

Prototype 1981 Peugeot Diesel Emissions Tests

by

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Background

The Environmental Protection Agency receives information about many systems which appear to offer potential for emission reduction or fuel economy improvement compared to conventional engines and vehicles. EPA's Emission Control Technology Division is interested in evaluating all such systems, because of the obvious benefits to the Nation from the identification of systems that can reduce emissions, improve fuel economy or both. EPA invites developers of such systems to provide complete technical data on the system's principle of operation, together with available test data on the system. In those cases for which review by EPA technical staff suggests that the data available shows promise, confirmatory tests are run at the EPA Motor Vehicle Emission Laboratory at Ann Arbor, Michigan. The results of all such test projects are set forth in a series of Test and Evaluation Reports, of which this report is one.

Peugeot inquired about possible EPA interest in testing a prototype 1981 diesel with progressive EGR and turbocharging. Since EPA had tested only a limited number of EGR equipped Diesels, arrangements were made to run an evaluation program. The vehicle arrived in December and was tested during December 1979 and January 1980.

The conclusions from the EPA evaluation test can be considered to be quantitatively valid only for the specific test car used; however, it is reasonable to extrapolate the results from the EPA test to other types of vehicles in a directional manner, i.e. to suggest that similar results are likely to be achieved on other types of vehicles.

Summary of Findings

This 1981 Peugeot Diesel (progressive EGR with turbocharging) met the statutory 1981 standards for gaseous emissions. NO_x levels (1.04 gm/mi) were actually slightly above the standard of 1.0 gm/mi^x but met the 1981 standard when this value was rounded off. (Note: The NO_x value is not corrected for a NO_x deterioration factor).

Particulate emissions were 0.324 gm/mi, thus readily meeting the 1982 light duty Diesel particulate standard of 0.6 gm/mi.

Fuel economy was 28.5 mpg for the FTP and 38.3 for the HFET.

The vehicle had good driveability.

Test Vehicle

The test vehicle was a prototype 1981 Peugeot 504 Diesel. The vehicle uses the 140 CID XD2S engine with a turbocharger. EGR is used for NO_x control. The vehicle weighed 3175 lbs and was tested at an inertia weight of^x 3500 lbs. The vehicle was equipped with a four speed manual transmission.

The vehicle's Bosch mechanical fuel injection is modulated at full load to compensate for turbo boost pressure and altitude. A boost pressure regulated full load stop limits the maximum fuel delivery. An altitude compensated full load stop reduces the full load fuel delivery to be proportional to the barometric pressure.

The vehicle's EGR system is a progressive EGR unit. At low load there is up to 35% EGR. The percentage of EGR progressively decreases as engine load is increased with there being no EGR at heavy loads. The system incorporates a vacuum converter fixed to the injection pump to provide an EGR vacuum signal proportional to accelerator pedal position. An electronic system overrides this vacuum system and eliminates EGR under heavy loads at both low and high engine RPM.

A Garrett AiResearch turbocharger is used to provide improved performance. A wastegate limits the absolute manifold pressure to 1.6 bar (1.6 times atmospheric pressure) for a net boost of .6 bar (9 psi). Injection pump timing is modified to increase low speed fuel charging and thereby increase low speed torque. The compression ratio is reduced from 22.5 to 1 for the naturally aspirated engine to 21.5 to 1 for the turbocharged engine.

Peugeot claims that, when compared with their naturally aspirated Diesel engine, this turbocharged Diesel has: improved performance and driveability, a reduction in noise, reduction in pollution and no loss in fuel economy.

Additional information on this vehicle is given in the vehicle information data sheet.

Test Procedures

Exhaust emission tests were conducted according to the Federal Test Procedure (FTP) described in the Federal Register of February 1, 1979 and the EPA Highway Fuel Economy Test (HFET) described in the Federal Register of September 10, 1976. The vehicle was tested using an EPA light duty Diesel particulate sampling system.

To evaluate the effectiveness of the EGR system, Peugeot suggested that the vehicle be tested both with and without EGR. EPA concurred and thus the vehicle was tested both with and without EGR.

Prior to testing the vehicle was given a specification check and visually inspected. The idle speed was checked and found to be within specification. Several engine bolts were loose and had to be tightened prior to testing.

Test Results

The FTP results are given in Table I and the HFET results are given in Table II. The tests noted with an asterisk were tests that were performed at non-standard conditions. The data on these tests was included for completeness. The vehicle's manual transmission is nominally shifted at 16, 27 and 35 mph. However, because there are varying acceleration rates in the FTP cycle, Peugeot modified the shift schedule to be more compatible with the engine power output. Therefore, several shifts occurred at slightly different speeds in the FTP. This is an acceptable practice and thus many manufacturers specify shifts at different speeds throughout the driving cycle.

Average FTP emissions were HC 0.23 gm/mi, CO 1.34 gm/mi, NO_x 1.04 gm/mi and particulate 0.32 gm/mi. Fuel economy was 28.5 mpg. Thus with the roundoff, this vehicle met the level of the 1981 NO_x standard of 1.0 gm/mi.

It should be noted that this NO_x value is uncorrected for the NO_x deterioration factor. Also, Peugeot has applied for a NO_x waiver to 1.5 gm/mi for their 1981 light duty Diesels. The original Peugeot request has been denied but Peugeot has reapplied for a NO_x waiver. This second request is currently under review by EPA.

When EGR was disconnected, the FTP HC emissions were unchanged, CO emissions decreased 12%, NO_x increased 90%, particulates decreased 18% and FTP fuel economy was unchanged. The FTP tests with shift speeds at exactly 16, 27, and 35 mph were unchanged from the baseline tests.

Peugeot tested the vehicle both with and without EGR at their own test facility. Their test data showed similar results.

The average HFET emissions were HC 0.06 gm/mi, CO 0.62 gm/mi, NO_x 0.72 gm/mi and particulates 0.23 gm/mi. Fuel economy was 38.3 mpg.

With the EGR System disconnected, the change in HFET emissions was nearly identical to the effect on FTP emissions. Namely HFET HC emissions were basically unchanged, CO emissions decreased 14%, NO_x emissions increased 122% and particulates decreased 22%. HFET fuel economy^x was unchanged. The HFET test with no shift to 4th gear caused HC, CO, NO_x and particulate emissions to be significantly increased over the baseline^x and EGR disconnected test conditions. Fuel economy decreased significantly.

The inverse relationship between NO_x and particulates exhibited by this vehicle for both the FTP and HFET has been seen in other diesel vehicles.

This vehicle was given a limited road test in the baseline configuration (turbocharged with EGR). The vehicle had good driveability and good acceleration.

Conclusions

The test vehicle met the gaseous standards for 1981 light duty diesel vehicles. The vehicle also met the 1982 particulate standard of 0.6 gm/mile. However, the NO_x level was at the level of the standard and realistically the engine would have to be recalibrated for lower NO_x levels for the vehicle to be certifiable at the 1981 NO_x level of 1.0 gm/mi.^x

Gaseous emissions and particulate results are summarized below.

Table I
1981 Turbocharged/EGR Prototype Peugeot 504 Diesel
FTP Mass Emissions
grams per mile

<u>Test No.</u>	<u>HC (HFID)</u>	<u>CO</u>	<u>CO₂</u>	<u>NO_x</u>	<u>MPG</u>	<u>Particulates</u>
<u>With progressive EGR</u>						
80-0780	.28	1.37	357	1.04	28.3	.315
80-0781	.20	1.32	351	1.05	28.8	----
80-0936	.22	1.32	354	1.04	28.5	.333
<u>EGR disconnected</u>						
80-0878	.24	1.16	350	1.96	28.9	.268
80-0880	.22	1.18	356	2.00	28.4	.262
<u>With progressive EGR, shift at 16, 27, 35 mph only</u>						
80-0776*	.26	1.31	357	1.08	28.3	.312
80-0779*	.23	1.35	349	1.01	28.9	.329

Table II
1981 Turbocharged/EGR Prototype Peugeot 504 Diesel
HFET Mass Emissions

<u>With progressive EGR</u>						
80-0777	.06	.63	269	.73	37.7	.218
80-0778	.06	.60	260	.70	39.0	.236
<u>EGR disconnected</u>						
80-0881	.09	.52	271	1.60	37.4	.172
80-0882	.09	.54	265	1.58	38.2	.172
<u>EGR disconnected, no shift to 4th gear</u>						
80-0879*	.22	.71	311	2.04	32.5	.343

* Non-standard test condition, test data included for information purposes only.

Test Vehicle Description

Chassis model year/make-Prototype 1981 Peugeot 504 Diesel

Engine

Type	Diesel inline, 4 cylinder
Engine family	XD2S
Bore x stroke	3.70 X 3.26 in/94.0 X 82.8 mm
Displacement	140.6 CID/2.3 Liter
Compression ratio	21.5:1
Maximum power @ rpm	80 hp/59.7 kW
Fuel metering	Bosch mechanical fuel injection
Fuel requirements	Diesel No. 2, tested with Diesel No. 2

Drive Train

Transmission type	4 speed manual
Final drive ratio	3.31:1

Chassis

Type	4 door sedan
Tire size	Michelin 175 HRx14
Inertia weight	3500 lbs.

Emission Control System

Basic type	Progressve EGR Garrett Turbocharger
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