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Exhaust Emissions and Fuel Economy of a Ford Pinto Powered by a Nissan Diesel Engine

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Technology Assessment and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
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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 economy, or both. EPA invites developers of such systems to provide to the EPA complete technical data on the system's principle of operation, together with available test data on the system. In those cases in which review by EPA technical staff suggests that the data available show promise, attempts are made to schedule tests 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 Technology Assessment and Evaluation Reports, of which this report is one.

The conclusions drawn from the EPA evaluation tests are necessarily of limited applicability. A complete evaluation of the effectiveness of an emission control system in achieving performance improvements on the many different types of vehicles that are in actual use requires a much larger sample of test vehicles than is economically feasible in the evaluation test projects conducted by EPA. For promising systems it is necessary that more extensive test programs be carried out.

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 or qualitative manner, i.e., to suggest that similar results are likely to be achieved on other types of vehicles.

In October of 1975, the Wilcap Company of Torrance, California offered to allow the EPA to test a Ford Pinto retrofitted with a 4-cylinder Diesel engine. This particular vehicle had been entered in a Student-Engineered Economy Design Rally sponsored by the University of California and Western Washington State College. The Pinto-Diesel won the overall fuel economy category and demonstrated exhaust emissions below the 1977 Federal Emission Standards.

Vehicle Description

The test vehicle is a 1971 Ford Pinto sedan, powered by a Chrysler-Nissan CN4-33 Diesel engine with a displacement of 132 cu. in. The engine has a prechamber type of combustion chamber and is equipped with glow plugs. The fuel pump is manufactured by C.A.V. Lucas. Test inertia weight was 2750 lbs.

The vehicle is equipped with a four-speed manual transmission and an axle-mounted Hone overdrive. The axle ratio is 2.80 without overdrive and 1.95 with the overdrive engaged. Oversize tires (225R x 15) have been fitted to the rear axle.

Engine cooling is accomplished with an oversize radiator. No engine cooling fan is fitted.

A tabulation of vehicle characteristics is given on the Vehicle Description Sheet at the end of this report.

Test Program

Exhaust emission tests were conducted in accordance with the 1975 Federal Test Procedure ('75 FTP) for light-duty Diesel vehicles. In addition to the '75 FTP, exhaust emissions and fuel economy were measured over the EPA Highway Fuel Economy Test (HFET) and under steady state operating conditions. Other testing included measurement of sulfate emissions and acceleration times.

The vehicle was tested at steady state speeds of 0 (idle), 15, 30, 45 and 60 mph. At 45 and 60 mph, the vehicle was tested with and without the overdrive engaged.

One HFET was run using the overdrive. The vehicle was shifted into overdrive when a cruise speed of 50 mph was attained. This allowed the overdrive to be used for about one half of the Highway Cycle. The shift into overdrive was made at about 325 seconds into the HFET. Overdrive was not used during the LA4.

Sulfate emissions were measured over the EPA Sulfate Cycle (SC-7). Eight such tests were run. The fuel used for the sulfate testing was #2 Diesel fuel containing 0.21 wt. % sulfur. A description of the procedure used for measuring sulfate emissions is given on page 11.

Acceleration times from 0-60 mph and 40-60 mph were measured. Accelerations from 40-60 mph were run in 4th gear, with and without overdrive engaged.

Test Results

The Diesel-Pinto demonstrated the following exhaust emissions and fuel economy:

'75 FTP Composite Mass Emissions
grams per mile
(grams per kilometer)

	HC	CO	NOx	Fuel Economy (Fuel Consumption)
Average of 2 tests	0.54 (0.34)	1.13 (0.70)	0.74 (0.46)	46.1 mpg (5.1 liters/100 km)

The exhaust emissions are well within the 1977 Federal emission standards (HC - 1.5 gpm, CO - 15.0 gpm, NOx - 2.0 gpm). HC and NOx emissions are above the 1978 Federal standards of 0.41 gpm and 0.4 gpm respectively.

Exhaust emissions and fuel economy measured over the EPA Highway Driving Cycle are presented in the following table:

EPA Highway Fuel Economy Test
grams per mile
(grams per kilometer)

	HC	CO	NOx	Fuel Economy (Fuel Consumption)
Without overdrive avg. of 2 tests	0.24 (0.15)	0.77 (0.48)	0.63 (0.39)	60.3 mpg (3.9 liters/100 km)
with overdrive 1 test	0.18 (0.11)	0.44 (0.27)	0.63 (0.39)	63.9 mpg (3.7 liters/100 km)

Steady state emissions and fuel economy are presented in Table IV. It should be noted that steady states are generally not representative of real-world driving conditions. The purpose of steady state testing is to give insight into operating characteristics of the test vehicle.

The '75 FTP and Highway fuel economies can be combined into a single fuel economy using weighting factors that have been determined by the Department of Transportation to be typical of the driving pattern in the United States. These factors are 55% for the '75 FTP and 45% for the HFET. The '75 FTP and HFET fuel economies are averaged harmonically to yield the combined fuel economy, which for the Diesel-Pinto is 51.6 mpg (4.6 liters/100 km).

Sulfate emissions measured over the EPA sulfate cycle are presented in Table V. Emissions of SO_4 are in milligrams per mile. The percent of fuel sulfur that is converted to SO_4 is also shown in Table V.

The acceleration time from 0-60 mph is 22.5 seconds. Acceleration from 40-60 mph in 4th gear takes 17.5 seconds. From 40-60 mph in 4th gear overdrive takes 57.5 seconds.

Road testing revealed that the Diesel-Pinto had adequate acceleration capability provided that overdrive was not used. It was not practical to use 4th gear overdrive below 60 mph because the engine had insufficient power in the engine speed range in which it was operating. Since road testing was conducted on public roads, no attempt was made to determine whether the overdrive could be used at speeds above 60 mph.

The oversize tires fitted to the rear of the Diesel-Pinto had an adverse effect on the handling of the vehicle. In addition, apparent adjustments to the front suspension to increase ground clearance also caused a degradation of steering response characteristics.

Discussion

It appears that much of the credit for the high fuel economy of the Diesel-Pinto (compared to other Diesel-powered passenger cars) is due to modifications to the vehicle to reduce the number of engine revolutions per mile traveled (N/V ratio). For instance, changing from standard A78 x 13 rear tires to the oversize 225 x 15 tires results in a reduction in N/V ratio of roughly 18%. EPA and DOT test data indicate that the change in composite fuel economy due to this change in N/V ratio will probably be 9-18%. So, without the oversize tires, the composite fuel economy can be expected to be between 42.3 mpg and 47.0 mpg.

The following table compares the exhaust emissions and fuel economy of the Diesel-Pinto to those of a Diesel-powered Volkswagen Rabbit tested by the EPA. The Diesel Rabbit is the only other Diesel-powered car tested by EPA that has had an equivalent power-to-weight ratio.

'75 FTP Mass Emissions
grams per mile
(grams per kilometer)

	HC	CO	NOx	Composite Fuel Economy (Fuel Consumption)	Inertia Class
Diesel-Pinto	0.54 (0.34)	1.13 (0.70)	0.74 (0.46)	51.6 mpg (4.6 liters/100 km)	2750 lbs.
VW Rabbit	0.19 (0.12)	0.98 (0.61)	1.19 (0.74)	41.5 mpg (5.7 liters/100 km)	2250 lbs.

The Rabbit is powered by a 4 cylinder, 4 stroke Diesel engine that developes 50 hp. The transmission is a manual 4 speed, and the final drive ratio is 4.22:1. Acceleration time from 0-60 mph was 16.5 seconds.

The road load at 50 mph used for the Diesel-Rabbit test was 7.3 hp. The road load for the Diesel-Pinto was 9.9 hp. Road load effects on fuel economy are seen primarily during the HFET. During the '75 FTP, change in fuel economy due to small changes in road load is negligible.

It is true that the Diesel-Pinto delivers substantially better fuel economy than other passenger cars, but the Diesel-Pinto also utilizes fairly extensive vehicle (not engine) modifications to achieve its high fuel economy. These modifications adversely affect the handling and roadability of the Diesel-Pinto.

Conclusions

1. The Diesel-Pinto demonstrated exhaust emissions below the levels required by the 1977 Federal emission standards for light-duty vehicles.

2. The Diesel-Pinto has higher fuel economy than any other passenger car tested to date by the EPA. However, much of the credit for this high fuel economy is due to modifications to the vehicle to reduce the number of engine revolutions per mile traveled.

3. Some of the chassis adjustments to improve fuel economy and facilitate the Diesel engine installation resulted in steering response characteristics which may seriously compromise handling in emergency situations.

4. It is not practical to operate the Diesel-Pinto in 4th gear overdrive at speeds under 60 mph.

Table I
1975 Federal Test Procedure
Mass Emissions in
grams per Mile
(grams per kilometer)

Test #	HC	CO	CO_2	NOx	miles/gallon (liters/100 kilometers)
77-551	0.50 (0.31)	1.06 (0.66)	218. (135.)	0.72 (0.45)	46.2 (5.1)
77-550	0.58 (0.36)	1.19 (0.74)	218. (135.)	0.75 (0.47)	45.9 (5.1)
Average	0.54 (0.34)	1.13 (0.70)	218. (135.)	0.74 (0.46)	46.1 (5.1)

Table II
EPA Highway Fuel Economy Test
Mass Emissions in
grams per Mile
(grams per kilometer)

Test #	HC	CO	CO_2	NOx	miles/gallon (liters/100 kilometers)
without overdrive					
77-548	0.23 (0.14)	0.77 (0.48)	169. (105.)	0.62 (0.39)	59.6 (3.9)
77-549	0.24 (0.15)	0.77 (0.48)	165. (103.)	0.63 (0.39)	60.9 (3.9)
Average	0.24 (0.15)	0.77 (0.48)	167. (104.)	0.63 (0.39)	60.3 (3.9)
with overdrive					
77-547	0.18 (0.11)	0.44 (0.27)	158. (98.)	0.63 (0.39)	63.9 (3.7)

Table III

1975 FTP Individual Bag Emissions in grams per mile

Test #	Bag 1: Cold Transient					Bag 2: Stabilized					Bag 3: Hot Transient				
	HC	CO	CO_2	NOx	MPG	HC	CO	CO_2	NOx	MPG	HC	CO	CO_2	NOx	MPG
77-551	0.72	1.31	246.	0.72	40.9	0.51	1.05	210.	0.73	48.0	0.31	0.91	212.	0.70	47.5
77-550	0.77	1.45	243.	0.74	41.0	0.60	1.19	212.	0.77	47.2	0.38	0.99	212.	0.72	47.4

Table IV
Steady State Mass Emissions in
grams per mile
(grams per kilometer)

Speed	HC	CO	CO_2	NOx	mpg (ℓ/100 km)
Idle (300 secs.)	0.18 gms	0.60 gms	80. gms	0.32 gms	
15 mph/24 kph 2nd gear	0.23 (0.14)	1.16 (0.72)	139. (86.)	0.47 (0.29)	72.0 mpg (3.3 ℓ/100 km)
30 mph/48 kph 4th gear	0.11 (0.07)	0.51 (0.32)	112. (70.)	0.49 (0.30)	89.8 mpg (2.6 ℓ/100 km)
45 mph/72 kph 4th gear	0.22 (0.14)	0.66 (0.41)	138. (86.)	0.60 (0.37)	72.9 mpg (3.2 ℓ/100 km)
45 mph/72 kph 4th gear overdrive	0.09 (0.06)	0.32 (0.20)	125. (78.)	0.67 (0.42)	80.8 mpg (2.9 ℓ/100 km)
60 mph/97 kph 4th gear	0.26 (0.16)	0.92 (0.57)	187. (116.)	0.73 (0.45)	53.9 mpg (4.4 ℓ/100 km)
60 mph/97 kph 4th gear overdrive	0.10 (0.06)	0.22 (0.14)	163. (101.)	0.74 (0.46)	62.3 mpg (3.8 ℓ/100 km)

Table V

Sulfuric Acid Emissions in milligrams per mile

	milligrams H_2SO_4	% of Fuel Sulfur Converted to SO_4
	8.5	1.8
	6.4	1.5
	12.5	2.5
	10.6	2.1
	6.6	1.5
	5.6	1.3
	8.2	1.8
	10.0	2.1
Average	8.6	1.8

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1971 Ford Pinto
Emission control system - None

Engine

type	4-stroke, Diesel, I-4, ohv, indirect injection
bore x stroke	3.277 x 3.94 in/83.2 x 100.1 mm
displacement	132 cu. in./2163cc
compression ratio	22:1
maximum power @ rpm	61 bhp at 4000 rpm/46kW at 4000 rpm
fuel metering	mechanical fuel injection
fuel requirement	#2 Diesel

Drive Train

transmission type	4-speed manual
final drive ratio	2.8 without overdrive 1.95 with overdrive

Chassis

type	front engine, rear wheel drive
tire size	225R x 15 (rear)
curb weight	2480 lbs/1125kg
inertia weight	2750 lbs.
passenger capacity	4

Emission Control System

basic type	none
durability accumulated on system	75,000 miles/121,000km

Diesel-Pinto
Procedure used to Measure Sulfate Emissions

1. The fuel was drained from the test vehicle. The vehicle was refueled with #2 Diesel fuel containing 0.21 wt. % sulfur. This fuel was used throughout the sulfate testing.

2. The vehicle was driven over one LA-4 cycle with the test fuel in preparation for the test series.

3. The following sequence of test cycles was used to measure sulfate emissions.

   a) Cold start '75 FTP
   b) Two hot start sulfate cycles
   c) One EPA Highway Driving Cycle
   d) Two hot start sulfate cycles.

   This sequence was run on two consecutive days.

4. The barium chloranilate procedure was used to determine the concentration of sulfates in the exhaust.