. Ray, D. Dropkin, F. Black, W. Crews, R. Snow, P. Siudak, C.O. Davis, L. Baker, and N. Perry (1989) The Influence of Ambient Temperature on Tailpipe Emissions from 1984-1987 Model Year Light Duty Gasoline Motor Vehicles. Atmospheric Environment Vol. 23, No. 2 pp. 307-320

2 Regulatory Support Document: Interm regulations for Cold Carbon Monoxide Emission from Light Duty Vehicles & Light Duty Trucks.

3 40 CFR 86.130-78

The Environmental Protection Agency (EPA) is currently promulgating rules that will require exhaust emission testing of vehicles at reduced ambient temperatures.

The EPA has currently proposed 20°F as the temperature at which the testing would be conducted. Lower ambient testing temperature is reflective of conditions that a vehicle actually encounters in-use in most areas of this country for at least a portion of the year.

The EPA was concerned that motor vehicle emissions may also be dependent on certain fuel properties. For current certification FTP emission testing, a fuel with a specified RVP and composition is used. This test fuel is commonly called Indolene. The RVP of Indolene is approximately 9 psi and is similar to summer grade commercial fuel. During the winter months, petroleum companies add butane (a by-product of petroleum refining) which raises the RVP of gasoline to between 10 and 15 psi. These fuels are termed winter grade commercial fuel. The RVP of winter grade fuel is much higher than that of the Indolene fuel currently used for certification testing.

RVP is a standard measurement (ASTM 4953) of fuel vapor pressure that is reported for each batch of fuel produced. It is measured in pounds per square inch (psi). Fuel vapor pressure is directly proportional to ambient temperature. As temperature decreases the vapor pressure decreases. A fuel which has a high RVP has a higher vapor pressure at any particular ambient temperature than a fuel with a lower RVP.

Use of a different fuel in winter months produces a market for butane (isobutane and n-butane) and improves cold starting vehicle performance. However, as ambient temperature increases, the butane vaporizes within the fuel system. In non-positive pressure fuel supply systems this may cause "vapor lock" which results in hard starting and driveability problems with the probability of greater vapor escape into the atmosphere which increases evaporative emissions. For these reasons the higher RVP fuels are only sold during the winter months.

TEST PROCEDURE

The test sample used in this program consisted of fifteen 1986 model year LDT's representing four different engine families and three different manufacturers. While these test vehicles were originally procured for a test program with a different objective in mind, the engine families tested represented fuel and emission technologies that are expected to be used in light-duty vehicles and LDT's for the foreseeable future. These emission technologies included fuel injection (multipoint and throttle body), closed loop fuel control, and three-way or three-way plus oxidation catalyst systems. Table 1 identifies the engine families and respective emission systems included in the test program.

The vehicles tested had accumulated between 50,000 - 95,000 miles. They were initially screened for tampering and malmaintenance. The LDT's passing program screening criteria represented typical, reasonably maintained mid to high mileage LDT's.

Once the vehicle was accepted into the program, it received restorative maintenance. This maintenance included a major tune up and repair of failed emission control components. The oil, oil filter, spark plugs and wires, coolant, distributor cap and rotor were replaced as required. The adjustable engine parameters were readjusted to the manufacturer's original specifications. Any emission component repair necessary to make the test vehicle properly operable was also done during this maintenance.

After the restorative maintenance, the fuel tank was filled to 40% capacity with Indolene test fuel, prepped and soaked at 20°F. The standard FTP emission test was performed at 20°F. The only deviation from protocol was that the fuel was not drained and refilled after the prep and the heat build was eliminated.

For the high RVP fuel, the LDT was soaked for at least two hours at a maximum of 40°F to reduce fuel tank skin temperature. The Indolene fuel was drained and the tank was filled with 15 psi RVP fuel and operated on the road for at least ten minutes to purge the fuel system and to avoid cross contamination of fuels. The fuel was drained and filled to a 40% capacity with fresh 15 psi RVP fuel. The LDT was then prepped and soaked at 20°F. The standard FTP emission test was performed on the LDT at 20°F. Again, the fuel was not drained and refilled and the heat build was eliminated.

During the course of testing, high RVP fuel samples were periodically drawn and tested before the 20°F prep. This was done to insure the RVP remained relatively constant throughout the test program. The Indolene and high RVP test fuel were tested to determine their fractional composition. These results are shown in Appendix A.

The RVP of Indolene and the commercial grade high RVP fuel were found to be 9.1 psi and 15.0 psi respectively. The RVP of the commercial fuel used in this test program represents the high end of commercially available winter grade fuels.

ANALYSIS OF SAMPLE REPRESENTIVITY

The emissions of the LDT's were recorded (See Appendix B) and compared according to two factors: engine family and fuel type. Because both fuels were used in the same sequence in each test vehicle, the vehicles form natural design blocks and the difference between Indolene and high RVP emissions for a given vehicle becomes the measurement of interest. Thus, for each emission category there were fifteen data points for each test bag as well as for the weighted average.

Because each of the four engine families tested represents a distinct technology, preliminary statistical tests were performed to determine if emissions differ among families. Using paired differences described above, one-way analysis of variance showed virtually no significant overall difference, at the 0.05 level of significance, among the families for any of the emissions in any of the test stages or in the weighted averages. These results can be found in Table 2.

Only one engine family in this test sample employed secondary air injection. Among the families tested, this engine familiy was the most unique. To isolate the air injection feature to determine whether the emissions from systems designed with secondary air injection would be significantly different from the emission from the other test families, the three engine families with no secondary air injection were grouped for comparison with family A614 which includes the air injection feature. This is shown in Table 3. The results of these tests also showed no significant overall difference in emissions between the family groupings, except in the case of the Bag 3 and weighted average hydrocarbon emissions.

Because there was little evidence of engine family differences, the fifteen vehicles were combined as a single sample for the purpose of comparing emissions within each emission type and FTP test stage. This produced a series of simple t-tests in which the mean paired difference of Indolene versus high RVP emissions is compared to zero (no difference). The results of these tests appear in Table 4.

<u>RESULTS</u>

The CO emission decrease in bag 1 when using high-RVP fuel was small but statistically significant. The decrease was probably caused by more complete fuel combustion (of the high RVP fuel over Indolene fuel) at reduced ambient temperatures due to the increased volatility of a fuel charge that has vaporized more effectively. More complete combustion would cause a lower concentration of CO. Once the vehicle reaches operating temperature the CO emissions difference is smaller between fuels, and on average, bag 2 and 3 CO emissions are significantly higher for high-RVP fuel. The individual bag differences offset each other, producing an overall weighted result that is not significant (see Figure 1).

HC emissions were significantly lower during bag 1 when commercial high RVP fuel was used in our test sample. At warmed up engine operating temperature (i.e., bags 2 and 3), HC emissions were higher using high RVP fuel, but not significantly (see Figure 2).

One possible reason for this observation is that the high RVP fuel vaporizes faster than Indolene at any one temperature. At a lower ambient temperature the rate at which the Indolene fuel vaporizes is less than that of the high RVP fuel. The liquid fuel would cause "flame quenching", resulting in unburned fuel being exhausted. This results in higher HC emissions when Indolene fuel is used during low ambient temperatures conditions. Once the vehicle reaches its stabilized operating temperature (i.e., after engine warm-up) the fuel vaporizes at a higher rate. This could explain the higher Indolene HC emissions observed in bag 1. The non-significant HC weighted emission value reflects the canceling of the individual bags.

Unlike the others, Nox emissions were significantly higher using high-RVP fuel in all bags and overall. This supports the assumption that a higher degree of combustion, and higher peak temperatures are occurring when the high-RVP fuel is used. (See Figure 3).

CONCLUSION

These results demonstrate that RVP may have a significant affect on individual bag data in at least some newer technology vehicles. This test program is not adequate to predict that the composite emissions from other current or future technology vehicles (not represented in this program) will not be significantly affected by the RVP of the test fuel. This conclusion is based on the significant effect RVP had on individual bag data. EPA can not conclude that the emission influence of RVP on bag 1 will always be compensated with a relatively equal and opposite emission influence in bags 2 and 3, as occurred in our limited vehicle sample.

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TABLE 1
LDT Fleet

Class	class#	Engine Family	Emission System Description	# veh. Tested
Ford 5.0L	A614	GFM5.0T5HAG9	Multipoint FI, 3-way plus oxidation catalyst, pump secondary air injection	5
Ford 2.9L	A611	GFM2.9T5FMF5	Multipoint FI, 3-way catalyst, no secondary air injection	4
GM 2.5L	A603	G2G2.5T5TPGX	Throttle body FI, 3-way catalyst, no secondary air injection	3
Toyota 2.4L	A610	GTY2.4T5FBB6	Multipoint FI, 3-way catalyst, no secondary air injection	3

TABLE 2

Analysis of Variance
Overall Comparison of Engine Families
F-value
(Significance)

Bag	HC	NOx	CO
1	2.042 (0.166)	2.350 (0.128)	0.464 (0.713)
2	0.655 (0.596)	0.462 (0.714)	0.354 (0.788)
3	3.097 (0.071)	0.274 (0.843)	0.601 (0.628)
Weighted	2.620 (0.103)	0.001 (1.000)	0.001 (1.000)

TABLE 3

Analysis of Variance
Engine Families A603, A610 and A611 vs. A614
F-value
(Significance)

Bag	HC	NOx	CO
1	0.015 (0.905)	4.069 (0.065)	0.383 (0.547)
2	0.982 (0.340)	0.300 (0.593)	0.000 (0.991)
3	10.965 (0.006)	0.516 (0.485)	0.906 (0.359)
Weighted	4.870 (0.046)	0.512 (0.487)	0.000 (0.983)

Table 4

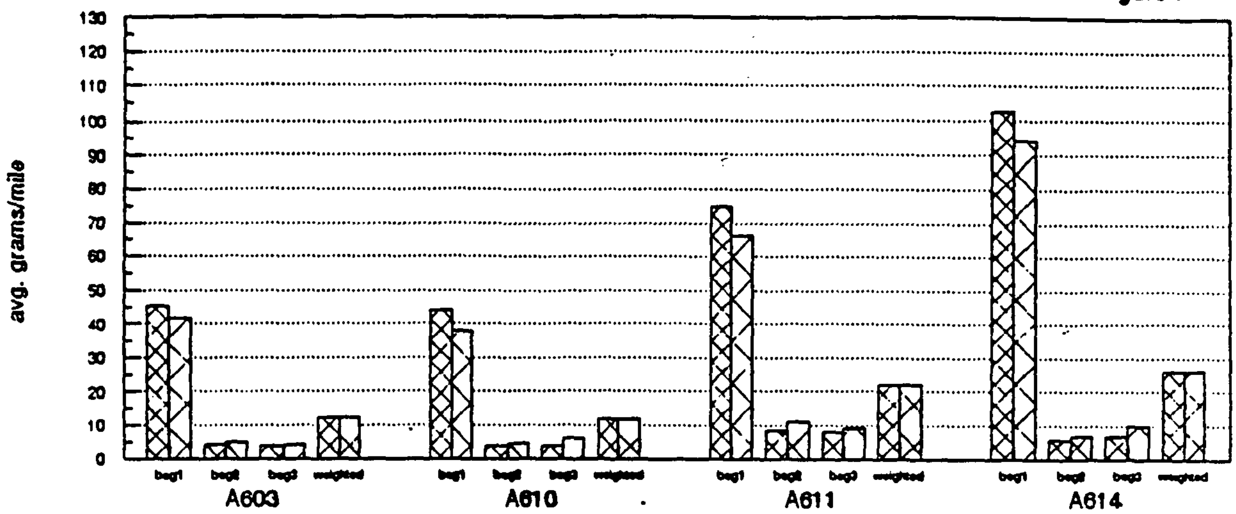
t-Tests on Difference: Indoline-High RVP
All Vehicles (n = 15)
(Negative t implies higher mean for High RVP than for Indoline)

Bag	HC	NOx	CO
1	6.28**	-6.65**	4.53**
2	-0.76	-2.93*	-2.16*
3	-2.13	-3.56**	-3.13**
Weighted	1.75	-5.15**	0.200

* Significant at 0.05 level
** Significant at 0.01 level

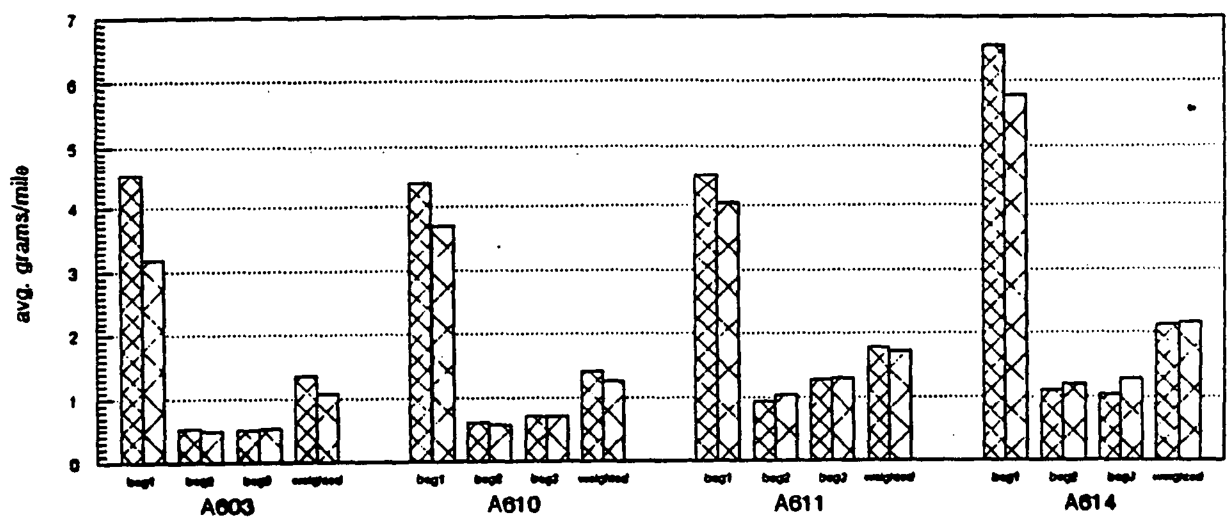
CO emissions

Figure 1



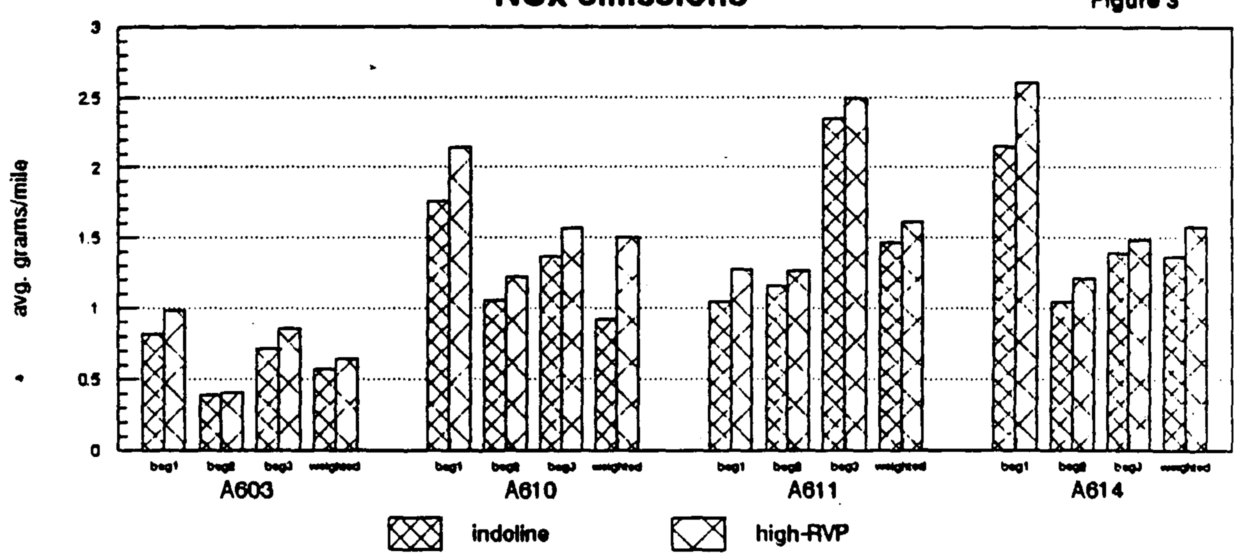
HC emissions

Figure 2



NOx emissions

Figure 3



APPENDIX A

FUEL COMPOSITION

Item	Method	EOD VALUES High RVP	Indoline
RVP	ASTM D 4953	15	9.1
Distillation	ASTM D 86		
Initial Boiling Point (°F)		83	84
10% Evap. Point (°F)		105	124
50% Evap. Point (°F)		182	219
90% Evap. Point (°F)		312	302
End Evap. Point (°F)		418	408
% Evaporated at 160°F		40.0	22.5
Sulfur	ASTM D 1266	0.0002	0.0045
Lead (g/gal)	ASTM D 3237	0.010	<0.003
Phosphorus (g/gal)	ASTM D 3231	0.0004	0.004
HC Composition	ASTM D 1319		
Olefins (vol%)		16.6	5.5
Aromatics (vol%)		26.6	28.5
Saturates (vol%)		56.8	66.0
Oxygenates (vol%)		<0.1	NA
Research octane number	ASTM D 2699	92.0	96.6
Motor octane number	ASTM D 2700	82.0	87.4
Antiknock Index	ASTM D 439	87.0	92.0
Sensitivity	RON-MON	10.0	9.2
Weight Fraction Carbon	ASTM D 3343	0.8631124	0.8653
Net Heat of Combustion (BTU/lb)	ASTM D 3338	18515.213	18470
Specific Gravity (60°F/60°F)	ASTM D 1298	0.7290057	0.7412258
Fuel Economy Numerator (grams carbon/gallon)		2377	2423
Fuel Economy Numerator with R Factor		2399.148	2425

APPENDIX B

Vehicle Specific Comparison

Emission Data Listing (grams/mile)

Vehicle ID	Bag1				Bag2				Bag3				Weighted Values			
TEST Fuel	HC	NOx	CO2	CO	HC	NOx	CO2	CO	HC	NOx	CO2	CO	HC	CO	CO2	NOx
A603/0024																
Indoline	4.631	1.063	392.7	50.16	0.346	0.428	420.4	3.492	0.427	1.026	359.9	3.854	1.251	13.2	398	0.72
High-RVP	3.779	1.455	387.8	46.89	0.367	0.535	414.2	5.036	0.438	1.259	361.0	5.202	1.096	13.8	394	0.92
A603/0052																
Indoline	4.989	0.551	366.3	49.37	0.445	0.245	386.3	4.307	0.452	0.432	328.1	3.14	1.389	13.3	366	0.36
High-RVP	3.269	0.754	362.7	45.99	0.505	0.306	382.1	5.58	0.553	0.649	332.4	4.346	1.092	13.6	365	0.49
A603/0084																
Indoline	3.952	0.849	373.8	36.03	0.828	0.488	382.2	4.894	0.643	0.696	324.1	4.469	1.429	11.3	364	0.62
High-RVP	2.516	0.749	351.5	32.53	0.632	0.393	362.8	4.149	0.591	0.664	309.7	3.461	1.014	9.9	346	0.54
A610/0024																
Indoline	4.601	1.656	443.2	49.51	0.15	0.659	430.6	1.782	0.429	0.713	368.9	2.769	1.151	12	416	0.88
High-RVP	3.787	2.314	450.4	37.56	0.226	0.732	425.6	2.876	0.356	0.875	371.8	2.861	1.003	10.1	416	1.1
A610/0036																
Indoline	4.143	1.103	449.2	39.19	0.808	0.5	409.3	4.404	0.82	0.647	383.3	3.818	1.508	11.5	410	0.67
High-RVP	3.7	1.295	442.5	36.23	0.632	0.574	398.7	5.556	0.747	0.744	370.1	5.375	1.298	11.9	400	0.77
A610/0175																
Indoline	4.768	3.295	427.5	43.12	1.418	2.441	424.3	7.333	1.415	3.383	370.5	6.942	2.113	14.7	410	2.88
High-RVP	4.146	3.709	435.3	36.49	1.341	2.729	423.9	8.431	1.465	3.78	377.3	7.632	1.959	14	413	3.22
A610/0102																
Indoline	3.968	1.001	473.4	44.33	0.102	0.637	428.4	1.517	0.16	0.718	392.3	1.979	0.923	10.6	428	0.73
High-RVP	3.211	1.232	468.9	41.75	0.116	0.836	430.0	1.839	0.3	0.885	386.7	9.465	0.81	12.2	426	0.93
A611/0027																
Indoline	3.847	0.867	441.4	62.58	1.251	1.036	475.9	9.085	1.23	1.854	390.9	7.922	1.788	19.9	445	1.23
High-RVP	3.733	1.08	432.5	59.87	1.446	1.317	460.2	13.86	1.45	2.137	380.3	12.62	1.919	23	433	1.49
A611/0032																
Indoline	4.039	1.155	481.1	71.24	0.795	1.191	506.2	8.246	1.086	2.385	431.4	6.83	1.55	21	480	1.51
High-RVP	3.264	1.369	472.2	53.84	0.631	1.113	482.7	7.05	0.997	2.382	413.8	4.781	1.278	16.1	462	1.52
A611/0067																
Indoline	5.742	1.13	452.4	91.02	0.749	1.256	510.8	8.128	1.535	2.822	411.7	9.169	2.011	25.8	471	1.66
High-RVP	5.147	1.4	448.0	86.03	1.026	1.372	492.0	12.70	1.445	2.956	409.5	10.88	1.993	27.4	460	1.81

APPENDIX B

Vehicle Specific Comparison
Emission Data Listing (grams/mile)

Vehicle ID	Bag1				Bag2				Bag3				Weighted Values			
TEST Fuel	HC	NOx	CO2	CO	HC	NOx	CO2	CO	HC	NOx	CO2	CO	HC	CO	CO2	NOx
A614/0163																
Indoline	5.209	1.855	558.7	92.99	0.8	1.256	573.0	3.852	0.85	1.406	495.7	6.169	1.723	22.9	549	1.42
High-RVP	4.892	2.435	559.4	87.91	0.857	1.328	579.0	4.051	1.1	1.462	493.9	10.09	1.771	23.3	551	1.6
A614/0046																
Indoline	5.171	2.08	533.7	108.9	0.85	0.941	573.9	6.243	0.831	1.287	503.6	6.386	1.741	27.6	546	1.27
High-RVP	4.398	2.592	536.9	88.67	0.851	1.454	576.4	3.763	1.088	1.516	491.0	10.58	1.655	23.3	545	1.71
A614/0004																
Indoline	7.136	1.659	530.1	137.4	1.294	1.251	629.4	13.37	0.718	1.445	530.7	4.188	2.358	36.8	581	1.39
High-RVP	6.056	2.057	511.8	136.2	1.539	1.185	582.1	20.73	0.709	1.503	510.0	5.755	2.249	40.6	548	1.45
A614/0131																
Indoline	11.40	1.554	546.6	119.5	1.489	0.974	615.0	1.087	1.743	1.31	552.3	11.05	3.168	28.4	584	1.19
High-RVP	9.774	1.834	542.9	112.1	1.944	1.111	605.7	2.646	2.168	1.681	548.1	11.42	3.625	27.6	577	1.42
A614/0127																
Indoline	3.889	3.597	615.2	55.90	1.004	0.849	607.3	3.508	1.039	1.478	548.4	7.828	1.607	15.5	593	1.59
High-RVP	3.793	4.142	618.7	50.43	0.786	0.948	612.3	3.911	1.335	1.277	545.6	12.12	1.563	15.9	595	1.7

APPENDIX C

Engine Family Specific Comparison
Statistical Analysis

Vehicle ID	Bag1				Bag2				Bag 3				Weighted Values			
TEST Fuel	HC	NOx	CO2	CO	HC	NOx	CO2	CO	HC	NOx	CO2	CO	HC	CO	CO2	NOx
A603/0024																
Indoline	4.631	1.063	392.7	50.16	0.346	0.428	420.4	3.492	0.427	1.026	359.9	3.854	1.251	13.2	398	0.72
A603/0052																
Indoline	4.989	0.551	366.3	49.37	0.445	0.245	386.3	4.307	0.452	0.432	328.1	3.14	1.389	13.3	366	0.36
A603/0084																
Indoline	3.952	0.849	373.8	36.03	0.828	0.488	382.2	4.894	0.643	0.696	324.1	4.469	1.429	11.3	364	0.62
avg. g/m	4.524	0.821	377.6	45.19	0.539	0.387	396.3	4.231	0.507	0.718	337.4	3.821	1.356	12.6	376	0.566
sd +-	0.430	0.209	11.09	6.483	0.207	0.103	17.10	0.574	0.096	0.242	16.00	0.543	0.076	0.920	15.57	0.151
A603/0024																
High-RVP	3.779	1.455	387.8	46.89	0.367	0.535	414.2	5.036	0.438	1.259	361.0	5.202	1.096	13.8	394	0.92
A603/0052																
High-RVP	3.269	0.754	362.7	45.99	0.505	0.306	382.1	5.58	0.553	0.649	332.4	4.346	1.092	13.6	365	0.49
A603/0084																
High-RVP	2.516	0.749	351.5	32.53	0.632	0.393	362.8	4.149	0.591	0.664	309.7	3.461	1.014	9.9	346	0.54
avg. g/m	3.188	0.986	367.3	41.80	0.501	0.411	386.4	4.921	0.527	0.857	334.4	4.336	1.067	12.43	368.3	0.65
sd +-	0.518	0.331	15.19	6.564	0.108	0.094	21.18	0.589	0.065	0.284	20.98	0.710	0.037	1.793	19.73	0.192
A610/0024																
Indoline	4.601	1.656	443.2	49.51	0.15	0.659	430.6	1.782	0.429	0.713	368.9	2.769	1.151	12	416	0.88
A610/0036																
Indoline	4.143	1.103	449.2	39.19	0.808	0.5	409.3	4.404	0.82	0.647	383.3	3.818	1.508	11.5	410	0.67
A610/0102																
Indoline	3.968	1.001	473.4	44.33	0.102	0.637	428.4	1.517	0.16	0.718	392.3	1.979	0.923	10.6	428	0.73
A610/0175																
Indoline	4.768	3.295	427.5	43.12	1.418	2.441	424.3	7.333	1.415	3.383	370.5	6.942	2.113	14.7	410	2.88
avg. g/m	4.37	1.763	448.3	44.04	0.619	1.059	423.1	3.759	0.706	1.365	378.8	3.877	1.423	12.2	416	1.29
sd +-	0.325	0.918	16.50	3.687	0.538	0.800	8.335	2.351	0.471	1.165	9.616	1.885	0.449	1.528	7.348	0.921

APPENDIX C

Engine Family Specific Comparison
Statistical Analysis (cont.)

A610/0024																
High-RVP	3.787	2.314	450.4	37.56	0.226	0.732	425.6	2.876	0.356	0.875	371.8	2.861	1.003	10.1	416	1.1
A610/0036																
High-RVP	3.7	1.295	442.5	36.23	0.632	0.574	398.7	5.556	0.747	0.744	370.1	5.375	1.298	11.9	400	0.77
A610/0102																
High-RVP	3.211	1.232	468.9	41.75	0.116	0.836	430.0	1.839	0.3	0.885	386.7	9.465	0.81	12.2	426	0.93
A610/0175																
High-RVP	4.146	3.709	435.3	36.49	1.341	2.729	423.9	8.431	1.465	3.78	377.3	7.632	1.959	14	413	3.22
avg. g/m	3.711	2.137	449.3	38.01	0.578	1.217	419.6	4.675	0.717	1.571	376.5	6.333	1.267	12.05	413.7	1.505
sd +-	0.333	1.003	12.55	2.217	0.480	0.877	12.26	2.557	0.464	1.276	6.482	2.473	0.435	1.382	9.283	0.997
A611/0027																
Indoline	3.847	0.867	441.4	62.58	1.251	1.036	475.9	9.085	1.23	1.854	390.9	7.922	1.788	19.9	445	1.23
A611/0032																
Indoline	4.039	1.155	481.1	71.24	0.795	1.191	506.2	8.246	1.086	2.385	431.4	6.83	1.55	21	480	1.51
A611/0067																
Indoline	5.742	1.13	452.4	91.02	0.749	1.256	510.8	8.128	1.535	2.822	411.7	9.169	2.011	25.8	471	1.66
avg. g/m	4.542	1.050	458.3	74.95	0.931	1.161	497.6	8.486	1.283	2.353	411.3	7.973	1.783	22.23	465.3	1.466
sd +-	0.851	0.130	16.73	11.90	0.226	0.092	15.47	0.426	0.187	0.395	16.52	0.955	0.188	2.561	14.83	0.178
A611/0027																
High-RVP	3.733	1.08	432.5	59.87	1.446	1.317	460.2	13.86	1.45	2.137	380.3	12.62	1.919	23	433	1.49
A611/0032																
High-RVP	3.264	1.369	472.2	53.84	0.631	1.113	482.7	7.05	0.997	2.382	413.8	4.781	1.278	16.1	462	1.52
A611/0067																
High-RVP	5.147	1.4	448.0	86.03	1.026	1.372	492.0	12.70	1.445	2.956	409.5	10.88	1.993	27.4	460	1.81
avg. g/m	4.048	1.283	450.9	66.58	1.034	1.267	478.3	11.20	1.297	2.491	401.2	9.430	1.73	22.16	451.6	1.606
sd +-	0.800	0.144	16.34	13.97	0.332	0.111	13.32	2.976	0.212	0.343	14.86	3.362	0.321	4.650	13.22	0.144

APPENDIX C

Engine Family Specific Comparison
Statistical Analysis (cont.)

A614/0163																
Indoline	5.209	1.855	558.7	92.99	0.8	1.256	573.0	3.852	0.85	1.406	495.7	6.169	1.723	22.9	549	1.42
A614/0046																
Indoline	5.171	2.08	533.7	108.9	0.85	0.941	573.9	6.243	0.831	1.287	503.6	6.386	1.741	27.6	546	1.27
A614/0004																
Indoline	7.136	1.659	530.1	137.4	1.294	1.251	629.4	13.37	0.718	1.445	530.7	4.188	2.358	36.8	581	1.39
A614/0127																
Indoline	3.889	3.597	615.2	55.90	1.004	0.849	607.3	3.508	1.039	1.478	548.4	7.828	1.607	15.5	593	1.59
A614/0131																
Indoline	11.40	1.554	546.6	119.5	1.489	0.974	615.0	1.087	1.743	1.31	552.3	11.05	3.168	28.4	584	1.19
avg. g/m	6.561	2.149	556.9	102.9	1.087	1.054	599.7	5.613	1.036	1.385	526.1	7.124	2.119	26.24	570.6	1.372
sd +-	2.632	0.745	30.89	27.62	0.264	0.167	22.58	4.212	0.368	0.074	22.96	2.280	0.586	6.993	19.29	0.136
A614/0163																
High-RVP	4.892	2.435	559.4	87.91	0.857	1.328	579.0	4.051	1.1	1.462	493.9	10.09	1.771	23.3	551	1.6
A614/0046																
High-RVP	4.398	2.592	536.9	88.67	0.851	1.454	576.4	3.763	1.088	1.516	491.0	10.58	1.655	23.3	545	1.71
A614/0004																
High-RVP	6.056	2.057	511.8	136.2	1.539	1.185	582.1	20.73	0.709	1.503	510.0	5.755	2.249	40.6	548	1.45
A614/0127																
High-RVP	3.793	4.142	618.7	50.43	0.786	0.948	612.3	3.911	1.335	1.277	545.6	12.12	1.563	15.9	595	1.7
A614/0131																
High-RVP	9.774	1.834	542.9	112.1	1.944	1.111	605.7	2.646	2.168	1.681	548.1	11.42	3.625	27.6	577	1.42
avg. g/m	5.782	2.612	554.0	95.09	1.195	1.205	591.1	7.020	1.280	1.487	517.7	9.996	2.172	26.14	563.2	1.576
sd +-	2.129	0.810	35.79	28.55	0.464	0.174	14.85	6.873	0.487	0.129	24.67	2.232	0.763	8.151	19.55	0.121