

Testing of Five Diesel-Powered Passenger Cars
at High and Low Altitude

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Abstract

A group of five in-use diesel-powered passenger cars was tested for emissions and fuel economy at both high altitude and low altitude locations. The test sequence consisted of the current Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET). Particulate emissions were also measured over both cycles at both locations. On the average, a substantial increase was noted at high altitude for hydrocarbons, carbon monoxide and particulates as compared to the low altitude measurements. As measured over the FTP, the average increases for these three pollutants were 130%, 75% and 45% respectively. Results of the HFET were in the same direction but were of a slightly smaller magnitude. The emission levels of oxides of nitrogen were approximately the same at each location. The average fuel economy values at high altitude were approximately 14% lower than those at low altitude.

Background

Although the diesel engine has long been used as a powerplant for commercial vehicles, its application to passenger cars had been limited due to factors such as weight, noise and cost. The changing economic and political situation has recently made this concept more feasible. Although several manufacturers, such as Mercedes-Benz and Peugeot, have been in the market for some time, the diesel engines recently introduced by Oldsmobile and Volkswagen have quickly gained a small but growing share of new-car sales. Because the potential exists for widespread use of diesel engines in all parts of the country, there is a need to obtain information concerning the emission levels of these vehicles when operated at high altitude locations.

Purpose

The purpose of this project was to assess the effect of altitude on the emission characteristics of diesel-powered, in-use passenger cars. This information will be used to project the emission characteristics of the high altitude fleet as well as for evaluation of new or expanded standards.

Program Design

This program was developed to test a sample of vehicles at low altitude and subsequently at high altitude. The low altitude testing was performed at EPA's Motor Vehicle Emission Laboratory (MVEL) in Ann Arbor. Testing at high altitude was performed by Automotive Testing Laboratories (ATL) in Aurora, CO. The vehicles were tested at each location without mileage accumulation or adjustments between the test sequences. The same fuel was also used at both locations. The test sequences consisted of the current Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET). Particulate emissions were also measured during each of these driving cycles.

The vehicles chosen for this program represented the more common diesel engine passenger cars available to the consumer. All were in daily use by private owners at the time they were recruited into the program. The characteristics of the test vehicles are as follows:

- #241 1980 Volkswagen Rabbit: 4 cylinder; 90 CID; Manual 5 speed; VIN-17A0815408; Engine Family-D; Odometer-5579
- #242 1979 Oldsmobile Cutlass Supreme: 8 cylinder; 260 CID; Automatic transmission; VIN-3R47P9M535761; Engine Family-930H9; Odometer-8930
- #243 1979 Oldsmobile Cutlass Supreme: 8 cylinder; 260 CID; Automatic transmission; VIN-3R47P9M540008; Engine Family-930H9; Odometer-13301
- #244 1974 Peugeot 504: 4 cylinder; 129 CID; Manual 4 speed; VIN 504D90-1759613; Odometer-73252
- #245 1977 Mercedes Benz 240D: 4 cylinder; 147 CID; Automatic transmission; VIN-123.123-12015320; Engine Family-77/2/L-4D/2.4; Odometer-52206

Conduct of the Program

The responsibility for the project was assigned to Automotive Testing Laboratories in April, 1980, under EPA contract No. 68-03-2891. They arranged for the procurement of the vehicles through a leasing firm in St. Louis. The vehicles were shipped to Ann Arbor in May. Upon arrival at the MVEL, each vehicle was inspected to insure it was in proper operating order. Two or three test sequences were performed on each vehicle to obtain the low-altitude baseline. The vehicles were then shipped to the Denver area for testing by ATL at their laboratory in Aurora. Identical test procedures using equivalent test equipment were performed there in July. No maintenance or adjustments were performed on any vehicle before testing at the high-altitude location.

Test Results

The average FTP emission levels for each vehicle at each location are shown in Table 1. Results from the HFET are displayed in Table 2. A listing of all test results on each vehicle is attached as Appendices A and B while ATL's report on the program (Reference 1) contains details on the test procedures.

Table 1

Average FTP Emission Levels of Diesel-Powered Passenger Cars

<u>Vehicle</u>	<u>Test Site</u>	<u>HC (g/mi)</u>	<u>CO (g/mi)</u>	<u>NOx (g/mi)</u>	<u>F.E. (mi/gal)</u>	<u>Part. (g/mi)</u>
#241 80 Volkswagen 90 CID Odometer-5579	High	.57	1.88	1.09	35.3	.40
	Low	.22	.78	1.05	39.5	.26
#242 79 Olds 260 CID Odometer-8930	High	1.39	2.21	1.29	20.5	.98
	Low	.68	1.50	1.43	22.9	.78
#243 79 Olds 260 CID Odometer-13301	High	.97	2.57	1.56	20.6	1.82
	Low	.39	1.49	1.67	24.2	1.13
#244 74 Peugeot 129 CID Odometer-73252	High	6.74	8.88	.98	21.0	2.43
	Low	3.86	3.83	.93	25.2	2.43
#245 77 Mercedes 147 CID Odometer-52206	High	.65	1.04	1.51	25.8	.47
	Low	.25	.67	1.29	31.8	.36
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Average (all vehicles)	High	2.06	3.32	1.28	23.6	1.22
	Low	1.08	1.65	1.27	27.6	.69
Increase		91%	101%	1%	-14%	78%
Average (without #244)	High	.89	1.93	1.36	24.3	.92
	Low	.38	1.11	1.36	28.2	.63
Increase		134%	74%	0%	-14%	46%

Table 2

Average HFET Emission Levels of Diesel-Powered Passenger Cars

<u>Vehicle</u>	<u>Test Site</u>	<u>HC (g/mi)</u>	<u>CO (g/mi)</u>	<u>NOx (g/mi)</u>	<u>F.E. (mi/gal)</u>	<u>Part. (g/mi)</u>
#241 80 Volkswagen 90 CID	High	.35	1.42	.81	42.7	.34
	Low	.13	.47	.73	51.8	.19
#242 79 Olds 260 CID	High	.47	1.04	1.20	28.5	.72
	Low	.29	.79	1.23	32.0	.48
#243 79 Olds 260 CID	High	.36	1.27	1.45	29.1	1.12
	Low	.22	.82	1.59	33.6	.74
#244 74 Peugeot 129 CID	High	1.87	3.55	1.08	25.9	.69
	Low	1.44	1.70	.88	33.1	.38
#245 77 Mercedes 147 CID	High	.26	.63	1.68	28.3	.23
	Low	.13	.57	1.42	33.5	.36
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Average (all vehicles)	High	.66	1.58	1.24	30.0	.62
	Low	.44	.87	1.17	35.6	.43
Increase		50%	82%	6%	-16%	44%
Average (without #244)	High	.36	1.09	1.29	31.2	.60
	Low	.19	.66	1.24	36.3	.44
Increase		89%	65%	4%	-14%	36%

Discussion of Test Results

As seen in Tables 1 and 2, the emission levels of unburned hydrocarbons (HC), carbon monoxide (CO) and particulates for each vehicle were substantially greater at high altitude. Despite this increase, the average levels for three of the vehicles are still below the standards under which they were certified. In the case of the 1980 Volkswagen, however, the effect of altitude on HC emissions put it over its .41 g/mi standard. The 1974 Peugeot failed HC at both altitudes. Although the emission levels of oxides of nitrogen (NOx) increased very slightly, the scatter in the data implies that the overall change in emissions of this pollutant may not be significant. Since vehicle No. 244, the 1974 Peugeot, was so different from the rest, in age, appearance and performance, the possibility exists that it had been improperly maintained. It could be concluded that this vehicle may not be representative of the current fleet. Therefore, the averages have also been calculated without its results. These values are also shown on Tables 1 and 2. For the remaining vehicles, the fuel economy penalty for operation at high altitude was quite apparent and consistent at about 14%.

Shown in Table 3 are the emission rates and fuel economy of a representative fleet of late model, gasoline-powered passenger cars tested at high altitude (Reference 2). These may be compared to the results of the four late model, diesel-powered cars tested in this program.

Table 3

Estimated Emission Levels of Late Model Passenger Cars at High Altitude (g/mi)

	<u>HC</u>	<u>CO</u>	FTP <u>NOx</u>	<u>Part.</u>	HFET <u>Part.</u>
These four late model diesel-powered cars	.9	1.9	1.4	.9	.6
Typical Late-model, gasoline- powered cars (average odometer 20,000 miles)	2.6	45.0	1.2	*	*

*Data on particulate emissions from gasoline-powered vehicles is currently being obtained in another test program.

Table 4 is a listing of these percentage increases compared to average emission and fuel economy changes expected of low altitude vehicles which are tested at high altitude. For the gasoline-powered vehicles the projection of emission changes was derived from information contained in Reference 2. The values for fuel economy penalty were determined by a comparison of results between identical vehicles tested at high and low altitude sites in the FY79 Passenger Car Emission Factor Testing Program.

Table 4

Changes in from Low Altitude Baseline Emissions (g/mi) and
Fuel Economy (mi/gal) at High Altitude

	FTP				HFET		
	<u>HC</u>	<u>CO</u>	<u>NOx</u>	<u>MPG</u>	<u>Part.</u>	<u>MPG</u>	<u>Part.</u>
Four late-model diesel-powered cars	+134%	+74%	0%	-14%	+46%	-14%	+36%
Typical late-model gasoline powered cars	+ 35%	+80%	-35%	- 7%	*	- 7%	*

*Data on particulate emissions from gasoline-powered vehicles is currently being obtained in another test program.

Conclusions

Based on the results of this program there are several conclusions which may be drawn:

1. Diesel-powered passenger cars tuned to operate at low altitude and subsequently operated at high altitude produce substantially greater amounts of HC, CO and particulates.
2. Despite their increased levels, HC and CO emissions from diesel-powered cars are still much lower than those from similar gasoline-powered vehicles operated at high altitude. On the other hand, levels of particulates may become of even greater concern.
3. There is a penalty in fuel economy apparent when a vehicle designed for low altitude is operated at high altitude. Diesel vehicles appear to suffer more than gasoline-powered models with respect to fuel economy.

References

1. Report from Automotive Testing Laboratories entitled "Tests on Five Diesel Passenger Cars at High Altitude", EPA Contract No. 68-03-2891, Task #1, September 1980
2. Jay S. Wallace, "Draft Compilation of Air Pollutant Emission Factors for On-Highway Mobile Sources, (AP-42)".
3. Report from Automotive Testing Laboratories entitled "Effect of Altitude on Maladjusted Vehicles", EPA Contract No. 68-03-2891, Task No. 2, Due November, 1980.