Effect of a Fuel Additive on Fuel Economy and Exhaust Emissions of Gasoline Automobiles During EPA Driving Cycles

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Introduction

In September, 1973, the U.S. Environmental Protection Agency (EPA) introduced a method of determining vehicle fuel economy in conjunction with its chassis dynamometer emissions test. This method determined fuel consumption based on the vehicle exhaust emissions, through a "carbon balance" calculation, rather than by direct measurement of fuel consumed.

Starting with 1974 models, fuel economy results were determined by the EPA voluntary fuel economy labeling programs. Initially, fuel economy data were determined solely on the EPA CVS-cold start emissions test cycle (LA-4 cycle, comprised mostly of city stop and go type driving, with an average speed of 19.5 mph). Starting with the 1975 models, the city cycle was modified to add a hot start, and a second test was added to obtain fuel economy data on a highway driving cycle (average speed 48.8 mph).

EPA specified chassis dynamometer experiments were conducted at the Automotive Testing Laboratory in Aurora, Colorado to examine the effects of the proprietary combustion catalyst on the fuel economy and exhaust emissions in gasoline powered automobiles. The combustion catalyst is distributed by UHI Corporation in Provo, Utah.

Procedure

Two late model vehicles were used in the study, as indicated in Table 1. Neither the Oldsmobile nor the Plymouth had ever been operated with treated fuel. Three different EPA tests were run at ATL. The Federal Test Procedure (FTP) consists of three segments: 1 505 second cold transient convering 3.59 miles, an 869 second cold stabilized segment covering 3.86 miles and a 505 second hot transient, a repeat of the initial schedule with a hot start.

This is prescribed by the EPA in Title 40, part 86, Subpart 6 of the CFR. The Hot '74 consists of a hot start FTP without the last hot transient segment. The highway fuel economy test (HFET) covers 10.24 miles in 765 seconds in one segment.

Tables 2 and 3 show the evaluation sequence for the Plymouth and Oldsmobile, respectively. Vehicle experiments were conducted at an ambient temperature ranging from 74 to 79 degrees fahrenheit using a climate controlled chassis dynamometer with direct drive inertia system and road load power control. The engines were set to the manufacturer's specifications prior to the evaluations. The exhaust gas was analyzed for carbon dioxide (CO2) and carbon monoxide (CO) using the nondispersive infrared technique. A heated flame ionization detector (HFID) was used for unburned hydrocarbons (HC). Oxides of nitrogen (NOx) were detected by chemiluminescence. A Fluidyne direct measurement flow meter was used to obtain fuel flow during the tests.

Both vehicles were treated with untreated commercial unleaded gasoline to obtain baseline results. The gasoline characteristics are shown with Indolene for comparison in

Table 4. Following two sets of baseline tests, the fuel tank of each vehicle, with essentially no catalyst mileage acceleration, was then subjected to two sets of EPA tests. The vehicles were then driven 800 miles each on the highway with additive treated gasoline, after which two sets of EPA tests were conducted with each vehicle. Each vehicle was then highway driven an additional 1000 miles with additive treated fuel. Finally, three sets of EPA tests were run with each vehicle.

Results and Discussion

Summaries of the exhaust emissions and fuel economy results for the Plymouth TC3 and Oldsmobile Cutlass are shown in Tables 5 and 6, respectively. The fuel economy was obtained using a Fluidyne direct measurement flow meter as well as the carbon balance method specified for the FTP. The Fluidyne direct measurements showed lower fuel economy for all FTP and Hot '74 evaluations but generally higher efficiencies were indicated during the HFET. The direct measurement of fuel consumption indicated approximately the same fuel economy trends between sets of tests.

The major sources of any discrepancy with the direct measurement are float bowl level fluctuation (especially at the end of beginning of a test) and air bubbles in the fuel. The carbon balance method is particularly sensitive to the measurement of carbon dioxide in the exhaust gases. Any variability in CO2 detection would contribute to inaccuracies in fuel economy calculations to a greater extent than NC or CO measurements.

Tables 7-10 present the fuel economy and exhaust emission results for the Plymouth TC3. The results shown are for the final set of EPA evaluations following more than 2000 accumulated miles with additive in the gasoline. The final group of tests consisted of three sets (tests 19-27, Table 5). It is very likely that the engine calibration changed between the first set (tests 19-21) and the second set which begins with test 22. The carbon monoxide level increased by nearly 70% and the oxides of nitrogen were almost cut in half, yet no external changes were made to the vehicle. Test personnel at ATL indicated that the engine calibration had changed and suggested the possibility that the EGR had begun operating differently, based on the markedly lower NOx level for tests 22-27. The apparent change in engine calibration rendered invalid the last two sets of FTP evaluations compared with the baseline tests. Therefore, the additive data reported in Tables 7-10 represent tests 19-21.

Table 7 shows that the fuel economy increased up to 6.6% for the Hot '74 test while the HFET showed an increase of 3.3%. The overall fuel economy increase is 5.37% and was calculated using the ratio of total miles for the FTP, Hot '74, and HFET to the total gallons used. Figures 1-3 depict the trends in fuel economy with mileage accumulation with the additive for each type of evaluations conducted at ATL. Figure 1 shows an increasing trend in FTP fuel economy as the Plymouth TC3 was driven with the additive to accumulate miles. Figure 2 shows the same trend for the Hot '74 test. Figure 3 indicates an initial very slight reduction in HFET fuel economy followed by an increase with mileage accumulation. These data support the concept of a conditioning period in the engine before full effectiveness is reached. It is possible that further increases in fuel economy would occur with additional additive use since the trend shows a continual increase.

Hydrocarbon emissions decline with the additive except for the HFET where a relatively large increase was noted (Table 8). Table 9 shows a consistent decline in CO levels, up to 48% during the Hot '74. A reduction in NOx, shown in Table 10, was also measured, ranging from 2.8% (HFET) to 13.6% (Hot '74).

Tables 11-14 present the fuel economy and exhaust emission results for the Oldsmobile Cutlass. The results shown are a harmonic average of the final three sets of EPA tests conducted over the space of two days, after more than 2000 miles with the additive were accumulated. Table 11 shows that the fuel economy increased up to 3.7% with the Hot '74 tests. The lowest increase was 2.8% with the HFET. The overall fuel economy increase on a total miles to total gallons of fuel basis is 3.15% for the Oldsmobile. Figures 4-6 illustrate the general trends in fuel economy as a function of vehicle mileage with the additive. The FTP fuel economy (Figure 4) generally increases with additive accumulation, although the actual magnitude of the trend in increased fuel economy in test sets 5,6, and 7 is uncertain due to the variance in the data. Figure 5, which shows the Hot '74 trend in fuel economy, indicateds a similar pattern as the FTP. It is unclear what caused the apparent drop-off from a nearly 7% improvement to approximately 2%. Test sets 1-5 in Figure 5 indicate a monotonic increase in fuel economy up to approximately 7%. The HFET results shown in Figure 6 are very scattered, but an increasing trend in indicated following an initial fuel economy decrease which occurred with no mileage accumulation.

The exhaust emission results show a reduction in hydrocarbon levels for all tests up to 31.6% for the HFET (Table 12). The carbon monoxide emissions increased 2.9% for the FTP but decreased approximately 21% for both the Hot '74 and the HFET as shown in Table 13. Table 14 shows that NOx levels ranged from a decrease of 2.6% to a 7.4% increase.

<u>Conclusions</u>

The use of the additive significantly increased fuel efficiency in both automobiles. The fuel economy of both vehicles showed a general positive trend with increased mileage with the additive. The maximum improvement may not have been attained in these evaluations, especially with the Plymouth TC3. The overall average fuel economy increase was 4.06% using the harmonic average of each vehicle's fuel economy.

The additive causes a decrease in all regulated exhaust tailpipe emissions under most conditions. Significant reductions in HC and CO occurred while NOx levels were less markedly affected.

Table 1. Specifications for Two Gasoline Powered Vehicles Used in FTP Evaluations of Ferrous Picrate Additive.								
							Odometer	
Vehicle	*Model Yr.*	*VIN*	*Engine (CID)*	*Trans*	*Catalyst*	*Weight*	*Start*	*End*
Plymouth TC3	1981	ML24AAD246034	I-4 (104)	M4	Oxidation	2500	12667	15034
Oldsmobile Cutlass	1979	3M47F9M423084	V-6 (262)	A3	Oxidation	3500	24775	27159

Table 2. Plymouth TC3 EPA Test Sequence for Additive Evaluations

Number	Date	Test	Fuel	Odometer
1	6/17/81	FTP	Base Gasoline	12667
2	6/17/81	Hot '74	Base Gasoline	12692
3	6/17/81	HFET	Base Gasoline	12700
4	6/29/81	FTP	Base Gasoline	12750
5	6/29/81	Hot '74	Base Gasoline	12775
6	6/29/81	HFET	Base Gasoline	12783
7	6/30/81	FTP	Gasoline w/Additive	12811
8	6/30/81	Hot '74	Gasoline w/Additive	12831
9	6/30/81	HFET	Gasoline w/Additive	12845
10	7/1/81	FTP	Gasoline w/Additive	12872
11	7/1/81	Hot '74	Gasoline w/Additive	12898
12	7/1/81	HFET	Gasoline w/Additive	12906
13	7/6/81	FTP	Gasoline w/Additive	13729
14	7/6/81	Hot '74	Gasoline w/Additive	13754
15	7/6/81	HFET	Gasoline w/Additive	13762
16	7/6/81	FTP	Gasoline w/Additive	13790
17	7/6/81	Hot '74	Gasoline w/Additive	13816
18	7/6/81	HFET	Gasoline w/Additive	13823
19	7/14/81	FTP	Gasoline w/Additive	14885
20	7/14/81	Hot '74	Gasoline w/Additive	14911
21	7/14/81	HFET	Gasoline w/Additive	14919
22	7/15/81	FTP	Gasoline w/Additive	14946
23	7/15/81	Hot '74	Gasoline w/Additive	14971
24	7/15/81	HFET	Gasoline w/Additive	14979
25	7/16/81	FTP	Gasoline w/Additive	15000
26	7/16/81	Hot '74	Gasoline w/Additive	15026
27	7/16/81	HFET	Gasoline w/Additive	15034

Table 3. Oldsmobile Cutlass EPA Test for Additive Evaluations

Number	*Date*	*Test*	*Fuel*	*Odometer*
1	6/26/81	FTP	Base Gasoline	24775
2	6/26/81	Hot '74	Base Gasoline	24801
3	6/26/81	HFET	Base Gasoline	24809
4	6/29/81	FTP	Base Gasoline	24837
5	6/29/81	Hot '74	Base Gasoline	24863
6	6/29/81	HFET	Base Gasoline	24872
7	6/30/81	FTP	Gasoline w/Additive	24899
8	6/30/81	Hot '74	Gasoline w/Additive	24925
9	6/30/81	HFET	Gasoline w/Additive	24933
10	7/1/81	FTP	Gasoline w/Additive	24960
11	7/1/81	Hot '74	Gasoline w/Additive	24987
12	7/1/81	HFET	Gasoline w/Additive	24994
13	7/6/81	FTP	Gasoline w/Additive	25827
14	7/6/81	Hot '74	Gasoline w/Additive	25853
15	7/6/81	HFET	Gasoline w/Additive	25861
16	7/7/81	FTP	Gasoline w/Additive	25882
17	7/7/81	Hot '74	Gasoline w/Additive	25908
18	7/7/81	HFET	Gasoline w/Additive	25916
19	7/15/81	FTP	Gasoline w/Additive	27007
20	7/15/81	Hot '74	Gasoline w/Additive	27038
21	7/15/81	HFET	Gasoline w/Additive	27046
22	7/16/81	FTP	Gasoline w/Additive	27067
23	7/16/81	Hot '74	Gasoline w/Additive	27094
24	7/16/81	HFET	Gasoline w/Additive	27102
25	7/17/81	FTP	Gasoline w/Additive	27124
26	7/17/81	Hot '74	Gasoline w/Additive	27150
27	7/17/81	HFET	Gasoline w/Additive	27159

Table 4. Fuel Specifications for Commercial Unleaded Gasoline Used in Tests Compared with Indolene

Test	*Method*	*Indolene Clear*	*Comm. Unleaded*
API Gravity, 60F	ASTM D287	57.2	61.7
Specific Gravity, 60/60F	ASTM D287	0.7499	0.7324
Vapor Pressure, lb/in	ASTM D323	7.1	10.1
Lead content in g/gal	ASTM D3237	0.031	0.023
Sulfur, % by wt.	Fed 5201	0.014	0.026
Phosphorous in g/gal	ASTM D3231	<.0003	<.0003
Aromatics, % by vol.	ASTM D1319	33	30.3
Saturates, % by vol.	ASTM D1319	65.3	68
Olefins, % by col.	ASTM D1319	1.7	1.7

Table 5. Summary of 1981 Plymouth TC3 Exhaust Emissions and Fuel Economy Data.

			Exhaust Emissions (g/ml)			*MPG*	
Number	*Test*	*Fuel*	*HC*	*CO*	*NOx*	*CB*	*FD*
1	FTP	Base	0.829	13.007	0.99	23.53	22.28
2	Hot '74	Base	0.472	9.6	1.001	23.53	22.38
3	HFET	Base	0.039	2.129	1.003	33.09	33.57
4	FTP	Base	0.823	15.026	0.998	23.17	21.46
5	Hot '74	Base	0.498	10.653	1.072	24.82	24.18
6	HFET	Base	0.039	2.344	1.077	32.77	33.07
7	FTP	Additive	0.823	12.574	1.022	23.65	21.94
8	Hot '74	Additive	0.49	10.507	1.05	25.23	24.24
9	HFET	Additive	0.039	2.25	1.015	32.86	33.24
10	FTP	Additive	0.803	13.297	1.048	23.67	21.79
11	Hot '74	Additive	0.511	8.496	1.063	25.24	24.57
12	HFET	Additive	0.049	2.74	1.099	32.77	33.07
13	FTP	Additive	0.794	12.766	1.122	23.93	22.48
14	Hot '74	Additive	0.517	10.199	1.111	25.44	24.52
15	HFET	Additive	0.038	2.199	1.2	33.58	33.74
16	FTP	Additive	0.803	13.678	0.818	24.04	21.78
17	Hot '74	Additive	0.482	8.71	0.873	25.69	23.59
18	HFET	Additive	0.033	1.971	0.861	33.92	33.73
19	FTP	Additive	0.865	12.81	0.923	24.74	22.52
20	Hot '74	Additive	0.407	7.264	0.89	26.49	25.35
21	HFET	Additive	0.049	1.618	1.01	34.02	33.34
22	FTP	Additive	0.955	20.637	0.52	22.72	20.99
23	Hot '74	Additive	0.394	12.177	0.514	24.8	23.79
24	HFET	Additive	0.04	4.952	0.419	30.33	30.23
25	FTP	Additive	0.979	19.538	0.599	23.1	21.44
26	Hot '74	Additive	0.545	13.971	0.535	24.84	23.97
27	HFET	Additive	0.035	4.055	0.448	30.59	30.78

Table 6. Summary of 1979 Oldsmobile Cutlass Exhaust Emissions and Fuel Economy Data.

		Exhaust Emissions (g/ml)				MGP	
Number	*Test*	*Fuel*	*HC*	*CO*	*NOx*	*CB*	*FD*
1	FTP	Base	1.337	34.853	1.086	16.74	15.88
2	Hot '74	Base	0.848	33.446	0.809	18.08	17.4
3	HFET	Base	0.813	28.641	1.123	23.56	24
4	FTP	Base	1.251	34.225	1.129	16.59	15.91
5	Hot '74	Base	0.806	28.053	0.853	18.38	17.55
6	HFET	Base	0.744	27.453	1.149	23.73	23.98
7	FTP	Base	1.235	33.854	1.133	16.96	16.13
8	Hot '74	Base	0.806	30.771	0.853	18.42	17.86
9	HFET	Base	0.847	32.588	1.189	22.99	23.38
10	FTP	Base	1.316	35.239	1.182	16.79	15
11	Hot '74	Base	0.789	30.341	0.884	18.45	17.64
12	HFET	Base	0.832	33.31	1.14	23.15	23.6
13	FTP	Base	1.42	37.241	1.071	16.95	16.17
14	Hot '74	Base	0.677	26.804	0.828	18.6	17.42
15	HFET	Base	0.411	15.816	1.155	24.63	24.86
16	FTP	Base	1.2	36.885	1.023	16.8	16.03
17	Hot '74	Base	0.726	29.993	0.776	18.71	18.58
18	HFET	Base	0.633	25.97	1.06	24.08	24.56
19	FTP	Base	1.274	36.536	1.034	17.44	16.35
20	Hot '74	Base	0.546	21.267	0.888	19.45	17.86
21	HFET	Base	0.436	17.293	1.204	25.32	24.37
22	FTP	Base	1.204	35.402	1.117	17.01	16.34
23	Hot '74	Base	0.606	24.363	0.91	18.7	18.16
24	HFET	Base	0.661	25.712	1.229	23.76	23.83
25	FTP	Base	1.195	34.763	1.089	17.05	16.29
26	Hot '74	Base	0.667	26.886	0.877	18.55	18.32
27	HFET	Base	0.666	26.008	1.156	23.88	24.09

Table 7. Final 1981 Plymouth TC3 EPA Fuel Economy (miles/gallon) for Additive Treated and Base Gasoline.

Test	*Base Gasoline*	*Additive**	*Percent Change*
FTP	23.35	24.74	5.9
Hot '74	24.85	26.49	6.6
HFET	32.93	34.02	3.3

*Results of three runs with 2000+ accumulated miles.
Engine calibration inexplicably changed for runs 22-27 (see Table 5).

Table 8. Final 1981 Plymouth TC3 HC Exhaust Emissions (grams/mile) for Additive Treated and Base Gasoline.

Test	*Base Gasoline*	*Additive**	*Percent Change*
FTP	0.83	0.87	4.7
Hot '74	0.48	0.41	-16
HFET	0.04	0.05	25.6

*see Table 7

Table 9. Final 1981 Plymouth TC3 CO Exhaust Emissions (grams/mile) for Additive Treated and Base Gasoline

Test	Base Gasoline	Additive*	Percent Change
EPA	13.94	12.81	-8.1
Hot '74	10.1	7.26	-47.9
HFET	2.23	1.62	-27.4

*see Table 7

Table 10. Final 1981 Plymouth TC3 NOX Exhaust Emissions (grams/mile) for Additive Treated and Base Gasoline

Test	Base Gasoline	Additive*	Percent Change
EPA	0.99	0.92	-7.1
Hot '74	1.03	0.89	-13.6
HFET	1.04	1.01	-2.8

*see Table 7.

Table 11. Final 1979 Oldsmobile EPA Fuel Economy (miles/gallon) for Additive Treated and Base Gasoline.

Test	*Base Gasoline*	*Additive*	*Percent Change*
FTP	16.67	17.17	3
Hot '74	18.23	18.9	3.7
HFET	23.65	24.32	2.8

Table 12. Final 1979 Oldsmobile HC Exhaust Emissions (grams/mile) for Additive Treated and Base Gasoline.

Test	*Base Gasoline*	*Additive*	*Percent Change*
FTP	1.29	1.22	-5.5
Hot '74	0.83	0.6	-27.1
HFET	0.78	0.57	-31.6

Table 13. Final 1979 Oldsmobile CO Exhaust Emissions (grams/mile) for Additive Treated and Base Gasoline.

Test	*Base Gasoline*	*Additive*	*Percent Change*
FTP	34.54	35.55	2.9
Hot '74	30.51	23.95	-21.5
HFET	28.03	22.19	-20.8

Table 14. Final 1979 Oldsmobile NOX Exhaust Emissions (grams/mile) for Additive Treated and Base Gasoline.

Test	*Base Gasoline*	*Additive*	*Percent Change*
FTP	1.11	1.08	-2.6
Hot '74	0.83	0.89	7.4
HFET	1.14	1.2	5.1