State of California
AIR RESOURCES BOARD

EVALUATION OF OMSTAR DIESEL FUEL ADDITIVE D-1280X

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EVALUATION OF OMSTAR DIESEL FUEL ADDITIVE D-1280X

by
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SUMMARY

The Air Resources Board (ARB) conducted a test program to evaluate the benefits of using a diesel fuel additive in heavy-duty diesel trucks.

In 1987-1988, the ARB conducted a preliminary evaluation of a diesel fuel additive with a chemical composition similar to that of Omstar, using a passenger car and a heavy-duty truck as test vehicles. The results of the evaluation indicated a significant reduction of unburned hydrocarbon (HC) and particulate emissions at a 95 percent confidence level when the fuel additive is blended with high sulfur "certification fuel".

As a result of the preliminary evaluation, a second phase of the test program was conducted at Automotive Testing and Development Services, Inc. (ATDSI) of Huntington Beach, California under a contract funded by the ARB. The Federal Exhaust Emissions Test Procedures (CVS-75) and Highway Fuel Economy Test procedures (HFET) were used to determine exhaust emissions and to measure the fuel economy of heavy-duty diesel vehicles. The Los Angeles City Department of Water & Power provided the test vehicles which were divided into the following test groups:

	CERTIFICATION FUEL	COMMERCIAL FUEL
VEHICLES WITH D-1280X	2 diesel trucks	2 diesel trucks
VEHICLES WITHOUT ADDITIVE	2 diesel trucks	2 diesel trucks

"Certification fuel" contains high sulfur while "commercial fuel" has low sulfur which is typical of that used in the South Coast Air Basin.

The test protocol included duplicate emission testing of the vehicles at 500 mile increments over the range of 0 to 1,500 miles.

The analysis of variance method (specifically the General Linear Model routine) was used to determine the effect of the additive on emissions and fuel economy. Statistical analysis of the test data reveals that:

1. At the 95 percent confidence level, three results were conclusive; namely, the additive reduced hydrocarbon emissions during urban-type driving for certification (high sulfur) fuel, highway-type driving for certification fuel, and highway-type driving for commercial (low sulfur) fuel.

2. All other test results were statistically nonsignificant at the selected 95 percent confidence level.

The results described above are depicted in this table:

EFFECT OF OMSTAR D-1280X AT 95 PERCENT CONFIDENCE LEVEL

	CERTIFICATION FUEL	COMMERCIAL FUEL
URBAN DRIVING		
HC	REDUCED	*
CO	*	*
NOx	*	*
FUEL ECONOMY	*	*
PARTICULATES	*	*
HIGHWAY DRIVING		
HC	REDUCED	REDUCED
CO	*	*
NOx	*	*
FUEL ECONOMY	*	*

*Statistically nonsignificant at the selected 95 percent confidence level. Statistical nonsignificance may result from many factors such as sample size, confidence level, the fuel additive, the fuel used, vehicle variability and mileage accumulation. Therefore, when the result is nonsignificant, a definite conclusion regarding the effect of the additive cannot be made.

The Probability of Effect of Omstar D-1280X was also determined by ARB statistical analysis as reflected in the following table:

PROBABILITY OF EFFECT OF D-1280X

	CERTIFICATION FUEL	COMMERCIAL FUEL
URBAN DRIVING		
HC	99.8% *	94.3%
CO	70.6%	51.3%
NOx	14.0%	85.1%
FUEL ECONOMY	92.1%	28.4%
PARTICULATES	65.5%	51.7%
HIGHWAY DRIVING		
HC	95.5% *	99.7% *
CO	94.9%	54.1%
NOx	45.8%	55.6%
FUEL ECONOMY	61.8%	17.5%

* Significant at the 95 percent confidence level.

[NOTE: The "Probability of Effect" does not indicate the direction of change (increase or decrease) in emissions or fuel economy.]

The ARB hired Sierra Research with assistance from a statistical consultant, Mr. H.T. McAdams, to give an independent review of the test program design, data analysis and conclusions. As part of Mr. McAdams report, the following recommendation was made:

> "A repeat test program should be considered in which the shortcomings of the initial test program are remedied. A test program involving a greater number of vehicles is suggested, with heavy emphasis on paired comparisons (with and without the additive) on the same vehicle. Reduction of significant levels for rejection of the null hypothesis should also be given careful consideration in the interest of achieving greater sensitivity for detection of fuel additive effects if they actually do exist."

The test program described in this report was designed as a screening test to provide a quick analysis of the additive's effect on emissions and fuel economy of diesel vehicles. As such, the ARB is aware of the shortcomings of the program as mentioned by Mr. McAdams. Any additional

testing by ARB to further substantiate the benefits that can be derived from the additive must be requested by the interested parties. Cost of testing shall be shouldered by the interested party in accordance with the provisions in Sections 2205.(b) and 2206, Title 13, California Code of Regulations.

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EVALUATION OF OMSTAR DIESEL FUEL ADDITIVE D-1280X

I. INTRODUCTION

The Air Resources Board (ARB) conducted a test program to evaluate whether exhaust emission benefits result from the use of Omstar diesel fuel additive D-1280X in a heavy-duty diesel engine.

In 1987-1988, the ARB conducted a preliminary evaluation of a similar diesel fuel additive being marketed under the name of Renergy D-1280. A passenger car and a heavy-duty truck were used as test vehicles for the evaluation. Results of the evaluation indicated a significant reduction of exhaust unburned hydrocarbon (HC) and particulate emissions at 95 percent confidence level when the fuel additive was blended with high sulfur "certification fuel". Because of the limited test sample in the preliminary evaluation, the staff was unable to determine if the emission reductions observed resulted from use of the additive. The staff identified other test program parameters that could have been responsible for the observed emission reductions. These include:

1) The use of high sulfur "certification fuel" (specified sulfur content of 0.2 to 0.5 percent by weight).
2) Mileage accumulation effects.
3) Variability of the test vehicles.

Based on the above considerations, the staff recommended that a second phase of the evaluation program be conducted to identify the source of the observed benefits.

This report addresses the results of the second phase of the test program using heavy-duty diesel vehicles. Testing was conducted at Automotive Testing and Development Services, Inc. (ATDSI) of Huntington Beach,

California, under a contract funded by the ARB. The Federal Exhaust Emissions Test Procedures (CVS-75) and Highway Fuel Economy Test procedures (HFET) as contained in Code of Federal Regulations (CFR), Title 40, Part 86 were used to determine the hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NOx), and particulate exhaust emissions and to measure the fuel economy of heavy-duty diesel vehicles. Visible smoke was not measured in the testing. The test vehicles were divided into these test groups:

	CERTIFICATION FUEL	COMMERCIAL FUEL
VEHICLES WITH D-1280X	2 diesel trucks	2 diesel trucks
VEHICLES WITHOUT ADDITIVE	2 diesel trucks	2 diesel trucks

"Certification fuel" contains high sulfur while "commercial fuel" has low sulfur which is typical of that used in the South Coast Air Basin.

The test protocol included duplicate emission testing of the vehicles at 500 mile increments over the range of 0 to 1,500 miles.

This report also includes the results of a laboratory analysis of both the commercial and certification fuels used in the program. Additionally, the results of the ARB laboratory analysis of the chemical composition of the fuel additive are reported.

II. CONCLUSION

Statistical analysis of the test data reveals that:

1) At the 95 percent confidence level, the use of Omstar fuel additive blended with high sulfur certification fuel (typical of fuel used outside of the South Coast Air Basin), resulted in a statistically significant reduction in hydrocarbon emissions during urban-type and highway-type driving. When the additive was used with the low sulfur fuel available in the South Coast Air Basin (SCAB), a

statistically significant reduction in hydrocarbon emissions from highway-type driving was evident.

2) All other test results were statistically nonsignificant at the selected 95 percent confidence level.

The above results are summarized in the following table:

EFFECT OF OMSTAR D-1280X AT 95 PERCENT CONFIDENCE LEVEL

	CERTIFICATION FUEL	COMMERCIAL FUEL
URBAN DRIVING		
HC	REDUCED	*
CO	*	*
NOx	*	*
FUEL ECONOMY	*	*
PARTICULATES	*	*
HIGHWAY DRIVING		
HC	REDUCED	REDUCED
CO	*	*
NOx	*	*
FUEL ECONOMY	*	*

*Statistically nonsignificant at the selected 95 percent confidence level. Statistical nonsignificance may result from many factors such as sample size, confidence level, the fuel additive, the fuel used, vehicle variability and mileage accumulation. Therefore, when the result is nonsignificant, a definite conclusion regarding the effect of the additive cannot be made.

III. TEST VEHICLES

Eight (8) 1984 GMC Sierra utility trucks powered by a 6.2 liter heavy-duty diesel engine were obtained from the City of Los Angeles Department of Water & Power for testing for this evaluation. The odometer readings of the test vehicles ranged from a low of 31,000 to a high of 65,000 miles.

Vehicles supplied by the Los Angeles Department of Water & Power for this test program were inspected by ATDSI personnel for integrity of mechanical condition. Inspection consisted of checking whether the vehicles

have been tampered or not, and if all emission-related components are intact and functioning. Vehicles were accepted when found not tampered and whose emission-related components were intact and functioning. Accepted vehicles received an oil change and filter change (oil, air, and fuel filters), and were inspected and adjusted, if necessary, to OEM specifications prior to testing.

The program was designed to include a fleet of four control vehicles that used untreated fuel in their emission testing and mileage accumulation. The purpose of the control vehicles was to generate test data that would allow quantification of the effects of mileage accumulation and mileage accumulation route on any observed emission reductions. Two of the vehicles in the control fleet utilized "commercial fuel" (vehicles 4B and 8) for all testing and mileage accumulation. The other two control vehicles were fueled with "certification fuel" (vehicles 4 and 2). A mixture of the fuel additive with "commercial fuel" in the proportion of 1 ounce by weight additive to 10 gallons of fuel were used in vehicles 9 and 6. Similarly, a mixture of the fuel additive with "certification fuel" in the prescribed proportion was used in vehicles 3 and 7.

The principal difference between the "commercial fuel" and "certification fuel" used in the program is sulfur content. "Commercial fuel" sold in the SCAB is limited to a maximum sulfur content of 0.05% by weight and generally has a lower aromatic hydrocarbon content than fuels used throughout the remainder of the United States. "Certification fuel" has a specified sulfur content of 0.2 to 0.5 percent by weight and is characteristic of diesel fuel used outside of the SCAB.

To ascertain the immediate effect of the additive, each test truck which was to use the additive was initially tested in duplicate using the

assigned fuel and no additive. A description of the trucks and of the fuel used in each truck is shown in the appendices.

IV. TEST SEQUENCE

Each test truck was subjected to the following test program:

1) Each of the vehicle fuel tanks (two per vehicle) was drained of the fuel delivered in the vehicle and refilled to 40% capacity with base (no additive) "commercial fuel" (vehicles 4B, 9, 8 and 6) or base (no additive) "certification fuel" (vehicles 4, 3, 2 and 7).

2) The truck was preconditioned twice as provided in the CFR, Title 40, Section 86.132-82. The purpose of the double preconditioning cycles was to assure that all fuel contained in the test vehicle's fuel system when it was delivered was flushed from the truck's fuel system.

3) Test personnel replenished the fuel that was used during step 2 with base fuel to maintain the fuel level in the fuel tanks at 40% capacity. The truck was preconditioned as provided in CFR, Title 40, Section 86.132-82 and cold soaked at 68 degree F to 86 degree F for a period of not less than 12 hours or more than 36 hours.

4) Two CVS-75 and HFET tests were performed per CFR, Title 40, Section 86.137-82 using a cold soak between each test series as noted in step 3). Exhaust HC, CO, and NOx emissions and fuel economy were measured on each test. Additionally, each CVS-75 test included a measurement of the exhaust particulate emissions. The fuel level in the tank was maintained at 40% capacity prior to the second CVS-75 and HFET test by addition of base fuel equal to the amount used during the first test.

5) The fuel tanks of each test vehicle were drained of base fuel and filled to 40% capacity with a mixture of "certification fuel"

(vehicles 3 and 7) or "commercial fuel" (vehicles 9 and 6) and fuel additive. The concentration of fuel additive used was 1 ounce by weight to 10 gallons of diesel fuel. The test fuel and additive were mixed using a 55 gallon drum filled to no more than 2/3 capacity. The drum was rolled back and forth vigorously about 30 times to mix the fuel and additive. Vehicles 4 and 2 were fueled with "certification fuel" only (no additive) and vehicles 4B and 8 were fueled with "commercial fuel" only (no additive).

6) Two preconditioning cycles were performed to assure that all untreated fuel was flushed from the truck's fuel system.

7) The fuel level in the test vehicles' (vehicles 9, 6, 3 and 7) fuel tanks was adjusted to 40% of capacity with the same mixture of fuel and fuel additive.

8) As in step 4) above two CVS-75 and HFET tests were performed.

9) The test vehicles' fuel tanks were filled with the proper mixture of fuel and fuel additive. The trucks were then driven on the road following the route outlined in Appendix B until 500 miles were accumulated. The trucks were stopped and the engine shut down for five (5) minutes at the completion of every loop. If fuel was added to the trucks' (vehicles 9, 6, 3 and 7) fuel tanks during mileage accumulation, the added fuel was of the proper mixture of fuel and fuel additive.

10) The fuel tanks were drained and refilled to 40% capacity with the appropriate mixture.

11) The truck was preconditioned as provided in CFR, Title 40, Section 186.132-82.

12) Two CVS-75 and HFET tests were performed as described in step 4) above.

13) Steps 9) through 12) were repeated in 500 mile increments and each test truck accumulated a total of 1,500 miles.

Testing for the control vehicles (vehicles 4B, 8, 4 and 2) followed the same procedure except that the fuel used during steps 5) through 13) did not contain any fuel additive.

Mileage accumulation on all vehicles was conducted using the assigned fuel, commercial or certification, with or without additive, as appropriate. The fuel additive evaluated was supplied in a 1 gallon bottle by Omstar.

Duplicate tests were performed on consecutive days when possible. In two cases, a long period of time elapsed between duplicate tests. In testing vehicle 4B, the first baseline test was made on November 28, 1988, and the second made on February 2, 1989. In testing vehicle 8, the 0-mile tests were separated by 1-1/2 months. In both cases, tests were separated because of emission test equipment failure that required about a month to repair. The second tests could not be performed until the reliability of the repaired equipment was established through quality control checks per procedures set forth in the federal test procedures. In addition, several pairs of duplicate tests were separated by a few days because of tests aborted, not completed, or cancelled due to other laboratory commitments.

V. EMISSIONS TEST RESULTS

The emissions and fuel economy data for the eight vehicles tested in the evaluation are summarized in Appendix C. Tables 1, 2, 3, 4, 5, 6, 7, and 8 summarize the data from vehicles 4B, 9, 8, 6, 4, 3, 2, and 7, respectively. Also shown in the tables are the percentage change in emissions, compared to the baseline emission levels, at each of the test points.

VI. FUEL COMPOSITION

All of the testing conducted with certification fuel used the same batch of fuel, except for the two 1500-mile tests performed on control Vehicle

No. 2 (VIN 521624). These two tests had to be performed using a different batch of fuel because the first batch of fuel was depleted. The first batch of fuel was supplied by Phillips Petroleum while the second batch was supplied by Howell Petroleum. The data in Table 7 of Appendix C indicate that the effect of fuel variations on emissions is insignificant.

Similarly, the testing conducted with commercial fuel used two batches of fuel purchased on different dates from a local Shell service station. The first batch was purchased at the onset of the testing of the commercial-fueled fleet. This batch of fuel was used for all emission tests and mileage accumulation performed prior to February 1, 1989. They included tests on the vehicles as specified below:

1. Test Vehicle 4B - first baseline test only.
2. Test Vehicle 9 - baseline tests only.
3. Test Vehicle 8 - baseline and first 0-mile test.
4. Test Vehicle 6 - baseline and first 0-mile test.

The second batch of fuel was purchased on February 1, 1989. The second batch was necessary because of limited fuel storage capacity at the test facility.

VII. FUEL ANALYSIS

The staff did not analyze the fuel from the first batch. However, analysis was done on the second batch. Three diesel fuel samples were analyzed for basic fuel properties. The samples are identified as "Commercial Fuel From Truck 4B", "Commercial Fuel From Same Pump", and "Certification Fuel", which were sent to E. W. Saybolt & Co., Inc., in Wilmington, California for analysis. The sample identified as "Commercial Fuel From Same Pump" was obtained at the completion of the vehicle tests from the Shell Oil Company service station that supplied the commercial fuel used for the tests. The sample was purchased to check on the variability of the commercial fuel used.

Each of the fuel samples was analyzed for sulfur content, flash point, cetane number and distillation curve. The results of the fuel analysis (see Appendix E) show that properties were similar.

VIII. CHEMICAL ANALYSIS

The ARB laboratory performed a chemical analysis of various samples of Omstar diesel fuel additive D-1280X. Samples were taken at the beginning and end of the test program, from a 1 gallon bottle of additive supplied by Omstar. Additionally, samples were obtained independently from 55-gallon drums Omstar supplied to General Petroleum and Hudson General (users of the Omstar additive), and Southern California Rapid Transit District for analysis. Gas chromatograph/mass spectrometer detector analysis indicated that all the Omstar additive D-1280X samples analyzed contained a mixture of methyl esters of fatty acids (C9 to C19). The principal components of all the samples analyzed were methyl dodecanoate with concentrations ranging from 50% to 62% and methyl tetradecanoate with concentrations ranging from 19% to 24%. The additive evaluated by the ARB contained 62% methyl dodecanoate and 24% methyl tetradecanoate. The analysis clearly established that the additive evaluated by the ARB was the same as the additive evaluated by General Petroleum, Hudson General and Southern California Rapid Transit District.

IX. STATISTICAL EVALUATION

A statistical analysis was performed to determine the effect of the fuel additive on vehicle emissions and fuel economy. The change in vehicle emissions and fuel economy can be attributed to various parameters - fuel additive, mileage accumulation, and test vehicle. Since the Student's t-test can not separate these effects, it is not appropriate for the analysis. The analysis of variance (ANOVA) method was used in which these effects are separated and their statistical significance determined. The 95% confidence level is used to determine the statistical significance of the various

effects. This is a standard practice which has been widely accepted by industry, government agencies, and persons involved in the field of vehicle emissions testing.

"Certification fuel" is representative (sulfur and aromatic content) of fuel generally available nationwide. The exception is in the SCAB where "commercial fuel" is limited to a much lower maximum sulfur content of 0.05 percent by weight. The statistical analysis was performed for both fuels.

At 95 percent confidence level, the results of the statistical analysis indicate that when used with "certification fuel" the effect of the fuel additive on CVS-75 HC and HFET HC emissions is statistically significant. All other changes in measured data including fuel economy, CO, NOx, and particulates were not statistically significant. (See Appendix D.)

The results of the statistical analysis at 95 percent confidence level also indicate that when used with "commercial fuel" the effect of the fuel additive on HFET HC emissions is statistically significant. All other changes in measured data including CVS-75 HC emissions, fuel economy, CO, NOx, and particulates were not statistically significant. (See Appendix D.)

X. DISCUSSION

From the test data collected in this evaluation of Omstar's diesel fuel additive D-1280X, the benefit of the additive was statistically apparent at 95 percent confidence level in three test results: reducing HFET HC emissions when blended in low sulfur "commercial fuel", reducing CVS-75 HC when blended in "certification fuel" and reducing HFET HC emissions when blended in "certification fuel". All other test results (CO, NOx, particulate, fuel economy and CVS-75 HC for commercial fuel) were statistically nonsignificant at the selected 95 percent confidence level.

The "commercial fuel" used in this program is limited by regulation to a sulfur content of 0.05% by weight. The actual sulfur content of the fuel

used was 0.016% by weight. This low sulfur content fuel is presently sold only in the SCAB area. It should, however, be noted that ARB has adopted regulations which will limit the sulfur content of diesel fuel to 0.05% by weight statewide beginning October, 1993. EPA is also considering limiting sulfur content to 0.05% by weight for diesel fuel sold in the other 49 states, to be implemented in 1993. For the remainder of the state and the other 49 states a sulfur content limit of 0.5% by weight is currently in effect (similar to specifications for the "certification fuel" used in this test program). The actual sulfur content of the "certification fuel" used was 0.38% by weight.

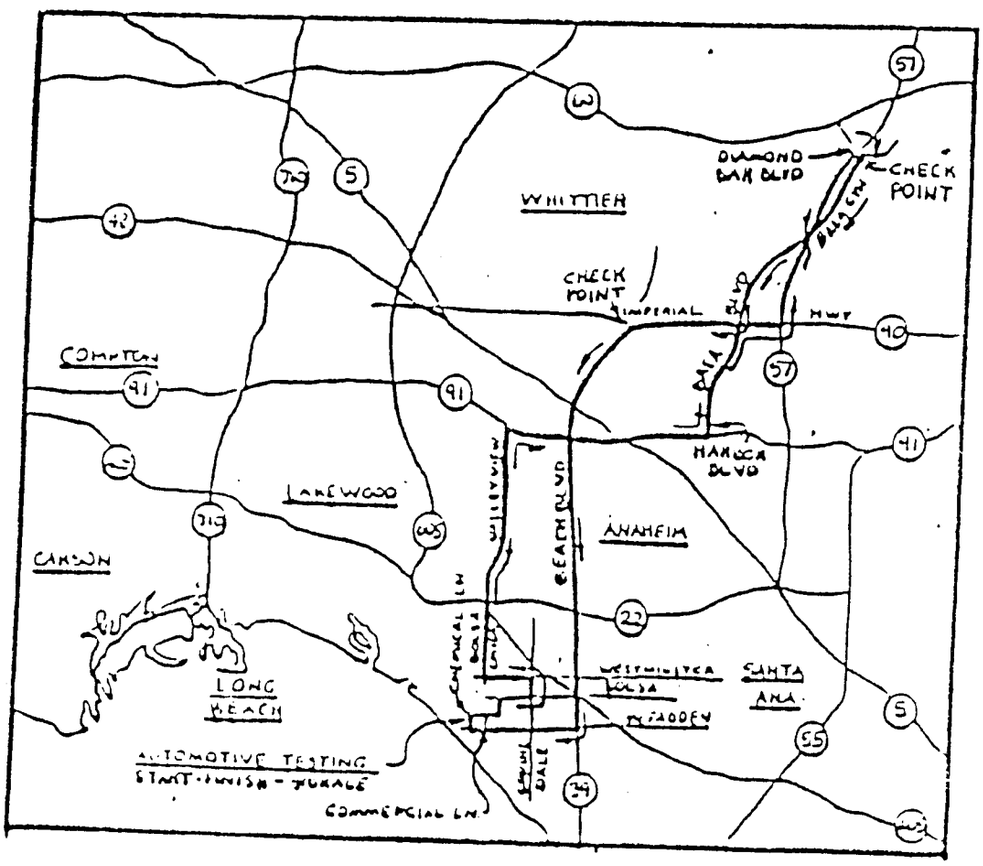
Quality control checks of the contractor's test equipment by the ARB staff were performed to assure reliability of the test results. They included periodical checks of the contractor's gaseous emissions measurement equipment by the ARB Quality Control staff as well as by the contractor's personnel. Additionally, the ARB conducted a correlation crosscheck between ARB's test facility and the contractor's test facility particulate measurement equipment. The quality control checks showed that the contractor's data are reliable.

APPENDICES

EVALUATION OF OMSTAR DIESEL FUEL ADDITIVE D-1280X
DESCRIPTION OF TEST VEHICLES

	Commercial Control 1	Commercial Additive 1	Commercial Control 2	Commercial Additive 2
Make:	GMC	GMC	GMC	GMC
Model-Year:	1984	1984	1984	1984
Model:	Sierra	Sierra	Sierra	Sierra
VIN:	521567	322580	522071	522350
Engine Displacement:	6.2 L	6.2 L	6.2 L	6.2 L
Odometer:	38,414	31,618	33,545	49,567
Test Veh. No.:	4B	9	8	6
Inertia Weight (lbs.):	7,500	8,000	8,000	8,000
Dyno Road HP (hp):	18.2	18.3	18.3	18.3
Base Fuel:	Commercial	Commercial	Commercial	Commercial

	Cert. Control 1	Cert. Additive 1	Cert. Control 2	Cert. Additive 2
Make:	GMC	GMC	GMC	GMC
Model-Year:	1984	1984	1984	1984
Model:	Sierra	Sierra	Sierra	Sierra
VIN:	521567	521824	521624	516289
Engine Displacement:	6.2 L	6.2 L	6.2 L	6.2 L
Odometer:	36,351	64,192	50,763	24,348
Test Veh. No.:	4	3	2	7
Inertia Weight (lbs.)	7,500	7,500	7,500	8,500
Dyno Road HP (hp):	18.2	18.2	18.2	18.4



URBAN MILEAGE ACCUMULATION ROUTE

Table 1
Omstar Fuel Additive D-1280X
Exhaust Emission Results
1984 GMC Sierra
(Test Veh. No. 4B - VIN 521567)
(Commercial - Control 1)

	CVS-75 (g/mi)					HFET (g/mi)			
Test Point	HC	CO	NOx	F.E.	Part.	HC	CO	NOx	F.E.
Baseline	0.14	1.19	3.70	15.75	0.298	0.13	0.81	2.81	19.15
Baseline	0.14	1.17	3.21	15.84	0.245	0.10	0.80	2.60	19.11
Average	0.14	1.18	3.46	15.80	0.271	0.12	0.80	2.71	19.13
0-mile	0.19	1.22	3.23	15.58	0.275	0.10	0.81	2.50	18.75
0-mile	0.12	1.18	3.13	15.59	0.233	0.12	0.84	2.45	18.99
Average	0.15	1.20	3.18	15.58	0.254	0.11	0.82	2.47	18.87
% Change	+10	+2	-8	-1	-6	-6	+3	-9	-1
500-mile	0.16	1.19	2.96	15.93	0.225	0.11	0.88	2.56	19.30
500-mile	0.18	1.28	3.16	15.70	0.242	0.12	0.92	2.63	18.34
Average	0.17	1.24	3.06	15.82	0.234	0.12	0.90	2.60	18.82
% Change	+20	+5	-11	+0	-14	+0	+12	-4	-2
1000-mile	0.16	1.00	2.86	15.75	0.273	0.12	0.93	2.38	18.83
1000-mile	0.22	1.34	2.97	15.75	0.256	0.12	0.90	2.51	18.75
Average	0.19	1.17	2.91	15.75	0.265	0.12	0.91	2.44	18.79
% Change	+34	-1	-16	+0	-2	+0	+22	-10	-0
1500-mile	0.22	1.41	3.29	15.62	0.267	0.13	0.93	2.52	19.16
1500-mile	0.24	1.36	3.11	15.86	0.290	0.15	0.98	2.63	19.09
Average	0.23	1.38	3.20	15.74	0.279	0.14	0.95	2.57	19.12
% Change	+62	+17	-7	-0	+3	+19	+19	-5	-0

NOTE: $\%\ \text{Change} = \left(\frac{\text{average x mile value} - \text{average baseline value}}{\text{average baseline value}}\right) \times 100$

Table 2
Omstar Fuel Additive D-1280X
Exhaust Emission Results
1984 GMC Sierra
(Test Veh. No. 9 - VIN 322580)
(Commercial + Additive 1)

	CVS-75 (g/mi)					HFET (g/mi)			
Test Point	HC	CO	NOx	F.E.	Part.	HC	CO	NOx	F.E.
Baseline	0.14	1.12	4.31	14.78	0.285	0.19	0.77	3.29	18.37
Baseline	0.10	1.06	4.27	15.69	0.267	0.18	0.74	3.33	18.97
Average	0.12	1.09	4.29	15.23	0.276	0.18	0.75	3.31	18.67
0-mile	0.12	1.00	4.72	15.44	0.269	0.13	0.77	3.44	18.41
0-mile	0.10	1.01	4.53	15.67	0.269	0.13	0.69	3.45	18.50
Average	0.11	1.01	4.63	15.55	0.269	0.13	0.73	3.44	18.46
% Change	-6	-8	+8	+2	-3	-28	-3	+0	-1
500-mile	0.08	0.97	4.52	15.58	0.278	0.10	0.68	3.42	18.44
500-mile	0.08	1.02	4.70	15.64	0.302	0.09	0.68	3.53	18.77
Average	0.08	0.99	4.61	15.61	0.290	0.10	0.68	3.47	18.60
% Change	-32	-9	+7	+2	+5	-46	-10	+5	-0
1000-mile	0.11	1.08	4.57	15.20	0.279	0.10	0.71	3.51	18.66
1000-mile	0.11	1.03	4.63	15.50	0.385	0.10	0.73	3.72	18.12
Average	0.11	1.05	4.60	15.35	0.332	0.10	0.72	3.61	18.39
% Change	-6	-3	+7	+1	+20	-45	-4	+9	-1
1500-mile	0.11	1.06	4.72	15.88	0.254	0.10	0.74	3.87	18.81
1500-mile	0.11	1.10	4.56	15.79	0.289	0.11	0.75	3.53	18.66
Average	0.11	1.08	4.64	15.83	0.272	0.10	0.74	3.70	18.75
% Change	-5	-1	+8	+4	-2	-44	-2	+12	+0

NOTE: $\%\ \text{Change} = \left(\frac{\text{average x mile value} - \text{average baseline value}}{\text{average baseline value}}\right) \times 100$

Table 3
Omstar Fuel Additive D-1280X
Exhaust Emission Results
1984 GMC Sierra
(Test Veh. No. 8 - VIN 522071)
(Commercial - Control 2)

	CVS-75 (g/mi)					HFET (g/mi)			
Test Point	HC	CO	NOx	F.E.	Part.	HC	CO	NOx	F.E.
Baseline	0.33	1.57	3.76	13.34	0.354	0.28	1.11	2.90	15.19
Baseline	0.29	1.41	3.95	13.92	0.276	0.25	1.02	2.91	15.75
Baseline	0.31	1.49	3.86	13.63	0.315	0.26	1.06	2.91	15.47
0-mile	0.28	1.42	4.00	14.00	0.237	0.18	0.88	2.90	16.90
0-mile	0.27	1.49	4.04	13.54	0.289	0.11	0.78	3.06	19.10
Average	0.28	1.46	4.02	13.77	0.263	0.15	0.83	2.98	18.00
% Change	-11	-2	+4	+1	-17	-43	-22	+3	+16
500-mile	0.26	1.46	4.18	13.73	0.252	0.16	0.86	3.49	16.74
500-mile	0.25	1.35	4.04	13.88	0.275	0.17	0.86	2.97	17.37
Average	0.26	1.41	4.11	13.81	0.264	0.17	0.86	3.23	17.06
% Change	-9	-4	+2	+1	-16	-38	-19	+11	+10
1000-mile	0.27	1.46	4.35	13.57	0.306	0.18	0.93	3.13	16.38
1000-mile	0.28	1.44	4.06	14.38	0.270	0.18	0.96	2.71	19.92
Average	0.28	1.45	4.20	13.98	0.288	0.18	0.94	2.92	18.15
% Change	-10	-3	+9	+2	-9	-32	-11	+0	+17
1500-mile	0.29	1.51	3.95	13.46	0.320	0.15	0.90	3.07	16.63
1500-mile	0.26	1.49	3.96	13.61	0.293	0.16	0.87	3.01	16.59
Average	0.28	1.50	3.95	13.53	0.307	0.16	0.88	3.04	16.61
% Change	-10	+1	+3	-1	-3	-41	-17	+4	+7

NOTE: $\%\ \text{Change} = \left(\frac{\text{average x mile value} - \text{average baseline value}}{\text{average baseline value}}\right) \times 100$

Table 4
Omstar Fuel Additive D-1280X
Exhaust Emission Results
1984 GMC Sierra
(Test Veh. No. 6 - VIN 522350)
(Commercial + Additive 2)

Test Point	CVS-75 (g/mi)					HFET (g/mi)			
	HC	CO	NOx	F.E.	Part.	HC	CO	NOx	F.E.
Baseline	0.21	1.20	3.62	15.00	0.233	0.21	0.97	2.74	18.27
Baseline	0.21	1.24	3.55	14.96	0.249	0.22	0.99	2.77	18.21
Average	0.21	1.22	3.59	14.98	0.241	0.22	0.98	2.76	18.24
0-mile	0.17	1.20	3.45	14.83	0.248	0.18	0.94	2.70	17.98
0-mile	0.18	1.25	3.77	14.68	0.264	0.18	0.98	2.86	18.04
Average	0.18	1.24	3.61	14.76	0.256	0.18	0.96	2.78	18.01
% Change	-18	+1	+1	-2	+6	-16	-2	+1	-1
500-mile	0.17	1.25	3.42	14.88	0.252	0.13	1.03	2.73	18.10
500-mile	0.21	1.34	3.50	15.34	0.228	0.18	1.15	2.55	21.80
Average	0.19	1.30	3.46	15.11	0.240	0.16	1.09	2.64	19.95
% Change	-11	+6	-3	+1	-0	-28	+11	-4	+9
1000-mile	0.12	1.29	3.48	14.85	0.284	0.11	0.93	2.80	18.03
1000-mile	0.17	1.30	3.26	14.53	0.263	0.13	0.98	2.46	17.99
Average	0.14	1.29	3.37	14.69	0.274	0.12	0.95	2.63	18.01
% Change	-34	+6	-6	-2	+13	-43	-3	-4	-1
1500-mile	0.16	1.27	3.58	14.93	0.246	0.11	0.96	2.61	18.51
1500-mile	0.15	1.23	3.41	14.94	0.264	0.12	0.91	2.88	17.83
Average	0.15	1.25	3.49	14.93	0.255	0.12	0.94	2.75	18.17
% Change	-29	+3	-3	-0	+6	-46	-5	-0	-0

NOTE: $\%\ \text{Change} = \left(\frac{\text{average x value} - \text{average baseline value}}{\text{average baseline value}}\right) \times 100$

Table 5
Omstar Fuel Additive D-1280X
Exhaust Emission Results
1984 GMC Sierra
(Test Veh. No. 4 - VIN 521567)
(Certification - Control 1)

	CVS-75 (g/mi)					HFET (g/mi)			
Test Point	HC	CO	NOx	F.E.	Part.	HC	CO	NOx	F.E.
Baseline	0.10	1.40	3.65	13.78	0.365	0.16	0.97	3.27	15.61
Baseline	0.07	1.35	3.87	14.18	0.289	0.23	1.05	3.26	16.74
Average	0.09	1.38	3.76	13.98	0.327	0.20	1.01	3.27	16.18
0-mile	0.12	1.51	3.52	14.18	0.380	0.17	1.02	3.06	16.71
0-mile	0.09	1.47	3.65	14.39	0.435	0.21	1.01	2.98	18.95
Average	0.11	1.49	3.59	14.29	0.408	0.19	1.02	3.02	17.83
% Change	+22	+8	-5	+2	+25	-5	+1	-8	+10
500-mile	0.22	1.40	3.27	15.95	0.308	0.26	0.95	2.89	19.45
500-mile	0.25	1.34	3.33	15.38	0.320	0.28	0.95	2.75	18.77
Average	0.24	1.37	3.30	15.67	0.314	0.27	0.95	2.82	19.11
% Change	+167	-1	-12	+12	-4	+35	-6	-14	+18
1000-mile	0.16	1.29	3.37	16.00	0.282	0.31	0.92	2.73	19.21
1000-mile	0.10	1.37	3.36	15.33	0.360	0.33	1.10	2.79	18.90
Average	0.13	1.33	3.37	15.67	0.321	0.32	1.01	2.76	19.06
% Change	+44	-11	-10	+12	-2	+60	+0	-16	+18
1500-mile	0.17	1.27	3.30	15.31	0.289	0.18	0.88	2.82	19.17
1500-mile	0.15	1.27	3.07	15.99	0.283	0.16	0.82	2.62	19.59
Average	0.16	1.27	3.19	15.65	0.286	0.17	0.85	2.72	19.38
% Change	+78	-8	-15	+12	-12	-15	-16	-17	+20

NOTE: $\%\ \text{Change} = \left(\frac{\text{average x mile value} - \text{average baseline value}}{\text{average baseline value}}\right) \times 100$

Table 6
Omstar Fuel Additive D-1280X
Exhaust Emission Results
1984 GMC Sierra
(Test Veh. No. 3 - VIN 521824)
(Certification + Additive 1)

	CVS-75 (g/mi)					HFET (g/mi)			
Test Point	HC	CO	NOx	F.E.	Part.	HC	CO	NOx	F.E.
Baseline	0.18	1.68	5.35	14.20	0.441	0.18	1.08	4.25	17.09
Baseline	0.24	1.77	5.03	14.03	0.443	0.26	1.28	3.94	19.73
Average	0.21	1.73	5.19	14.12	0.442	0.22	1.18	4.10	18.41
0-mile	0.14	1.87	4.54	15.35	0.499	0.16	1.17	3.89	19.78
0-mile	0.17	1.90	4.65	15.48	0.410	0.22	1.25	3.82	20.20
Average	0.16	1.89	4.60	15.42	0.454	0.19	1.21	3.86	19.99
% Change	-24	+10	-11	+9	+3	-14	+3	-6	+9
500-mile	0.21	1.60	4.56	15.70	0.391	0.17	1.03	3.82	20.78
500-mile	0.19	1.63	4.77	15.14	0.389	0.17	1.10	3.89	18.97
Average	0.20	1.62	4.67	15.42	0.390	0.17	1.07	3.86	19.88
% Change	-5	-6	-10	+9	-12	-23	-9	-6	+8
1000-mile	0.12	1.56	4.75	15.61	0.421	0.22	0.97	3.72	19.62
1000-mile	0.10	1.61	4.70	15.36	0.430	0.21	0.94	3.88	19.04
Average	0.11	1.59	4.73	15.49	0.426	0.22	0.96	3.80	19.33
% Change	-48	-8	-9	+10	-4	+0	-19	-7	+5
1500-mile	0.22	1.58	5.24	15.42	0.377	0.12	0.93	4.02	19.85
1500-mile	0.13	1.56	4.92	15.44	0.367	0.11	0.92	3.90	19.79
Average	0.18	1.57	5.08	15.43	0.372	0.12	0.93	3.96	19.82
% Change	-14	-9	-2	+9	-16	-45	-21	-3	+8

NOTE: $\%\ \text{Change} = \left(\frac{\text{average x mile value} - \text{average baseline value}}{\text{average baseline value}}\right) \times 100$

Table 7
Omstar Fuel Additive D-1280X
Exhaust Emission Results
1984 GMC Sierra
(Test Veh. No. 2 - VIN 521624)
(Certification - Control 2)

	CVS-75 (g/mi)					HFET (g/mi)			
Test Point	HC	CO	NOx	F.E.	Part.	HC	CO	NOx	F.E.
Baseline	0.11	1.06	5.48	15.80	0.363	0.11	0.76	4.34	19.26
Baseline	0.12	1.19	5.57	15.82	0.380	0.11	0.75	4.60	19.24
Average	0.11	1.13	5.52	15.81	0.372	0.11	0.76	4.47	19.25
0-mile	0.10	1.18	5.82	15.55	0.398	0.12	0.77	4.45	19.09
0-mile	0.12	1.21	5.46	15.48	0.420	0.12	0.77	4.58	18.69
Average	0.11	1.20	5.64	15.52	0.409	0.12	0.77	4.51	18.89
% Change	-2	+6	+2	-2	+10	+3	+1	+1	-2
500-mile	0.12	1.15	4.98	15.59	0.384	0.10	0.78	4.06	19.00
500-mile	0.11	1.22	5.08	15.13	0.354	0.11	0.76	4.09	18.37
Average	0.11	1.18	5.03	15.36	0.369	0.11	0.77	4.08	18.68
% Change	-0	+5	-9	-3	-1	-4	+1	-9	-3
1000-mile	0.12	1.07	5.07	14.17	0.412	0.10	0.70	4.02	18.83
1000-mile	0.12	1.25	5.09	15.03	0.318	0.08	0.71	4.03	18.91
Average	0.12	1.16	5.08	14.60	0.365	0.09	0.70	4.03	18.87
% Change	+4	+3	-8	-7	-2	-19	-7	-10	-2
1500-mile	0.08	1.18	5.00	14.88	0.401	0.10	0.69	4.02	18.96
1500-mile	0.15	1.24	5.10	15.19	0.366	0.09	0.67	4.17	19.17
Average	0.12	1.21	5.05	15.03	0.384	0.10	0.68	4.09	19.06
% Change	+2	+7	-9	-5	+3	-15	-11	-8	+1

NOTE: $\%\ \text{Change} = \left(\frac{\text{average x mile value} - \text{average baseline value}}{\text{average baseline value}}\right) \times 100$

Table 8
Omstar Fuel Additive D-1280X
Exhaust Emission Results
1984 GMC Sierra
(Test Veh. No. 7 - VIN 516289)
(Certification + Additive 2)

Test Point	CVS-75 (g/mi)					HFET (g/mi)			
	HC	CO	NOx	F.E.	Part.	HC	CO	NOx	F.E.
Baseline	0.35	1.52	4.61	12.73	0.315	0.33	1.30	3.20	14.56
Baseline	0.27	1.51	4.21	13.22	0.277	0.30	1.32	3.14	14.79
Average	0.31	1.52	4.41	12.98	0.296	0.32	1.31	3.17	14.68
0-mile	0.19	1.46	4.42	13.04	0.348	0.34	1.40	2.88	14.58
0-mile	0.28	1.36	4.77	13.43	0.326	0.30	1.13	3.26	15.22
Average	0.24	1.41	4.60	13.24	0.337	0.32	1.27	3.07	14.90
% Change	-23	-7	+4	+2	+14	-4	-3	-3	+2
500-mile	0.18	1.34	4.83	13.17	0.326	0.21	0.97	3.28	15.57
500-mile	0.07	1.27	4.14	13.27	0.401	0.12	1.02	3.08	15.11
Average	0.13	1.30	4.49	13.22	0.364	0.17	1.00	3.18	15.34
% Change	-60	-14	+2	+2	+22	-47	-24	+0	+5
1000-mile	0.17	1.23	4.66	13.25	0.233	0.19	1.04	3.11	15.42
1000-mile	0.18	1.25	4.40	13.33	0.288	0.20	1.02	3.28	15.15
Average	0.17	1.23	4.53	13.29	0.261	0.20	1.03	3.19	15.28
% Change	-44	-19	+3	+2	-12	-39	-21	+1	+4
1500-mile	0.16	1.25	4.36	13.33	0.267	0.17	0.91	3.51	15.14
1500-mile	0.18	1.33	4.33	13.41	0.300	0.17	0.93	3.42	15.20
Average	0.17	1.29	4.35	13.37	0.284	0.17	0.92	3.46	15.17
% Change	-44	-15	-1	+3	-4	-48	-30	+9	+3

NOTE: $\%\ \text{Change} = \left(\frac{\text{average x mile value} - \text{average baseline value}}{\text{average baseline value}}\right) \times 100$

EVALUATION OF OMSTAR DIESEL FUEL ADDITIVE D-1280X
STATISTICAL ANALYSIS
RESULTS OF ANALYSIS OF VARIANCE FOR EFFECT OF ADDITIVE
(at 95% Confidence Level)

	Certification Fuel		Commercial Fuel	
	N	Prob(F)[a]	N	Prob(F)[a]
CVS-75 HC	40	0.0023**	40	0.0570
CVS-75 CO	40	0.2938	40	0.4865
CVS-75 NOx	40	0.8601	40	0.1491
CVS-75 FE	40	0.0790	40	0.7159
CVS-75 PART	40	0.3447	40	0.4825
HFET HC	40	0.0448**	40	0.0030**
HFET CO	40	0.0512	40	0.2586
HFET NOx	40	0.5416	40	0.4440
HFET FE	40	0.3819	40	0.8252

[a]Probability of no effect
** Significant at 95% confidence level

EVALUATION OF OMSTAR DIESEL FUEL ADDITIVE D-1280X
FUEL ANALYSIS

	ASTM	Comm. Fuel (1)	Comm. Fuel (2)	Cert. Fuel (3)	Cert. Fuel (4)
Distillation Deg. F.	D-86				
IBP		370	344	367	380
10%		450	424	427	420
20%		484	454	447	434
30%		510	484	472	448
40%		530	504	490	460
50%		552	534	509	470
60%		570	546	525	492
70%		590	570	544	514
80%		610	592	565	550
90%		636	620	593	590
95%		659	640	623	624
E.P.%		668	658	645	656
Recov. %		98.0	98.5	-	98.0
Residue %		1.0	1.5	-	1.5
Loss %		1.0	0	-	0.5
Cetane #	D-613	45.3	46.0	44.8	48.4
Sulfur % by weight	D-4294	0.016	0.01	0.38(5)	0.26
PM Flash point Deg. F.	D-93	160	150	161	150

(1): Fuel obtained from truck number 4B at the completion of the test program.
(2): Fuel obtained from same Shell Oil Company gas station where fuel for tests were procured. Fuel was obtained after the completion of the tests.
(3): Fuel specifications supplied by Phillips Petroleum. This fuel was used for all tests performed on vehicles fueled with certification diesel fuel, except for 1500-mile tests performed on truck number 2.
(4): Fuel purchased from Howell Petroleum for 1500-mile tests performed on truck number 2. This replacement fuel was supplied by the ARB to the contractor because their supply of certification test fuel was depleted.
(5): Phillips Petroleum used ASTM method D-3120 for determining sulfur percent.