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Technical Report

Effects of Gasoline Volatility on the Hydrocarbon Exhaust Emissions From a 1984 Oldsmobile Cutlass

By

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Standards Development and Support Branch
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Office of Mobile Sources
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U. S. Environmental Protection Agency

I. Executive Summary

This report describes the results of a gasoline volatility/exhaust emission test program done under EPA contract by ATL Laboratories in Columbus, Ohio. The program was developed to help explain why HC exhaust emissions frequently increase when using fuels with high volatility. The testing involved a 1984 3.8L Olds Cutlass with multi-point fuel injection. Two different fuels (9.0 and 11.5 psi RVP) were used, along with three different conditions of the evaporative canister (no purge, "standard" canister loading, and a loading beyond breakthrough). In addition, tests were performed with both fuels with the catalytic converter removed and a standard canister loading to determine the effect of RVP on engine-out emissions.

For this vehicle, it appeared that the increase in HC exhaust emissions with increased fuel RVP is due to the increase in vapors generated in the fuel tank during vehicle operation. Canister weight (loading) did not affect exhaust emissions. Thus, this increase in fuel tank vapors may help explain the RVP differences seen in EPA's Emission Factor data base.[1] This means that the temperature of the fuel tank simulated during FTP testing may be more critical than previously believed.

This report is divided into four major sections: Background and Test Format; Test Results; Discussion of Results; and Conclusions. The fuel summary sheets are included in the Appendix.

II. Background and Test Format

As previously mentioned, the purpose of this study was to determine why HC exhaust emissions increase with increased fuel volatility. Related test programs indicate that unmetered fuel may be the cause, although direct fuel effects could not be confidently ruled out.[2,3,4] Most of this unmetered fuel was thought to have come from the canister purge, with the rest being generated in the fuel tank during vehicle operation. To better evaluate the RVP/exhaust emission interaction, a test program was developed calling for testing with 9.0 and 11.5 RVP fuel, each with no purge, standard canister loading, and a canister loading beyond breakthrough condition (hereafter referred to as saturated though this was not strictly the case). Under the no purge condition, unmetered fuel to the engine from the fuel tank was also interrupted.

In addition to the canister variations described above, a series of tests with the catalyst removed were performed using a standard canister loading for both fuels. These engine-out emission values would indicate whether the differences in HC exhaust emissions occurred in the engine or catalyst. Assuming increased purged hydrocarbons (HC) to be the major cause of increased HC tailpipe emissions, two mechanisms were considered possible. According to the first mechanism, the increase in HC emissions could be occurring mostly during combustion. The catalytic converter - being primarily a proportional reduction device - would then allow a proportional increase in tailpipe emissions. According to the second mechanism, formation of the excess hydrocarbons could be the same as with the smaller purged HC quantities, but a reduction in excess oxygen could be reducing catalyst efficiency, resulting in an increase in tailpipe emissions.

During combustion, the hydrogen atoms in the fuel are oxidized before the carbon atoms. Therefore, as the oxygen level starts to decrease, incomplete oxidation will occur first for the carbon atoms causing an increase in CO levels (with little or no increase in HC levels). Because of this greater sensitivity, CO emissions from all tests were also evaluated along with HC emissions.

Due to the large number of unknowns and the correspondingly high test costs for a comprehensive program, only one vehicle was tested at this stage of the evaluation. To further reduce costs, hot-start LA-4's were used rather than full FTPs. A revised version of this program using more vehicles was left as a future option, depending on these test results.

To select a vehicle for this test program, an analysis was made of the test results of 308 cars from EPA's Emission Factor (EF) data base to determine which, if not all, types of vehicles have an exhaust emission sensitivity to fuel RVP. The analysis of these vehicles showed that several groups of vehicles had a fairly high statistical sensitivity to fuel RVP (volatility). The most notable were 3.8 L GM vehicles with multi-point fuel injection (PFI). A car was then chosen from this group (a 1984 Oldsmobile Cutlass Cierra) for testing. Before starting the actual test program, back-to-back hot start LA-4's on both 11.5 and 9.0 RVP fuels were run at ATL to verify the vehicle's continued sensitivity.

Each test condition was to receive a single replicate run, except for the "baseline" (standard canister loading), which was to receive two replicates. The second and third baseline runs (for a given fuel) were made in between the no purge and saturated canister runs to confirm the vehicle's repeatability. The adaptive memory software in the vehicle's computer was a particular concern, since it could be causing the exhaust emissions of one test to be affected by the previous tests conditions.

To ensure consistent canister loadings, the canister was artificially loaded prior to each test. A baseline canister weight was obtained by purging the canister for one hour at one scfm, and then increasing the weight by 30/46 grams for a "standard" load (9.0/11.5 RVP, respectively), and 80 grams for the loading beyond breakthrough (both 9.0 and 11.5 RVP). The standard load represents the estimated uncontrolled emissions from one diurnal and one hot soak, plus an additional 10 grams to account for the estimated residual in a "typical" in-use canister.

In addition to measuring exhaust emissions and canister weights, fuel tank, engine block, and engine oil temperatures were also recorded, along with purge and manifold vacuum. All tests were performed with the same driver and on the same dynamometer.

The general testing sequence consisted of:

1. Drain vehicle fuel.
2. Weigh canister (record wet and dry bulb temps).
3. Purge canister for 1 hour at 1 scfm.
4. Weigh canister.
5. Install canister on portable fuel tank.
6. Load canister to desired weight by adding 75°F test fuel to the portable tank. This pushes fuel vapors out of the tank into the canister.
7. Weigh canister.
8. Fuel the vehicle to 40 percent of tank capacity using 75°F test fuel.
9. Vent tank line to air intake of car and plug purge line. (Canister is not installed on vehicle.) Push vehicle onto dyno. LA-4 prep to warm-up engine and catalyst.
10. 10-minute soak. During soak, install canister on vehicle, connect tank and purge lines.
11. Hot-start LA-4. Measure emissions, traces on temperatures and vacuums.
12. One hour soak in soak room. (Push vehicle there). Immediately after soak, remove canister and weigh.

III. Test Results

Summaries of hot-start LA-4 emissions, temperatures, and canister weights areas are shown in Tables 1, 2, and 3, respectively. The emission results for bags 1 and 2 of the LA-4 are shown in Table 4. The tests generally went as planned. Four additional tests were run, usually to further replicate questionable data. The retest for 9.0 RVP fuel with no catalyst was due to a malfunction in the temperature chart recorder. Since the "no purge" (NP) conditions did not involve the charcoal canister, the one-hour post-run soaks were not done.

Table 1

Emission Test Results (g/mi)
1984 Olds Cutlass Cierra (3.8L PFI)

Condition	Fuel RVP	Rep	HC	CO	NOx	CO2	MPG	Odom	Run Order	Test Date
				EPA EF TEST RESULTS						
FTP	11.5	1	.36	7.56	.76	449.8	19.15	23512	-	10/08/85
	9.0	1	.23	4.05	.64	461.4	18.94	23550	-	10/11/85
EPA Calc.Hot Start (Bag 2&3)	11.5	1	.16	5.26	.65	----	-----	23512	-	-----
	9.0	1	.10	2.25	.39	----	-----	23550	-	-----
				ATL TEST RESULTS*						
Qualification	11.5	1	.15	5.60	.65	433.9	20.01	38431	A	11/19/86
	9.0	1	.10	3.00	.55	442.5	19.82	38461	B	11/20/86
Standard Loading	11.5	1	.19	5.57	.70	442.1	19.64	38490	1	11/25/86
		2	.17	5.93	.71	441.6	19.64	38505	2	11/25/86
		3	.13	5.83	.71	451.2	19.24	38610	7	12/01/86
	9.0	1	.13	2.72	.62	429.8	20.41	38639	8	12/02/86
		2	.11	2.60	.54	407.9	21.51	38713	13	12/04/86
		3	.19	4.68	.61	449.6	19.38	38728	14**	12/04/86
Retest		2	.13	3.00	.54	443.2	19.78	38742	13r	12/05/86
		3	.13	3.90	.55	441.8	19.78	38757	14r	12/05/86
No Purge	11.5	1	.13	2.67	.68	456.1	19.25	38520	3	11/26/86
		2	.11	2.44	.67	454.9	19.32	38535	4	11/26/86
	9.0	1	.10	2.25	.64	451.8	19.46	38654	9	12/02/86
		2	.10	2.00	.63	451.7	19.48	38669	10	12/02/86
Saturated Loading	11.5	1	.13	4.10	.70	438.4	19.92	38580	5	12/01/86
		2	.16	5.51	.76	443.6	19.59	38595	6	12/01/86
	9.0	1	.11	2.58	.62	432.3	20.31	38683	11	12/03/86
		2	.13	3.67	.63	444.9	19.66	38698	12	12/03/86
Standard Loading	11.5	1	2.30	16.59	2.05	407.3	20.12	38831	17	12/09/86
No Catalyst		2	1.97	16.91	2.06	417.8	19.68	38846	18	12/09/86
Retest		1	1.86	16.60	2.09	405.6	20.27	38860	17r	12/10/86
	9.0	1	2.19	13.78	2.21	413.4	20.07	38772	15	12/08/86
Retest		1	2.16	13.58	2.10	412.4	20.13	38787	15r	12/08/86
		2	2.12	14.61	2.17	417.7	19.82	38802	16	12/08/86

* LA-4 (2 bag) tests.

** Test results excluded from statistical analysis.

Table 2

Temperature Data
1984 Olds Cutlass Cierra

TEMPERATURES (°F)

Condition	Fuel RVP	Rep	Fuel Tank Soldered T/C Test Start	Fuel Tank Soldered T/C Test End	Fuel Tank Magnetic T/C Test Start	Fuel Tank Magnetic T/C Test End	Engine Block Test Start	Engine Block Test End	Oil Test Start	Oil Test End	Run Order	Test Date
Qualification	11.5	1	87	97	87	95	196	185	199	243	A	11/19/86
	9.0	1	89	98	88	97	192	183	197	242	B	11/20/86
Standard Loading	11.5	1	88	97	87	96	187	181	192	242	1	11/25/86
		2	91	100	91	98	189	182	200	242	2	11/25/86
		3	88	98	88	96	197	186	197	242	7	12/01/86
	9.0	1	90	100	89	99	192	187	198	243	8	12/02/86
		2	86	98	86	97	189	183	193	242	13	12/04/86
		3	90	102	90	101	194	189	198	243	14	12/04/86
Retest	9.0	2	86	98	85	97	191	184	194	241	13r	12/05/86
		3	90	100	90	99	194	179	201	244	14r	12/05/86
No Purge	11.5	1	88	98	87	97	196	180	195	242	3	11/26/86
		2	91	100	90	99	195	182	204	243	4	11/26/86
	9.0	1	92	103	91	102	193	185	200	243	9	12/02/86
		2	97	107	96	105	197	184	205	244	10	12/02/86
Saturated Loading	11.5	1	85	95	84	93	191	186	193	242	5	12/01/86
		2	89	99	89	98	195	185	199	243	6	12/01/86
	9.0	1	86	98	86	97	190	183	194	242	11	12/03/86
		2	90	100	90	99	193	183	202	242	12	12/03/86
Standard Loading No Catalyst	11.5	1	88	97	88	96	195	185	200	242	17	12/09/86
		2	90	98	89	97	193	181	202	242	18	12/09/86
Retest		1	88	98	88	97	192	183	194	242	17r	12/10/86
	9.0	1	–	–	–	–	–	–	–	–	15	12/08/86
Retest		1	88	96	87	95	191	181	201	242	15r	12/08/86
		2	91	99	90	98	193	180	199	243	16	12/08/86

Table 3

Canister Weights*
1984 Olds Cutlass Cierra

ondition	Fuel RVP	Rep	Fully Purged Weight**	Wet Bulb (°F)	Dry Bulb (°F)	Begin Test Seq.	Wet Bulb (°F)	Dry Bulb (°F)	End Test Seq.	Wet Bulb (°F)	Dry Bulb (°F)	Weight Change	Run Order
ualification	11.5	1	791.24	61	76	802.13	62	76	816.86	61	77	+14.73	A
	9.0	1	799.39	61	72	802.83	62	72	801.07	59	68	- 1.76	B
andard Loading	11.5	1	788.14	61	71	834.78	62	77	845.70	63	74	+10.92	1
		2	788.14	60	71	834.84	63	74	851.79	63	74	+16.95	2
		3	799.03	58	73	844.64	58	71	851.72	59	70	+ 7.08	7
	9.0	1	793.35	57	72	823.08	59	73	818.14	61	72	- 4.94	8
		2	788.55	59	72	819.49	58	71	815.17	58	72	- 4.32	13
		3	788.55	59	72	817.89	58	72	819.64	58	71	+ 1.75	14
Retest		2	788.55	59	72	819.39	59	69	823.17	57	69	+ 3.78	13r
		3	788.55	59	72	819.76	56	70	819.47	56	69	- .29	14r
Purge	11.5	1	---	---	---	---	---	---	---	---	---	---	3
		2	---	---	---	---	---	---	---	---	---	---	4
	9.0	1	---	---	---	---	---	---	---	---	---	---	9
		2	---	---	---	---	---	---	---	---	---	---	10
ndard Loading	11.5	1	793.15	63	72	864.44	56	72	867.03	58	70	+ 2.59	5
		2	793.15	63	72	864.67	59	70	870.06	59	71	+ 5.39	6
	9.0	1	789.54	58	71	850.88	57	70	838.11	57	70	-12.77	11
		2	789.54	57	70	850.54	56	71	839.28	59	71	-11.26	12
andard Loading Catalyst	11.5	1	798.42	65	75	844.90	65	75	851.11	66	76	+ 6.21	17
		2	798.40	65	75	844.51	64	74	854.48	65	75	+ 9.97	18
Retest		1	798.42	65	75	844.34	61	71	857.31	56	68	+12.97	17r
	9.0	1	791.68	57	71	821.98	58	70	815.09	56	69	- 6.89	15
Retest		1	791.88	57	70	821.75	57	70	815.67	59	70	- 6.08	15r
		2	791.68	59	70	822.00	58	70	825.21	57	69	+ 3.21	16

* All weights are in grams.
** The canister was fully purged at the beginning of each day, except for days with retests.

Table 4

Emission Results by LA-4 Bag (g/mi)
1984 Olds Cutlass Cierra

Condition	Fuel RVP	Rep	Bag 1 HC	Bag 1 CO	Bag 2 HC	Bag 2 CO	Run Order	Test Date
Qualification	11.5	1	.095	2.74	.058	2.86	A	11/19/86
	9.0	1	.074	1.46	.026	1.54	B	11/20/86
Standard Loading	11.5	1	.121	2.32	.067	3.25	1	11/25/86
		2	.106	2.44	.064	3.50	2	11/25/86
		3	.108	2.94	.052	2.89	7	12/01/86
	9.0	1	.111	1.42	.018	1.30	8	12/02/86
		2	.083	1.33	.024	1.27	13	12/04/86
		3	.134	2.59	.053	2.09	14	12/04/86
Retest		2	.105	1.61	.029	1.40	13r	12/05/86
		3	.109	2.37	.022	1.53	14r	12/05/86
No Purge	11.5	1	.117	2.05	.017	.62	3	11/26/86
		2	.093	1.90	.015	.54	4	11/26/86
	9.0	1	.097	1.82	.005	.[illegible]2	9	12/02/86
		2	.095	1.64	.006	.36	10	12/02/86
Saturated Loading	11.5	1	.081	1.61	.047	2.49	5	12/01/86
		2	.108	2.68	.053	2.83	6	12/01/86
	9.0	1	.077	1.19	.028	1.39	11	12/03/86
		2	.102	2.04	.029	1.62	12	12/03/86
Standard Loading	11.5	1	.956	7.27	1.34	9.32	17	12/09/86
No Catalyst		2	.829	7.30	1.05	9.18	18	12/09/86
Retest		1	.808	7.43	1.14	9.61	17r	12/10/86
	9.0	1	.978	5.76	1.22	8.02	15	12/08/86
Retest		1	.945	5.67	1.22	7.90	15r	12/08/86
		2	.902	6.50	1.22	8.11	16	12/08/86

Scatter plots of the HC and CO emissions for the tests run with the catalytic converter on the vehicle are shown in Figures 1 and 2, respectively. In both figures, the value for run 14 - standard loading, 9.0 RVP fuel - is uncharacteristically high compared to the other indolene (9.0 RVP) values. Using the 9 actual test values for indolene (5 with std. loading, 2 with sat. loading, 2 with no purge), the mean HC value is 0.125 g/mi with a standard deviation of 0.027. Since the 0.187 HC value for run 14 was greater than two standard deviations above the mean (.179 g/mi), run 14 was excluded from the statistical analysis. Figures 3 through 6 are scatter plots of the HC and CO emissions from each bag of the LA-4.

Although run 14 was statistically excluded from this analysis, an investigation was made of the possible reasons for the higher emissions. No correlation was found with canister weights. However, run 14 had the highest ending fuel tank temperature (except for the no purge tests which did not include a 1-hour soak between runs), which may have caused the unusually high emission results. (The effect of fuel tank temperature on the emission results will be fully discussed later). It is plausible that some change in test cell air flow occurred for this test, possibly a slightly misplaced fan - the engine block temperatures are also high, which could alter the test conditions. Based on the consistency, trends, and values of the other results, a change in vehicle (fuel tank) cooling is the most likely identifiable cause of the unusually high emissions.

IV. Discussion of Results

The scatter plots shown in Figures 1 through 6 provide a good visual indication of how the various conditions relate to each other. The exhaust emissions were further analyzed using a series of one-way analyses of variance (ANOVAs) with a 10 percent significance level, which compared the variances between cases to those within cases. However, these statistics must be considered carefully due to the small amount of data. Also, ANOVAs assume normal distributions, which cannot be confirmed with only single replicates at each condition.

A summary of the F-ratios from the one-way ANOVAs are shown in Tables 5 and 6 for HC and CO emissions, respectively. Analyses were made of the LA-4 composite emissions, Bag 1 emissions, and Bag 2 emissions. Figures 1 through 6 will be used simultaneously with Tables 5 and 6 in the following discussion.

As shown in Figures 1 and 2, the HC and CO emissions are generally larger with 11.5 RVP fuel than with 9.0 RVP fuel. Comparisons can also be made for the three canister conditions

FIGURE 1

LA-4 HC Tailpipe Emissions

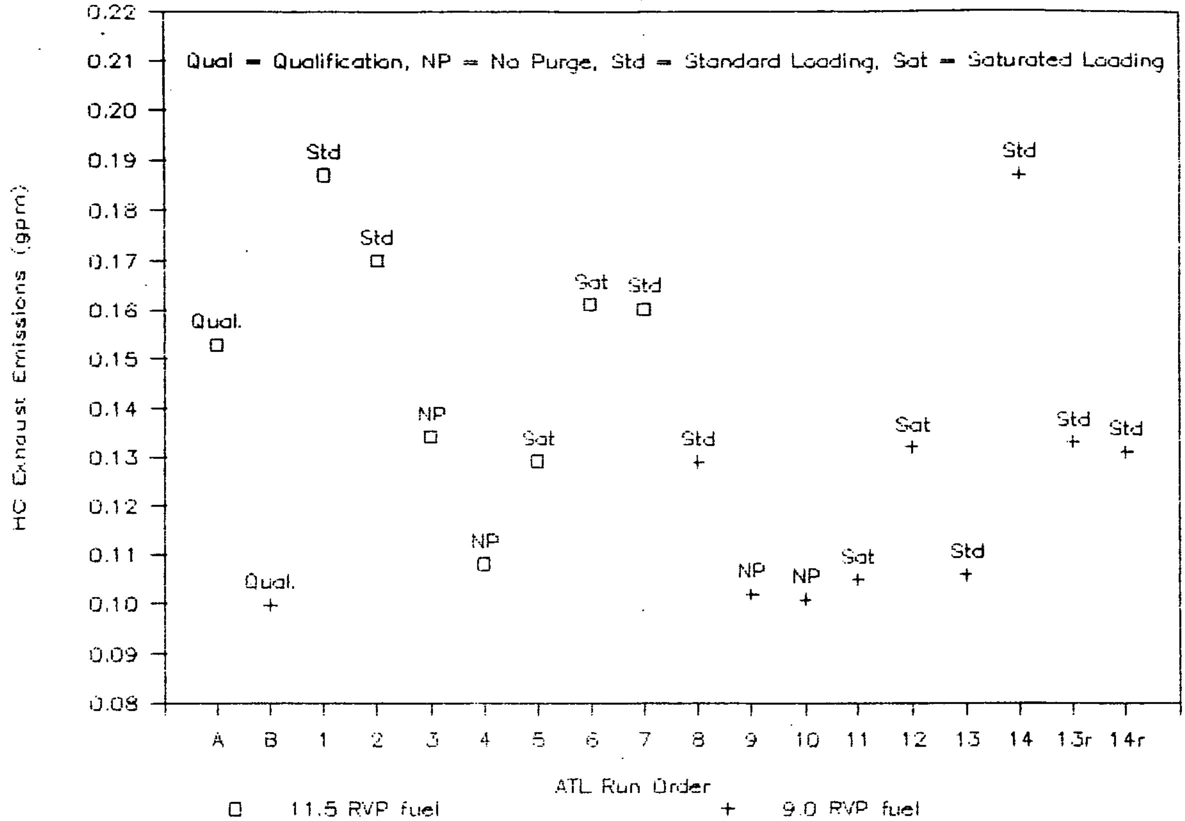


FIGURE 2

LA-4 CO Tailpipe Emissions

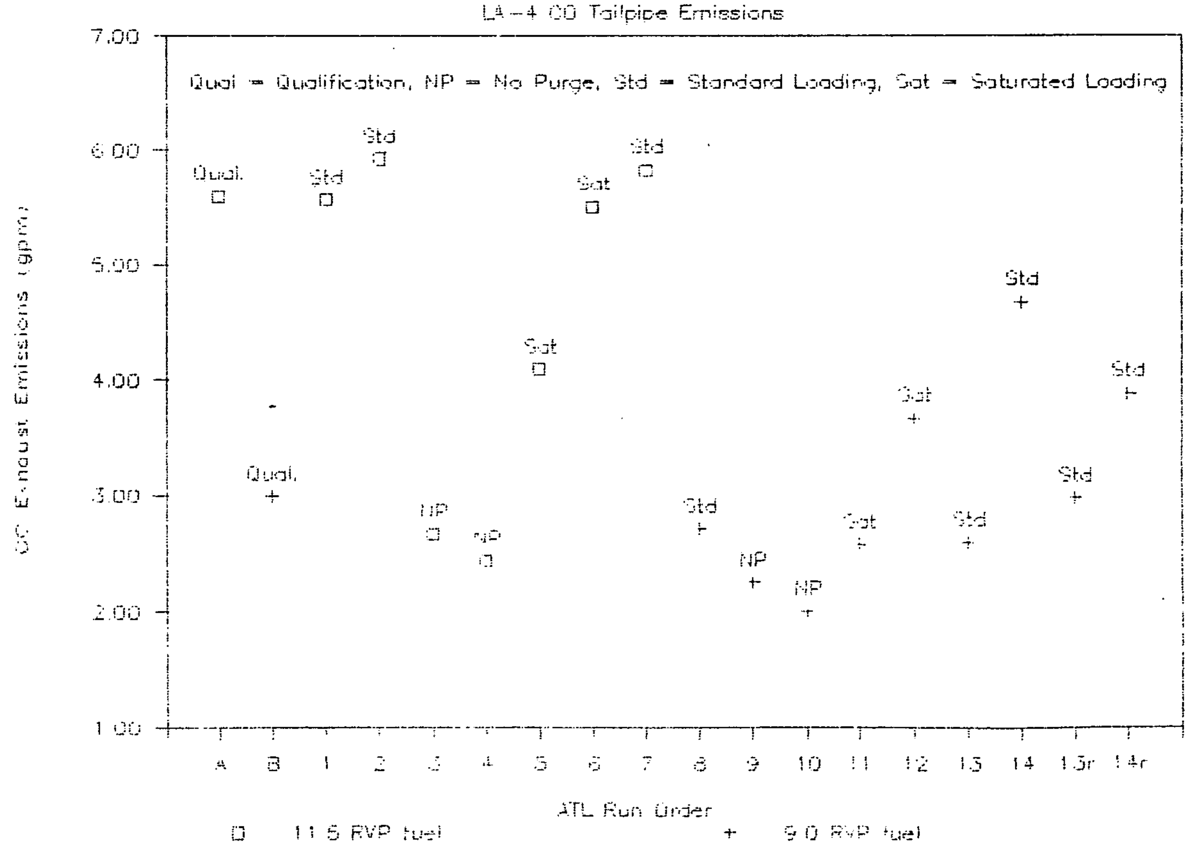


FIGURE 3

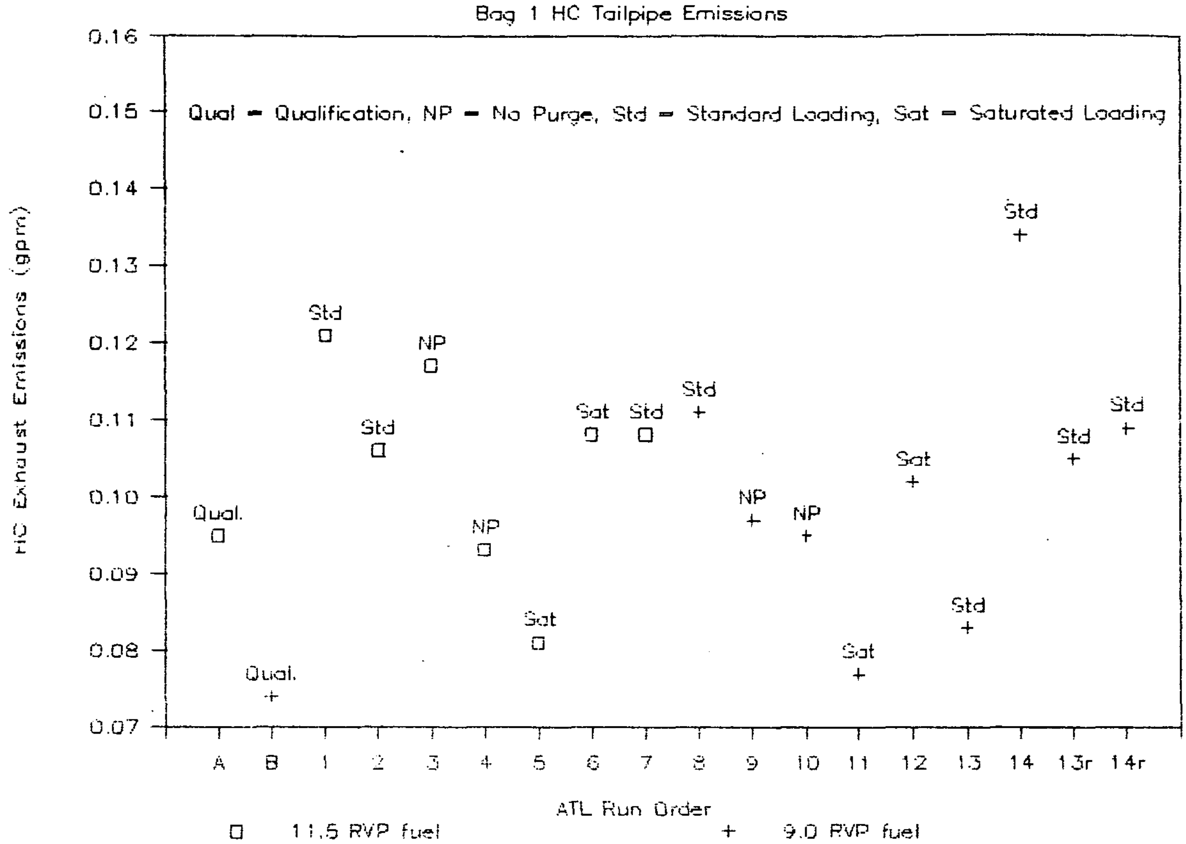


FIGURE 4

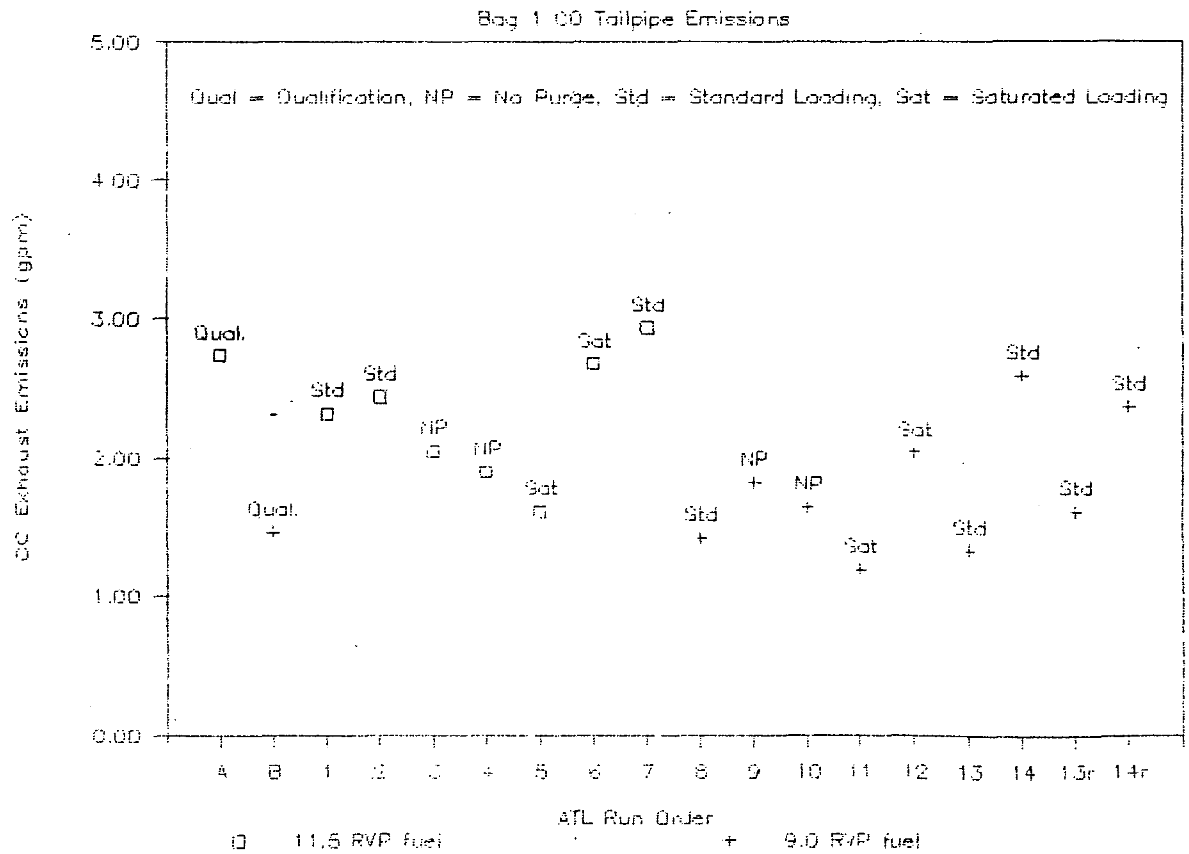


FIGURE 5

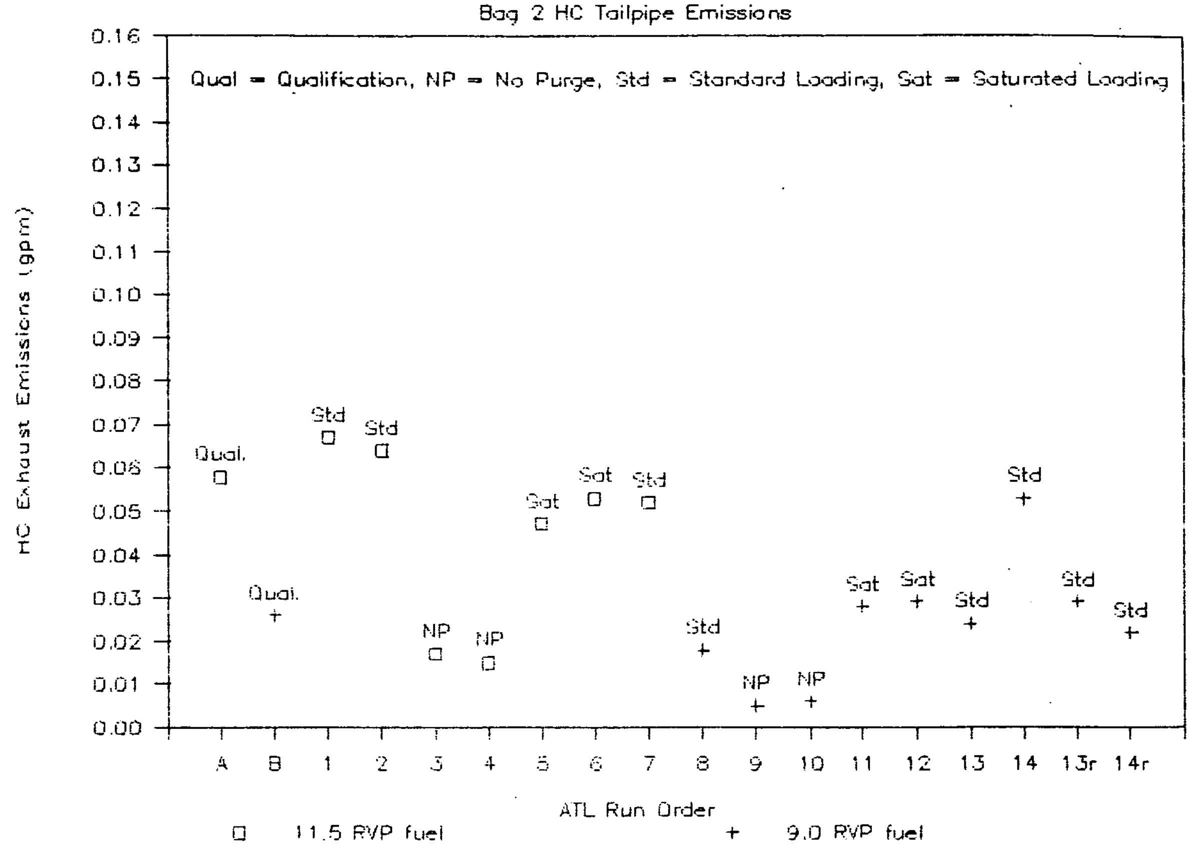


FIGURE 6

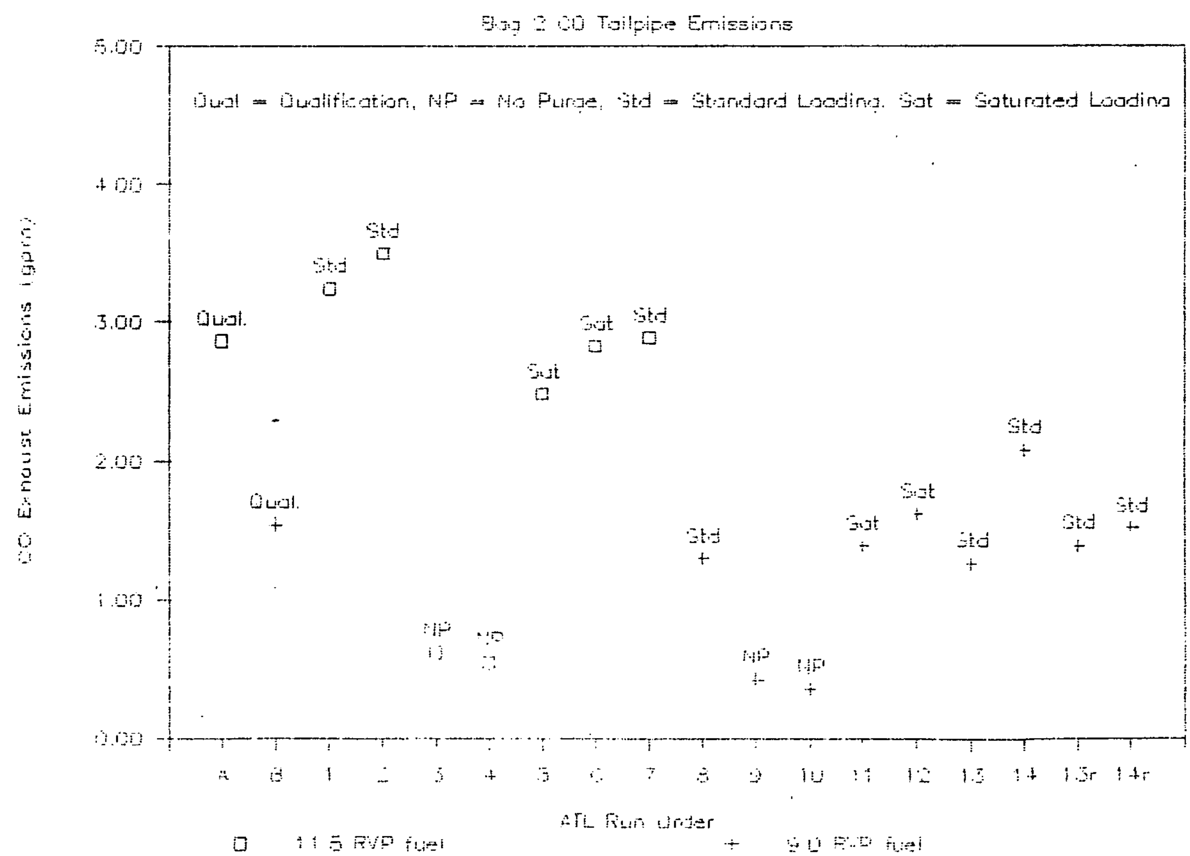


Table 5

ANOVA Results of HC Emissions*
(10% Significance Level)

Comparison	Sample Size	Deg. of Freedom**	F-ratio	Fo***	Conclusion
Variance in Canister Loadings					
(11.5 psi RVP fuel)					
LA-4 Values					
NP vs. Std. vs. Sat.	7	2,4	5.21	4.32	Differences
Std. vs. Sat.	5	1,3	2.97	5.54	No Difference
Purge vs. NP	7	1,5	5.08	4.06	Diff. is Purge
Bag 1 Values					
NP vs. Std. vs. Sat.	7	2,4	1.02	4.32	No Difference
Bag 2 Values					
NP vs. Std. vs. Sat.	7	2,4	34.2	4.32	Differences
Std. vs. Sat.	5	1,3	3.04	5.54	No Difference
Purge vs. NP	7	1,5	41.1	4.06	Diff. is Purge
Variances in Canister Loadings					
(9.0 psi RVP Fuel)					
LA-4 Values					
NP vs. Std. vs. Sat.	8	2,5	2.21	3.78	No Difference
Bag 1 Values					
NP vs. Std. vs. Sat.	8	2,5	.60	3.78	No Difference
Bag 2 Values					
NP vs. Std. vs. Sat.	8	2,5	23.5	3.78	Differences
Std. vs. Sat.	6	1,4	2.55	4.54	No Difference
Purge vs. NP	8	1,6	34.1	3.78	Diff. is Purge
9.0 vs. 11.5 RVP Fuel					
LA-4 Values					
NP/Std./Sat. Subset	15	1,13	8.4	3.14	Differences
Std./Sat. Subset	11	1,9	13.2	3.36	Diff. w/fuels
No Purge Subset	4	1,2	2.3	8.53	No Difference
No Catalyst Subset	6	1,4	.80	4.54	No Difference
Bag 2 Values					
No Catalyst Subset	6	1,4	.22	4.54	No Difference

* Excludes run 14. NP means No Purge.

** x,y = the degree of freedom (number of independent observations) of the F distribution. x equals the degrees of freedom for the number of cases studied, y equals the degrees of freedom for the number of results.

*** Fo = the theoretical F ratio for the given degrees of freedom.

Table 6

ANOVA Results of CO Emissions*
(10% Significance Level)

Comparison	Sample Size	Deg. of Freedom**	F-ratio	Fo***	Conclusion
Variance in Canister Loadings					
(11.5 psi RVP fuel)					
LA-4 Values					
NP vs. Std. vs. Sat.	7	2,4	22.8	4.32	Differences
Std. vs. Sat.	5	1,3	3.14	5.54	No Difference
Purge vs. NP	7	1,5	25.8	4.06	Diff. is Purge
Bag 1 Values					
NP vs. Std. vs. Sat.	7	2,4	1.17	4.32	No Difference
Bag 2 Values					
NP vs. Std. vs. Sat.	7	2,4	69.4	4.32	Differences
Std. vs. Sat.	5	1,3	4.43	5.54	No Difference
Purge vs. NP	7	1,5	67.2	4.06	Diff. is Purge
Variances in Canister Loadings					
(9.0 psi RVP Fuel)					
LA-4 Values					
NP vs. Std. vs. Sat.	8	2,5	2.06	3.78	No Difference
Bag 1 Values					
NP vs. Std. vs. Sat.	8	2,5	.03	3.78	No Difference
Bag 2 Values					
NP vs. Std. vs. Sat.	8	2,5	58.1	3.78	Differences
Std. vs. Sat.	6	1,4	.80	4.54	No Difference
Purge vs. NP	8	1,6	103	3.78	Diff. is Purge
9.0 vs. 11.5 RVP Fuel					
LA-4 Values					
NP/Std./Sat. Subset	15	1,13	8.79	3.14	Differences
Std./Sat. Subset	11	1,9	34.3	3.36	Diff. w/ fuels
No Purge Subset	4	1,2	6.38	18.51	No Difference
No Catalyst Subset	6	1,4	66.4	4.54	Diff. w/fuels
Bag 2 Values					
No Catalyst Subset	6	1,4	93.7	4.54	Diff. w/fuels

* Excludes run 14. NP means No Purge.

** x,y = the degrees of freedom (number of independent observations) of the F distribution. x equals the degrees of freedom for the number of cases studied, y equals the degrees of freedom for the number of results.

*** Fo = theoretical F ratio for the given degrees of freedom.

(no purge, "standard" canister loading, "saturated" canister loading) within a given fuel type. With 9.0 RVP fuel, all three conditions show basically the same HC exhaust emissions. CO emissions for all three conditions were also in the same range. With 11.5 RVP fuel, the HC results are more scattered than the 9.0 RVP results. Also, the no purge condition (no purge of the canister or fuel tank vapors) shows a reduction of the HC emissions to the 9.0 RVP level. The difference in the 11.5 RVP CO emissions between purge and no purge is even more pronounced. In addition to these comparisons, the F-ratios in Tables 5 and 6 also show a basic difference in emission levels between the 9.0 and 11.5 RVP fuels, and a difference between purge and no purge conditions with 11.5 RVP.

The bag 1 HC and CO results show no difference between the three conditions, for both 9.0 and 11.5 RVP fuel. However, the bag 2 emissions shown in Figures 5 and 6 show a very definite difference between purge and no purge conditions. The difference between the theoretical and calculated F-ratios for bag 2 (see Tables 5 and 6) statistically show a large difference between the purge and no purge conditions. The amount of canister loading appears to be irrelevant. In some cases, the lowest of the purged emissions occur with a saturated canister.

The difference between purge and no purge conditions, regardless of canister loading, indicates that the fuel tank vapors generated during vehicle operation are probably the overriding factor in the emission increases. Table 2 (test temperatures) shows approximately a 10°F increase in fuel tank temperature during the LA-4. The temperature traces (not shown) are approximately linear with run time. No data are available to confirm that this temperature increase is representative of in-use conditions for this particular vehicle. However, both on-road and dynamometer testing of a 1986 Buick and a 1984 Plymouth have shown the current dynamometer cooling arrangement to be more representative than alternative arrangements which enhance cooling.[3,4]

As can be seen in Table 2, the starting and ending fuel tank temperatures always increase by a few degrees when the replicate run occurs on the same day. Except for the no purge condition, the CO emissions also increase according to this same testing pattern. The HC emissions are a little more variable and do not show this trend.

A rise in fuel tank temperature would also have a larger effect (generate more vapors) on a high volatility fuel (i.e., 11.5 RVP), along with having a larger effect during the latter and hotter part of the run, (i.e., bag 2). Comparing the figures for bag 1 and bag 2 (Figures 3 versus 5 and 4 versus 6), the differences in emissions between the two fuels is most apparent in bag 2. Once again, increased emissions from the fuel tank due to the higher RVP fuel appear to be the cause of the increased exhaust emissions.

The bag 2 tailpipe HC and CO emissions versus the ending fuel tank temperatures are shown in Figures 7 and 8, respectively. Run 14 is also included in the plots, since temperature was suspected to have affected the results in the first place. The no purge conditions are plotted separately from the conditions which included purge. It is not known why the no purge HC values are different for the two fuels. However, these values are in a range where any uncontrolled test variation could cause such a difference in HC emissions. The NP CO emissions are approximately the same for both fuels, with just a slight inverse relation to fuel tank temperature. The reason for this apparent trend is not known and may be by coincidence.

As previously discussed, the HC and CO values which include purge are larger than the no purge values. With 9.0 RVP fuel, the HC emissions are too scattered to make a definite correlation with fuel tank temperature. However, the CO emissions appear to have a slight positive slope. This CO/temperature correlation may actually be in the form of an exponential curve, depending on the accuracy of run 14. With 11.5 RVP fuel, both HC and CO appear to have a positive slope with respect to temperature. In all cases, more data is needed to draw a strong conclusion.

Table 3 (canister weights) shows that the canister always gained weight with 11.5 RVP fuel, whereas with 9.0 RVP fuel the canister usually lost weight. The average change was 9.0 grams for 11.5 RVP fuel and -3.8 grams for 9.0 RVP fuel. Therefore, with 11.5 RVP fuel the canister absorbed more vapors from the fuel tank during the run and the 1-hour post-LA4 soak than were purged during the LA-4. With 9.0 RVP fuel, the opposite was true. For the saturated test with 11.5 RVP fuel, the canister weight gain was small, indicating the canister may have been close to actually being saturated, or that equilibrium was obtained between purge and adsorption.

The question still remains as to whether the increase in hydrocarbon emissions occurred in the engine or catalytic converter. The emissions in Table 1 for the no catalyst test show the engine-out HC levels are virtually equal for both fuels, while the engine-out CO emissions for 11.5 RVP are higher than for 9.0 RVP. The F-ratios included in Table 6 show the CO emissions with 11.5 RVP fuel to be significantly higher than the 9.0 RVP values. Therefore, the increase in tailpipe HC emissions appears to be due to a drop in catalyst efficiency, since engine-out levels are not changing significantly. The drop is catalyst efficiency is likely due to reduced oxygen availability, as evidenced by higher engine-out CO levels.

FIGURE 7

HC vs. Ending Fuel Tank Temp., Bag 2

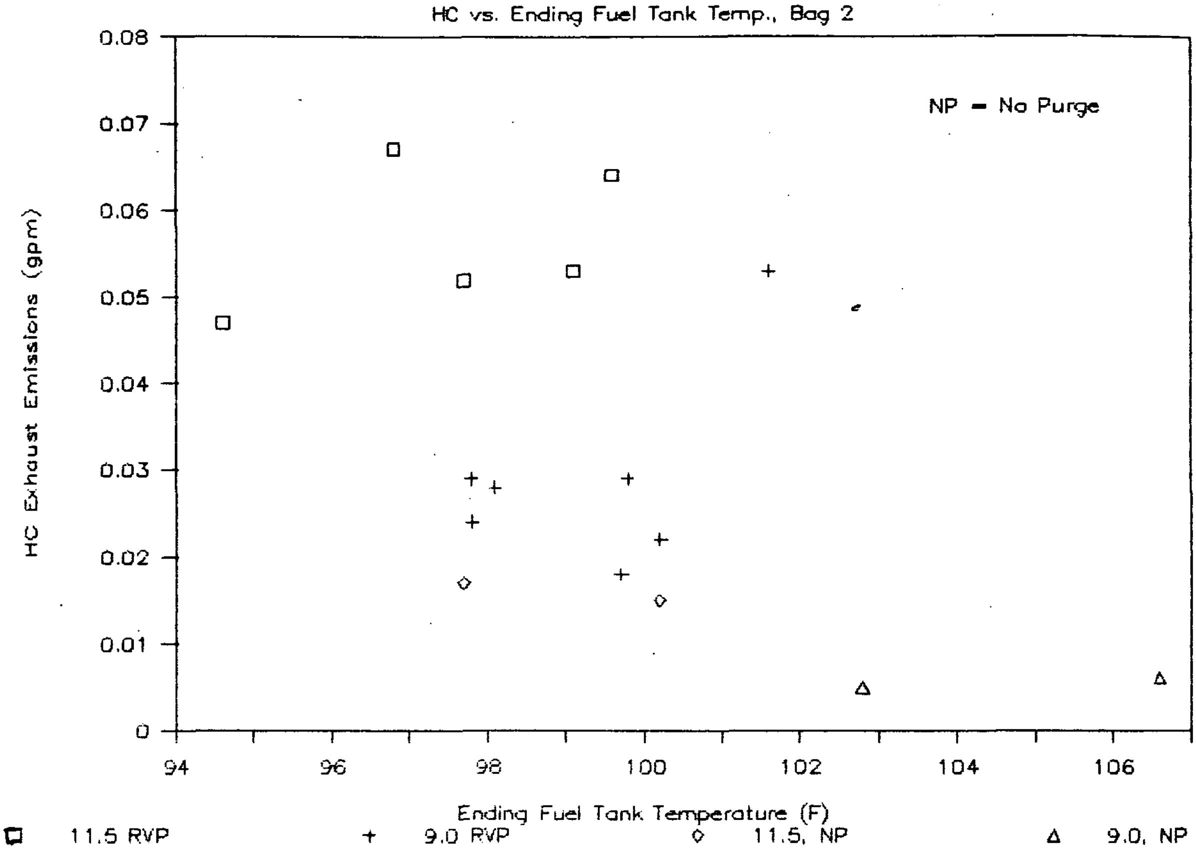
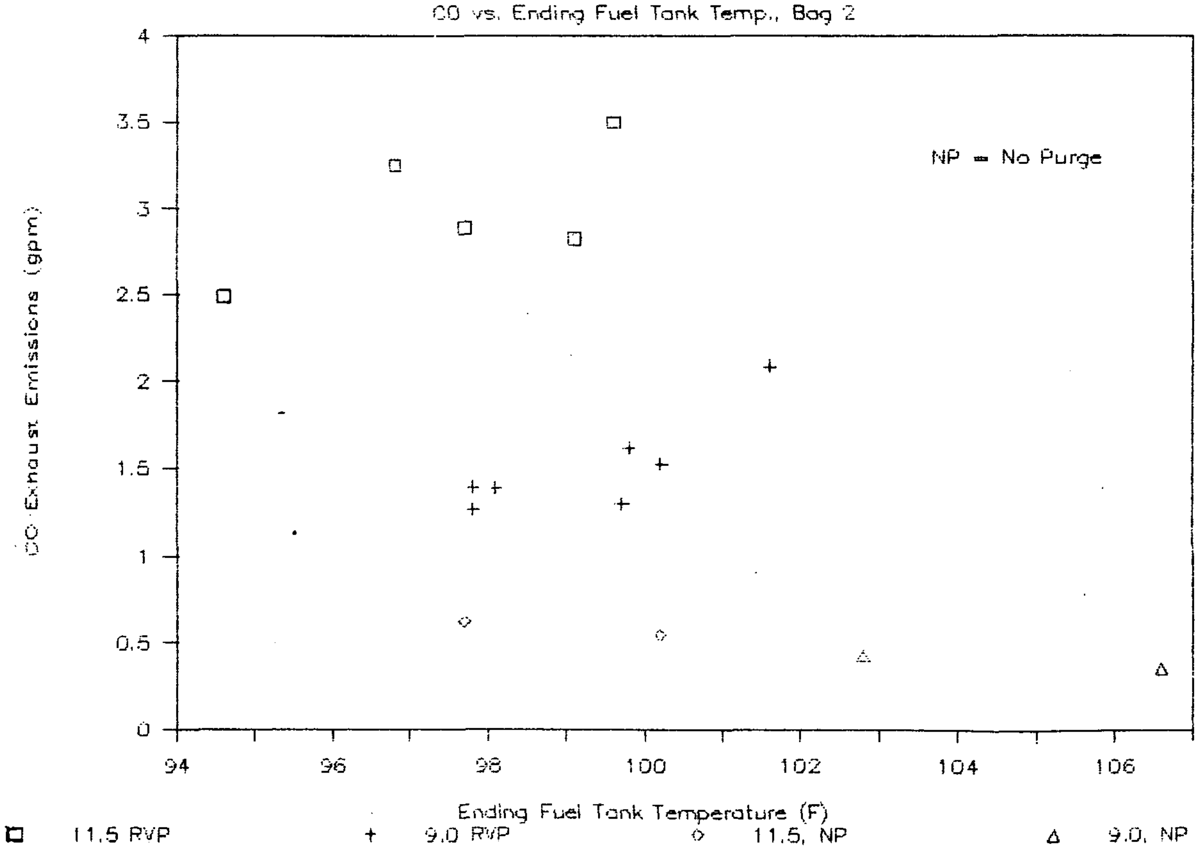


FIGURE 8

CO vs. Ending Fuel Tank Temp., Bag 2



Thus, for this vehicle at least, this testing confirms the assumption made in the Draft Regulatory Inpact Analysis in support of in-use RVP controls that the effect was occurring in the catalyst and that no fuel economy credit should accrue with the elimination of these exhaust emissions.[5]

V. Conclusion

The testing of a 1984 Olds Cutlass conducted in this program indicates that the increase in exhaust HC emissions caused by high RVP fuel is occurring in the catalyst and not in the engine. This was evidenced by the absence of an increase in engine-out HC emissions. Engine-out CO emissions did increase, indicating that the engine was running richer and that oxygen levels in the catalyst were likely lower, thereby decreasing the efficiency of the catalyst.

The richer running of the engine with higher RVP fuel was apparently caused by an increase in fuel tank HC emissions occurring while the engine was running. The effect was not apparently due to the purge of vapors previously stored in the evaporative control canister, since changing the loading of the canister had no effect on exhaust HC emissions. To further verify this conclusion, the amount of vapors generated in the fuel tank over the course of a LA-4 could be measured directly.

Further testing of additional vehicles under a procedure similar to that described in this memo may not be necessary, since there may not be a need to precisely determine whether the canister or the fuel tank is the primary cause of the RVP effect. A control program which lowers in-use RVP will directly reduce or eliminate both effects. A control program which raises certification fuel RVP will also eliminate the exhaust HC excess, regardless of whether the source of the additional unmetered fuel is the canister or the fuel tank, as long as the amount of vapors generated in the fuel tank and the sum of all vapors sent to the canister are representative of in-use amounts. The costs of the vehicle modifications should also be similar since they will focus on the amount and control of purge air during operation. In any event, given that the fuel tank is definitely implicated by this test program, extra care should be given to ensure that test cell cooling is representative of in-use conditions.

References

1. "Relationship Between Exhaust Emissions and Fuel Volatility," EPA memo from Thomas L. Darlington to Charles L. Gray, EPA, OMS, ECTD, June 24, 1985.

2. Final Weekly Report; "Task 1 - EPA/ATL Correlation/Temperature Effects," EPA Motor Vehicle Emission Laboratory, Ann Arbor, MI, June 20, 1986.

3. Letter to API from Exxon Research and Engineering Company, March 19, 1986.

4. "Effect of Auxiliary Cooling on Fuel Tank Temperatures," EPA Memorandum from Edward Barth to Robert Maxwell, February 21, 1986.

5. "Draft Regulatory Impact Analysis; Control of Gasoline Volatility and Evaporative Hydrocarbon Emissions from New Motor Vehicles," OMS, OAR, EPA, July 1987.

Appendix

ENGINEERING OPERATIONS DIVISION
Fuel Analysis Report
ATL Test Fuel

Supplier: AMOCO
Proposed Use('s): Emission Factors
Quantity: 1 gallon sample   Location: ATL AMOCO Indolene
Date placed in service: **Nov-86**
Date of resupply: End of Program
Analysis by: CORE

Item	Method	Blend Specifications	Official EOD Values
RVP (psi)	ASTM D 323	8.7-9.0	9.0
Distillation	ASTM D 86		
Initial Boiling Point(°F)		(a)	92
10% Evap. Point (°F)		(a)	133
50% Evap. Point (°F)		(a)	218
90% Evap. Point (°F)		(a)	318
End Point (°F)		(a)	439
%Evaporated at 160°F		(a)	20.4
HC Composition	ASTM D 1319		
Olefins (vol%)		(a)	4.4
Aromatics (vol%)		(a)	24.2
Saturates (vol%)		(a)	71.4
Weight Fraction Carbon	ASTM D 3343	(a)	0.8628
Net Heat of Combustion (BTU/lb)	ASTM D 3338	(a)	18539
Specific Gravity (60°F/60°F)	ASTM D 1298	(a)	0.7428
Fuel Economy Numerator (grams carbon/gallon)		(a)	2421
Fuel Economy Numerator with R Factor (grams carbon/gallon)		(a)	2414

(a) No requirements or not addressed

Prepared by: ______________________________ Date:__________
Validated by: ______________________________ Date:__________

Supplier: AMOCO
Proposed Use('s): Emission Factors
Quantity: 1 gallon sample Location: ATL AMOCO Indolene
Date placed in service: Nov-86
Date of resupply: End of Program
Analysis by: CORE

ITEM	----METHOD----			R	ASTM R	Official EOD Values
RVP (PSI)	ASTM D 323		9.0	9.0	0.55	9.0
Distillation	ASTM D 86					
initial boiling point			92			92
5% evaporated			118			118
10% evaporated			133			133
20% evaporated			159			159
30% evaporated			184			184
40% evaporated			204			204
50% evaporated			218			218
60% evaporated			229			229
70% evaporated			241			241
80% evaporated			264			264
90% evaporated			318			318
95% evaporated			364			364
end point			439			439
evaporated at 160 °F			20.4			20
Sulfur	ASTM D 1266					0
Lead	ASTM D 3237					0
Manganese	AA					
Phosphorous	ASTM D 3231					0
Water (Wt%)	Karl Fischer					
Hydrocarbon Composition	ASTM D 1319	0	100			
olefins			4.4			4.4
aromatics			24.2			24.2
saturates			71.4			71.4
Research octane number	ASTM D 2699					0.0
Motor octane number	ASTM D 2700					0
Antiknock index	ASTM D 439		0.0			0.0
Sensitivity	RON-MON		0.0			0.0
Weight fraction carbon	ASTM D 2789					
Weight fraction carbon	ASTM E 191					
Weight fraction carbon	ASTM D 3343		0.8628		0.0009	0.8628
Net heat of combustion	ASTM D 240					
Net heat of combustion	ASTM D 3338		18539		20	18539
API GRAVITY	ASTM D 1298		59		0.4	59.0
Specific gravity (60°F/60°F)			0.7428			0.7428
Fuel economy numerator (g carbon/gal)			2421			2421
Fuel economy numerator (g carbon/gal) with R Factor			2414			2414

ENGINEERING OPERATIONS DIVISION
Fuel Analysis Report
ATL Test Fuel

Supplier: Chevron
Proposed Use('s): Emission Factors
Quantity: 1 gallon sample   Location: ATL Chevron UL/CQ
Date placed in service: Nov-86
Date of resupply: End of Program
Analysis by: CORE

Item	Method	Blend Specifications	Official EOD Values
RVP (psi)	ASTM D 323	11.6-11.9	11.6
Distillation	ASTM D 86		
Initial Boiling Point(°F)		(a)	74
10% Evap. Point (°F)		(a)	112
50% Evap. Point (°F)		(a)	204
90% Evap. Point (°F)		(a)	343
End Point (°F)		(a)	423
%Evaporated at 160°F		(a)	31.7
HC Composition	ASTM D 1319		
Olefins (vol%)		(a)	5.5
Aromatics (vol%)		(a)	28.1
Saturates (vol%)		(a)	66.4
Weight Fraction Carbon	ASTM D 3343	(a)	0.8649
Net Heat of Combustion (BTU/lb)	ASTM D 3338	(a)	18484
Specific Gravity (60°F/60°F)	ASTM D 1298	(a)	0.7416
Fuel Economy Numerator (grams carbon/gallon)		(a)	2423
Fuel Economy Numerator with R Factor (grams carbon/gallon)		(a)	2423

(a) No requirements or not addressed

Prepared by: ______________________ Date: __________
Validated by: ______________________ Date: __________

Supplier: Chevron
Proposed Use('s): Emission Factors
Quantity: 1 gallon sample Location: ATL Chevron UL/CQ
Date placed in service: Nov-86
Date of resupply: End of Program
Analysis by: CORE

ITEM	----METHOD----		Chromaspec	R	ASTM R	Official EOD Values
RVP (PSI)	ASTM D 323		11.6	11.6	0.55	11.6
Distillation	ASTM D 86					
initial boiling point			74			74
5% evaporated			102			102
10% evaporated			112			112
20% evaporated			132			132
30% evaporated			156			156
40% evaporated			185			185
50% evaporated			204			204
60% evaporated			235			235
70% evaporated			251			251
80% evaporated			291			291
90% evaporated			343			343
95% evaporated			376			376
end point			423			423
evaporated at 160 °F			31.7			32
Sulfur	ASTM D 1266					0
Lead	ASTM D 3237					0
Manganese	AA					
Phosphorous	ASTM D 3231					0
Water (Wt%)	Karl Fischer					
Hydrocarbon Composition	ASTM D 1319	0	100			
olefins			5.5			5.5
aromatics			28.1			28.1
saturates			66.4			66.4
Research octane number	ASTM D 2699					0.0
Motor octane number	ASTM D 2700					0
Antiknock index	ASTM D 439		0.0			0.0
Sensitivity	RON-MON		0.0			0.0
Weight fraction carbon	ASTM D 2789					
Weight fraction carbon	ASTM E 191					
Weight fraction carbon	ASTM D 3343		0.8649		0.0009	0.8649
Net heat of combustion	ASTM D 240					
Net heat of combustion	ASTM D 3338		18484		20	18484
API GRAVITY	ASTM D 1298		59.3		0.4	59.3
Specific gravity (60°F/60°F)			0.7416			0.7416
Fuel economy numerator (g carbon/gal)			2423			2423
Fuel economy numerator (g carbon/gal) with R Factor			2423			2423