77-2 AW

Exhaust Emissions from a Ford Pinto Equipped with the General Dynamics Electrosonic Control System

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Technology Assessment and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
U.S. Environmental Protection Agency

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 Emissions 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.

One such system has been developed jointly by General Dynamics and Autotronic Controls Corporation. This system is called the Electronic Engine Control System (Electrosonic), and utilizes the principles of lean-burn combustion to control exhaust emissions.

The Electrosonic system is designed to control engine parameters affecting exhaust emissions. As such, the system controls ignition timing, air-fuel ratio and idle speed. The system does have EGR control capability, although EGR was not on the vehicle supplied to the EPA for evaluation.

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.

Test Vehicle Description

The test vehicle was a 1976 Ford Pinto MPG powered by a four cylinder 140 cu in. engine and equipped with a four speed manual transmission. The Electrosonic system retains the standard compression ratio, manifolds and spark plugs. As manufactured, the Pinto was equipped with an air pump, EGR and oxidation catalyst. but the Electrosonic system does not require the use of these control devices. Consequently the catalyst had been removed from the test vehicle, and the air pump and EGR had been rendered inoperative. With the exception of these changes, no other modifications had been made to the engine or vehicle. A list of pertinent vehicle statistics is given on the Vehicle Information page at the end of this report.

The Electrosonic system is designed to maintain lean-burn combustion by monitoring vehicle parameters, operating modes and ambient conditions, and supplying the correct amount of fuel to match the air-flow through the engine. Figure 1 is a schematic diagram showing the essential features of the Electrosonic system. Figure 2 is a flow diagram showing the input and output signals of the electronic controller.

The information supplied to the controller by the air flow transducer and the ambient condition sensors allows the controller to determine the mass flow of air into the engine. Further input information regarding vehicle operating mode (idle, acceleration, cruise, etc.) is used by the controller to determine the correct amount of fuel to be fed into the intake manifold to maintain the desired air-fuel ratio. Fuel is supplied to the intake system by a fuel metering pump. A conical throttle controls the engine inlet air.

For the prototype system tested by the EPA, the controller was located in the trunk and utilized circuit boards for the mounting of electronic components. For development work, the circuit board approach simplifies the changing of electronic components. During the EPA test program the Pinto was tested at two NOx emission calibrations: 2.0 gm/mile and 1.0 gm/mile. The change in calibration was accomplished by changing circuit boards in the controller. For mass production of the Electrosonic system, a microprocessor would replace the bulky circuit boards used in the development version.

Figures 3 and 4 show the actual installation of the Electrosonic system in the test vehicle.

The air-fuel ratio delivered by the Electrosonic system varies from approximately 13.5:1 (cold start) to 19.5:1 (cruise). Intermediate air-fuel ratios are used for acceleration and power enrichment conditions.

Test Program

Exhaust emission and fuel economy tests were conducted in accordance with the 1975 Federal Test Procedure ('75 FTP) for light-duty vehicles (Federal Register, June 30, 1975, Vol. 40 No. 126, Part III), and the EPA Highway Fuel Economy Test (HFET). Evaporative emissions were not measured.

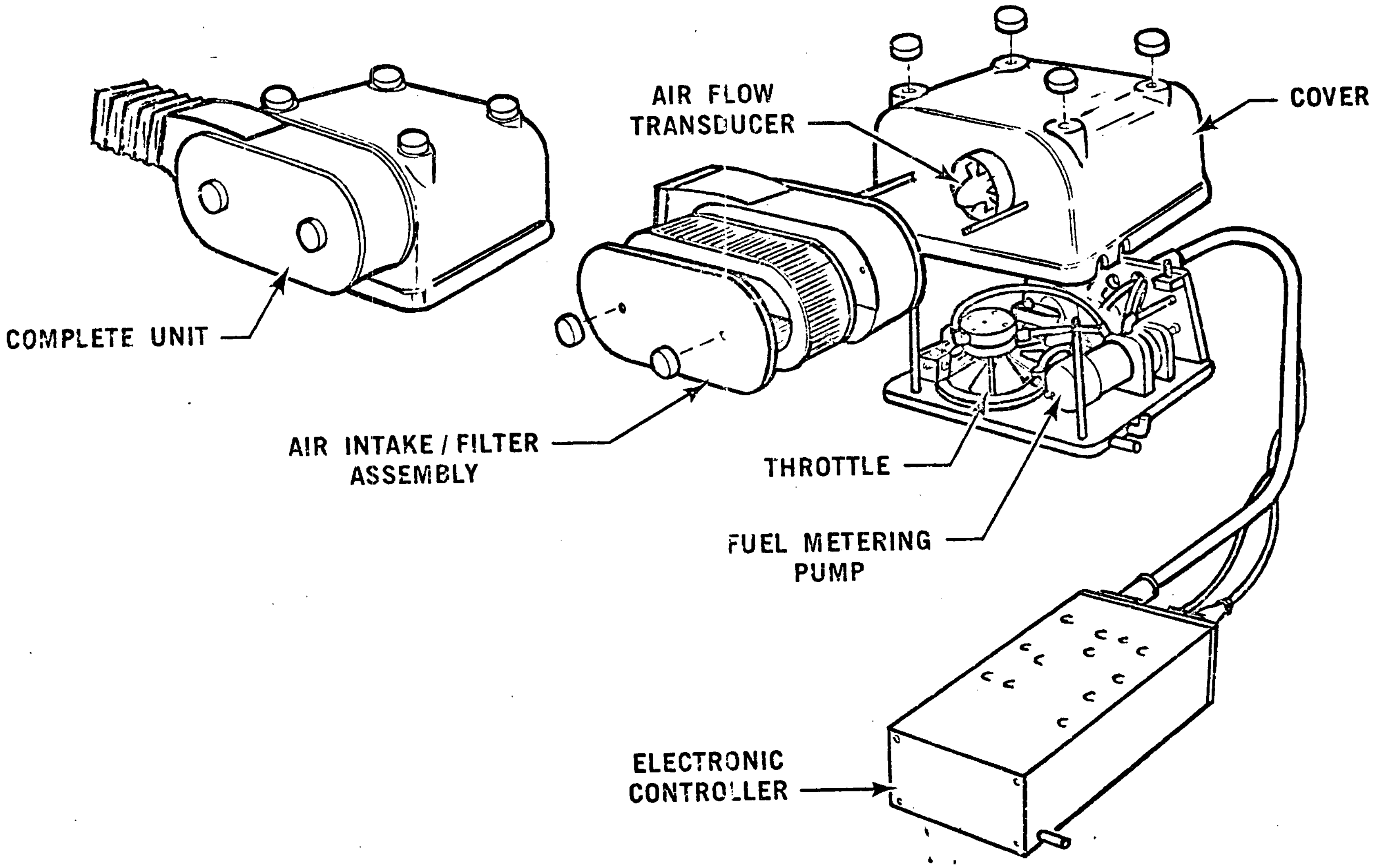

Figure 1 - Schematic of Electrosonic System

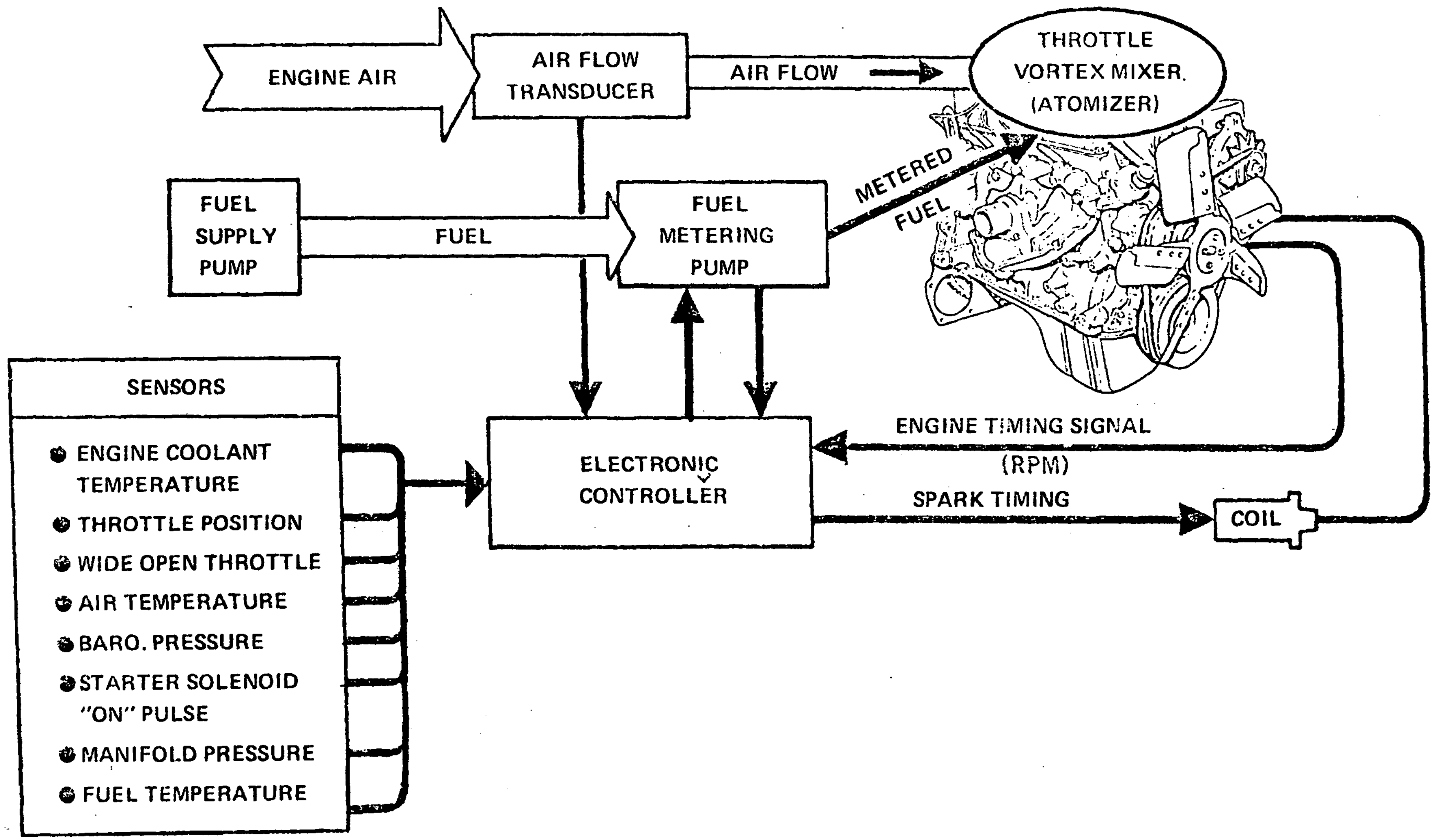

Figure 2 - Electronic Controller Signals

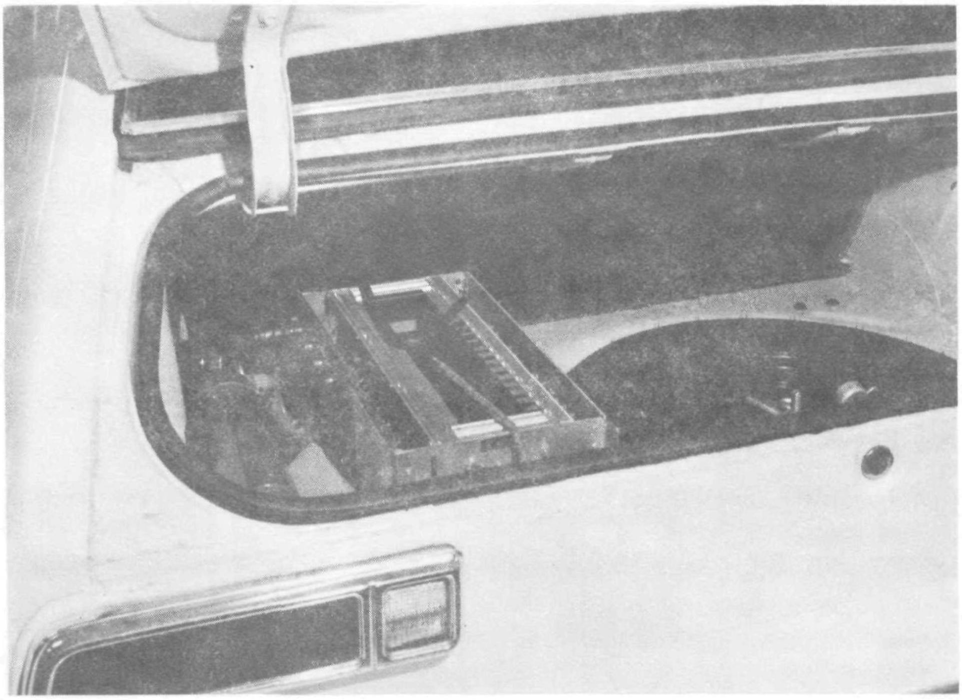

Figure 3

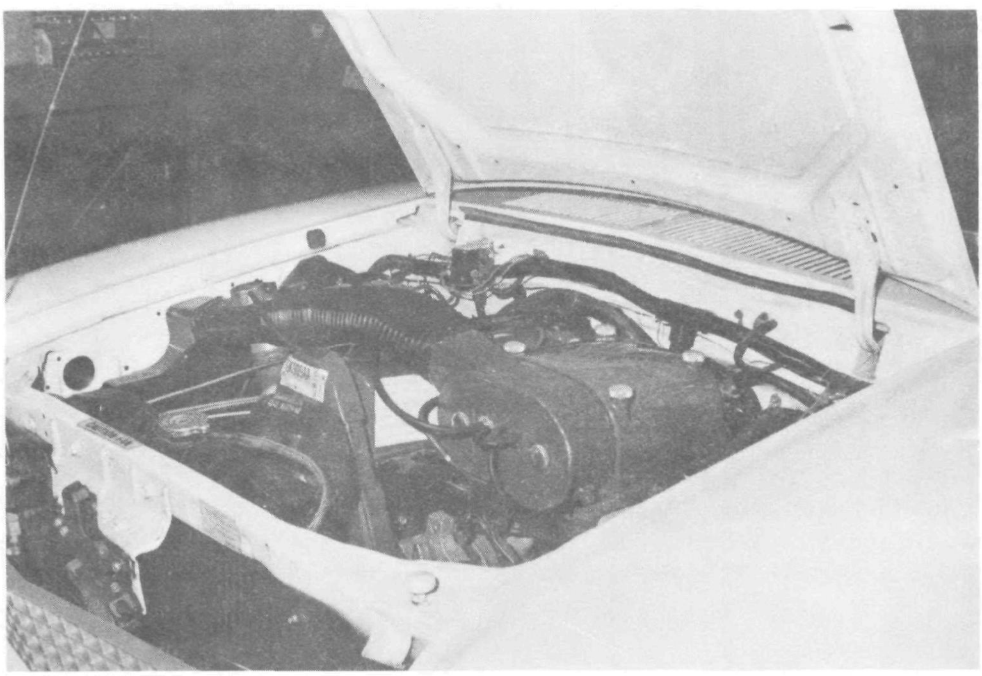

Figure 4

The Pinto was tested at two NOx emission calibrations. The vehicle was alternately calibrated for a 2.0 gm/mile NOx standard and a 1.0 gm/mile NOx standard. NOx emissions were expected to be about 25% below the target standards.

Two inertia weights were used during the test program, 3000 lb. and 2750 lb. The 3000 lb. inertia is correct for the curb weight of the vehicle. The 2750 lb. inertia represents the expected inertia for future model years of the Pinto.

Finally, an optional shift pattern was used during the test program. This optional shift pattern was used by Ford Motor Company during 1976 certification testing of comparable Pintos. The optional shift pattern generally calls for shifting into 4th gear when cruise conditions occur during the emission test. At some points during the test, the transmission is shifted directly from 2nd to 4th gear. For comparative purposes, one test was conducted using the standard shift speeds specified in the Federal Register for the '75 FTP. The optional pattern was not used during the HFET.

The following Table lists the configurations and conditions under which the Pinto was tested.

Test Program

2.0 gm/mile NOx:

3000 lb. inertia, optional shift pattern
('75 FTP + HFET) duplicate tests

2750 lb. inertia, optional shift pattern
('75 FTP + HFET) duplicate tests

1.0 gm/mile NOx:

2750 lb. inertia, optional shift pattern
('75 FTP + HFET) duplicate tests

2750 lb. inertia, standard shift pattern
('75 FTP + HFET) single test

After completing the exhaust emission and fuel economy tests, the Pinto was subjected to a cursory driveability test. For the purpose of the driveability test, the vehicle was given a short test drive and any significant driveability faults were noted. The vehicle was warmed up prior to the driveability test.

Test Results

The following tables summarize the exhaust emissions and fuel economy of the Pinto test vehicle.

'75 FTP mass emissions in grams per mile (grams per kilometer)[1]

	HC	CO	NOx	Fuel Economy (Fuel Consumption)
2.0 gm/mi. NOx 3000 lb. inertia opt. shift	1.37 (0.86)	3.7 (2.3)	1.73 (1.07)	26.2 miles/gal. (9.0 liters/100 km)
2750 lb. inertia opt. shift	1.28 (0.79)	3.2 (2.0)	1.65 (1.03)	26.2 miles/gal. (9.0 liters/100 km)
1.0 gm/mi. NOx 2750 lb. inertia opt. shift	1.19 (0.74)	4.0 (2.4)	1.03 (0.64)	24.7 miles/gal. (9.5 liters/100 km)
2750 lb. inertia standard shift	1.11 (0.69)	3.4 (2.1)	1.09 (0.68)	23.4 miles/gal. (10.0 liters/100 km)

[1] Values in parenthesis denote metric units.

Highway Fuel Economy (Consumption)

2.0 gm/mi. NOx 3000 lb. inertia	36.7 miles/gal. (6.5 liters/100 km)
2750 lb. inertia	37.2 miles/gal. (6.3 liters/100 km)
1.0 gm/mi. NOx 2750 lb. inertia	35.9 miles/gal. (6.6 liters/100 km)

For comparison, the following emissions and fuel economy were measured from the comparable 1976 certification vehicle.

'75 FTP mass emissions in
grams per mile
(grams per kilometer)[1]

HC	CO	NOx	Fuel Economy (Fuel Consumption)
0.62 (0.39)	2.5 (1.6)	2.63 (1.63)	25 miles/gal. (9.4 liters/100 km)

Highway Fuel Economy (Consumption)

38 miles/gal.
(6.2 liters/100 km)

(1) Values in parenthesis denote metric units.

The inertia class of the certification vehicle was 2750 lbs. The fuel economy of the certification vehicle has been rounded to the nearest whole mile per gallon figure.

Due to problems with laboratory analysis equipment, it was necessary to use two dynamometer sites (EPA dynamometers 6 and 7) during the course of the test program. The data generated on dynos 6 and 7 show a greater variation in NOx emissions (between the two dynamometers) than would be encountered as a consequence of normal test variability. Because of time constraints on the test program, it was necessary to complete the program without identifying the reasons for the variation in NOx emissions between the two sites. (Subsequent investigations are being made to identify the reasons for the variation.)

NOx emissions measured from testing on dyno 6 were lower than those measured on dyno 7. In addition, data measured during tests on dyno 6 were in agreement with data from other test programs conducted by General Dynamics prior to and following the EPA evaluation.

Details of the individual emission tests, Highway Cycles and steady states are presented in Tables I-IV following the text of this report. Individual tests in Table I and II are also identified according to dynamometer site.

The driveability test did not reveal any significant driveability problems. A slight lean surge could be detected under some cruise conditions. Generally, the Pinto did not exhibit the driveability problems common to lean burn vehicles, i.e., hesitation on accelerations and significant lean surge, and was rated as Acceptable in EPA's informal evaluation.

The fuel economy improvement (during the '75 FTP) due to the optional shift pattern is roughly 5%. CO emissions are slightly higher when the optional shift pattern is utilized.

Acceleration times were not measured during the EPA program. However, General Dynamics has conducted acceleration tests, and found 0-60 mph acceleration times of 13-14 seconds.

Conclusions

The General Dynamics Pinto demonstrated NOx emissions below 2.0 grams per mile without incurring a fuel economy penalty (compared to the baseline 1976 model vehicle). Emissions of HC and CO are well within the 1977 emission standards of 1.5 gms/mi. and 15.0 gms/mi. respectively. Data supplied to the EPA by General Dynamics indicate that HC emissions below 0.41 gms/mi. can be obtained with the addition of an oxidation catalyst.

Because of the nature of this short evaluation program, no conclusions could be made regarding the durability of this system or the deterioration factor associated with its use.

Table I

1975 Federal Test Procedure
mass emissions in
grams per mile
(grams per kilometer)[1]

Test #	HC	CO	CO2	NOx	miles/gal. (liters/100 km)
2.0 gm/mi NOx					
3000 lb. inertia, opt. shift					
77-4293[2]	1.33 (0.83)	3.5 (2.2)	323. (201.)	1.52 (0.94)	26.7 (8.8)
77-4331	1.41 (0.88)	3.8 (2.3)	335. (208.)	1.93 (1.20)	25.7 (9.1)
2750 lb. inertia, opt. shift					
77-4418	1.18 (0.73)	3.0 (1.9)	329. (205.)	1.75 (1.09)	26.3 (9.0)
77-4419	1.37 (0.85)	3.3 (2.0)	331. (205.)	1.55 (0.96)	26.1 (9.0)
1.0 gm/mi. NOx					
2750 lb. inertia, opt. shift					
77-4327	1.19 (0.74)	3.8 (2.3)	348. (216.)	1.06 (0.66)	24.8 (9.5)
77-4361	1.23 (0.77)	4.1 (2.5)	357. (222.)	1.05 (0.66)	24.2 (9.7)
77-4397[2]	1.14 (0.71)	4.0 (2.5)	342. (213.)	0.97 (0.60)	25.2 (9.4)
2750 lb. inertia, standard shift					
77-4362	1.11 (0.69)	3.4 (2.1)	371. (230.)	1.09 (0.68)	23.4 (10.0)

[1] Values in parenthesis denote metric units.

[2] Dynamometer 6.

Table II

EPA Highway Fuel Economy Test
mass emissions in
grams per mile
(grams per kilometer)[1]

Test #	HC	CO	CO2	NOx	miles/gal. (liters/100 km)
2.0 gm/mi NOx 3000 lb. inertia					
77-4294[2]	0.85 (0.53)	1.3 (0.8)	231. (144.)	1.28 (0.80)	37.6 (6.3)
77-4332	0.88 (0.55)	1.3 (0.8)	243. (151.)	1.62 (1.01)	35.8 (6.6)
2750 lb. inertia					
77-4420	0.78 (0.48)	1.2 (0.8)	231. (143.)	1.36 (0.85)	37.7 (6.2)
77-4421	0.88 (0.55)	1.4 (0.9)	237. (147.)	1.28 (0.80)	36.7 (6.4)
1.0 gm/mi. NOx 2750 lb. inertia					
77-4328	0.72 (0.45)	1.6 (1.0)	243. (151.)	0.72 (0.45)	35.8 (6.6)
77-4356	0.68 (0.42)	1.6 (1.0)	249. (155.)	0.73 (0.45)	35.0 (6.7)
77-4329[2]	0.65 (0.41)	1.6 (1.0)	236. (147.)	0.62 (0.38)	36.9 (6.4)

[1] Values shown in parenthesis denote metric units.

[2] Dynamometer 6.

Table III

1975 Federal Test Procedure
Individual Bag Emissions in
grams per mile

	Bag 1: Cold Transient					Bag 2: Stabilized					Bag 3: Hot Transient				
Test #	HC	NOx	CO_2	CO	MPG	HC	NOx	CO_2	CO	MPG	HC	NOx	CO_2	CO	MPG
2.0 gm/mi. NOx 3000 lb. inertia, opt. shift															
77-4293	1.60	2.13	322.	5.9	26.4	1.30	1.05	343.	3.0	25.2	1.19	1.94	287.	2.8	30.1
77-4331	1.70	2.72	339.	6.2	25.1	1.31	1.39	350.	2.6	24.8	1.38	2.37	304.	4.2	28.1
2750 lb. inertia, opt. shift															
77-4418	1.36	2.45	327.	4.9	26.2	1.17	1.28	348.	2.5	25.0	1.07	2.14	296.	2.6	29.3
77-4419	1.65	2.14	327.	5.1	26.1	1.31	1.13	349.	2.8	24.8	1.25	1.90	298.	2.8	28.9
1.0 gm/mi. NOx 2750 lb. inertia, opt. shift															
77-4327	1.60	1.58	339.	6.6	25.0	1.12	0.74	369.	2.8	23.5	1.03	1.29	313.	3.5	27.6
77-4361	1.65	1.61	355.	6.1	24.0	1.13	0.74	379.	3.5	22.9	1.10	1.24	319.	3.6	27.0
77-4397	1.58	1.54	341.	5.8	25.0	1.02	0.65	360.	3.4	24.1	1.05	1.13	310.	3.8	27.8
2750 lb. inertia, standard shift															
77-4362	1.34	1.58	360.	4.9	23.9	1.08	0.80	396.	3.0	22.0	0.99	1.28	331.	3.0	26.2

Table IV

Steady State mass emissions in grams per mile (grams per kilometer) (1)

	HC	CO	CO_2	NOx	miles/gal (Liters/100 km)
2.0 gm/mi. NOx 3000 lb. inertia					
idle (neutral)	7.31 gms/hr	24.0 gms/hr	3118. gms/hr.	1.68 gms/hr	2.8 gal/hr. (10.6 liters/hr.)
15 mph (24kph) 2nd gear	2.80 (1.74)	2.8 (1.7)	294. (182.)	0.15 (0.10)	28.9 (8.1)
30 mph (48 kph) 4th gear	1.04 (0.64)	1.0 (0.6)	188. (117.)	0.23 (0.15)	45.9 (5.1)
45 mph (72 kph) 4th gear	0.85 (0.53)	1.1 (0.7)	209. (130.)	0.70 (0.43)	41.6 (5.7)
60 mph (97 kph) 4th gear	0.86 (0.53)	1.2 (0.8)	244. (151.)	2.00 (1.25)	35.7 (6.6)
2750 lb. inertia					
15 mph (24 kph) 2nd gear	2.42 (1.50)	2.7 (1.7)	292. (181.)	0.15 (0.10)	29.2 (8.0)
30 mph (48 kph) 4th gear	1.04 (0.65)	1.0 (0.6)	185. (115.)	0.18 (0.11)	46.7 (5.0)
45 mph (72 kph) 4th gear	0.79 (0.49)	1.1 (0.70)	201. (125.)	0.57 (0.36)	43.2 (5.4)
60 mph (97 kph) 4th gear	0.79 (0.49)	1.2 (0.8)	233. (145.)	1.66 (1.03)	37.3 (6.3)
1.0 gm/mi NOx 2750 lb. inertia					
idle (neutral)	7.39 gm/hr	22.4 gm/hr	3069. gms/hr.	1.51 gms/hr	2.8 gal/hr. (10.6 liters/hr.)

(1) Values in parenthesis denote metric units.

Table IV (con't)

Steady State mass emissions in grams per mile (grams per kilometer) (1)

	HC	CO	CO_2	NOx	miles/gal (Liters/100 km)
15 mph (24 kph) 2nd gear	2.47 (1.53)	3.0 (1.9)	306. (190.)	0.14 (0.09)	27.8 (8.5)
30 mph (48 kph) 4th gear	0.98 (0.61)	1.2 (0.8)	199. (123.)	0.14 (0.09)	43.6 (5.4)
45 mph (72 kph) 4th gear	0.73 (0.46)	1.3 (0.8)	218. (135.)	0.33 (0.21)	39.9 (5.9)
60 mph (97 kph) 4th gear	0.71 (0.44)	1.6 (1.0)	251. (156.)	0.80 (0.50)	34.7 (6.8)

(1) Values in parenthesis denote metric units.

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1976 Ford Pinto MPG
Emission control system - Lean-Burn combustion

Engine

type	4 stroke, Otto cycle, I-4, ohc
bore x stroke	3.78 x 3.13 in./96.0 x 79.5 mm
displacement	140 cu in./2295 cc
compression ratio	9.0:1
maximum power @ rpm	not available
fuel metering	metering pump
fuel requirement	unleaded

Drive Train

transmission type	4 speed manual

Chassis

type	front engine, rear wheel drive
tire size	A78 x 13
curb weight	2575 lbs./1168 kg
inertia weight	see text
passenger capacity	4

Emission Control System

basic type	lean-burn combustion
durability accumulated on system. .	7500 mi./12100 km