EPA-AA-TAEB 75-20

Evaluation of a PPG-Questor Prototype Vehicle

March 1975

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

Background

Houston Chemical Division of PPG Industries developed a lead trap to be used on a low pollutant emission vehicle which could be run on leaded fuel. For the emission control system PPG had Questor Corporation equip the vehicle with a third generation Questor Reverter System. After the vehicle had been tested by the California Air Resources Board and showed promising results, the Emission Control Technology Division of the Environmental Protection Agency requested testing of the vehicle. The vehicle was delivered to the Motor Vehicle Emissions Laboratory in Ann Arbor, Michigan on January 27, 1975.

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.

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.

System Description

The emission control system of the vehicle was developed by Questor Corporation and is called the Questor Reverter System. The vehicle was equipped with the latest third generation system and had accumulated about 7000 miles of durability.

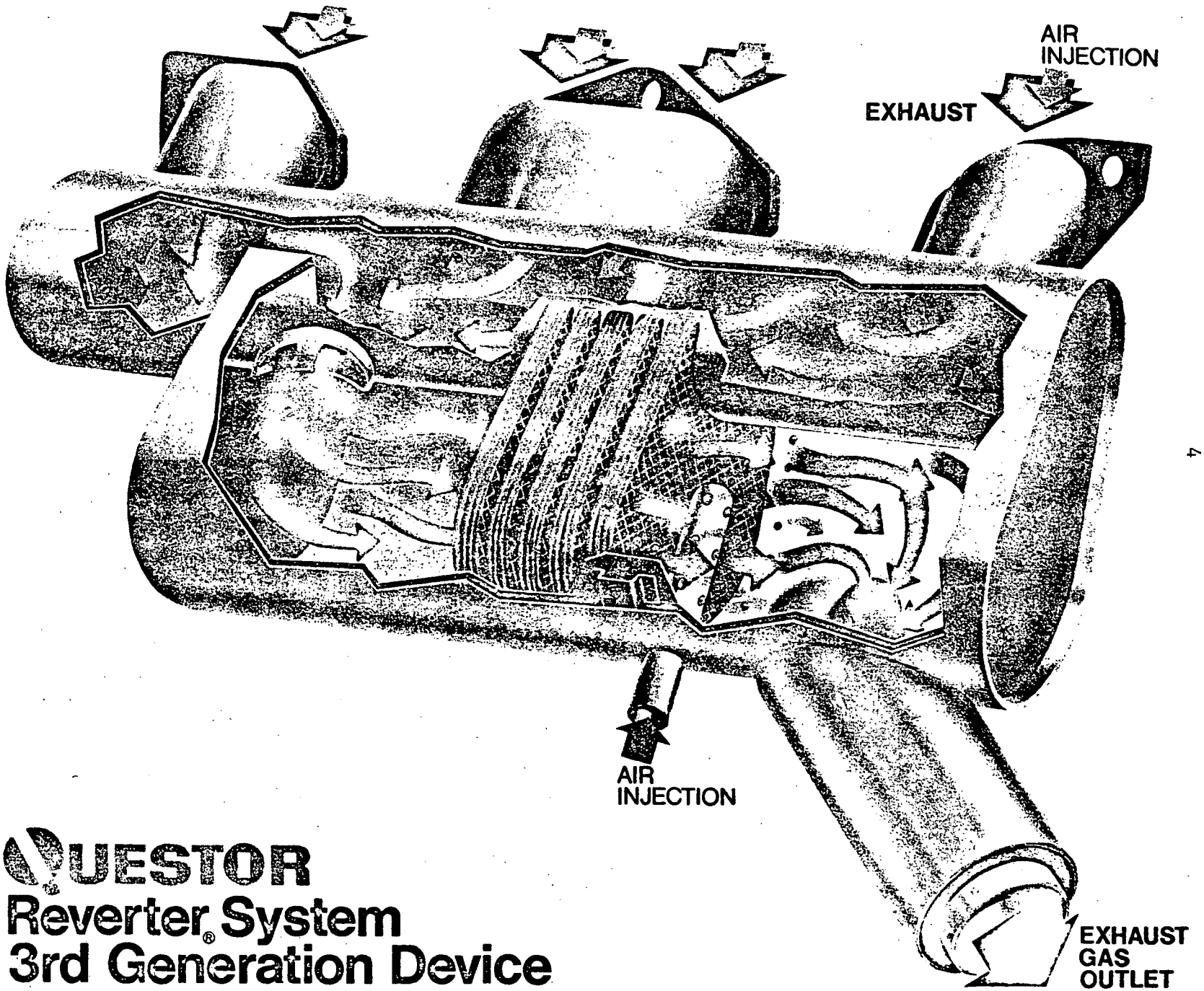
The Questor Reverter process is a three-step process which employs both thermal oxidation and catalytic reduction. Replacing the conventional exhaust manifold is a device which contains the three zones of operation. Exhaust gas enters the first reaction zone called the limited oxidation zone. In the vicinity of the exhaust ports air from an air pump is injected, producing a thermal reaction which oxidizes a portion of the hydrocarbons and carbon monoxide. The primary purpose of the limited oxidation zone is to rapidly increase the temperature in the emission control system, as well as maintain an abundance of carbon monoxide at the entrance to the catalyst bed. Because the engine is run richer than stoichiometric (air/fuel ratios of 12:1 {idle} to 13.5:1) an abundance of carbon monoxide is still present.

The partially oxidized exhaust gas then passes into the second zone containing the reduction catalyst. The catalyst materials are base metals impregnated on a stainless alloy screen. The catalyst material on this vehicle is 1N 1013, a copper-chromium-nickel composition, impregnated on an Inconel 601 substrate. In this zone oxides of nitrogen and carbon monoxide combine to form free nitrogen and carbon dioxide.

In the third zone the balance of air from the air pump is injected which oxidizes most of the remaining carbon monoxide and hydrocarbons. A schematic of the Reverter System and description of the chemical processes are shown on the following two pages.

Because of the high temperatures maintained, the Questor system can be used with either leaded or unleaded gasoline. Lead passes through the system in a vapor state which will not damage the catalyst. This system did not utilize Transmission Controlled Spark or Exhaust Gas Recirculation to control oxides of nitrogen (NOx) and the engine had a higher compression ratio than standard (9.4:1 compared to 8.4:1) for increased efficiency. Questor reports that current third generation systems yield a 5 to 8% fuel economy penalty as compared to 1973 baseline vehicles.

A lead trap developed by Houston Chemical Division of PPG Industries for reduction of particulate emissions was included in the exhaust system.



QUESTOR
Reverter® System
3rd Generation Device

CHEMICAL PROCESS

LIMITED OXIDATION ZONE

$2H_2 + O_2 \rightarrow 2H_2O + Heat$

$4HC + 5O_2 \rightarrow 4CO_2 + H_2O + Heat$

$2CO + O_2 \rightarrow 2CO_2 + Heat$

Total CO not oxidized due to lack of O_2

- Oxidize portion of HC
- Oxidize portion of CO
- Maintain CO rich atmosphere
- Increase temperature

REDUCTION ZONE

$2NO + 2CO \rightarrow N_2 + 2CO_2 + Heat$

In presence of copper

- NO_x reduced to N_2 in presence of catalyst
- Portion of CO oxidized to CO_2
- Catalyst is unaffected
- Predominatly CO and some HC passed to the Final Oxidation Zone

FINAL OXIDATION ZONE

$2H_2 + O_2 \rightarrow 2H_2O + Heat$

$4HC + 5O_2 \rightarrow 4CO_2 + H_2O + Heat$

$2CO + O_2 \rightarrow 2CO_2 + Heat$

- Final oxidation of remaining CO
- Oxidation continues in exhaust

REVERTER PROCESS

QUESTOR

The vehicle which was equipped with this system was a 1974 Ford Pinto Squire Station Wagon with a 140 cubic inch (2300 cc) engine and automatic transmission. A complete vehicle description is given on the following page.

Test Procedure

Exhaust emissions tests were conducted according to the 1975 Federal Test Procedure ('75 FTP), described in the Federal Register of November 15, 1972. Additional tests included the EPA Highway Cycle. All tests were conducted using an inertia weight of 3000 lbs. (1362 Kg) with a road load setting of 10.3 horsepower (7.68 kW) at 50 miles per hour (80.5 km/hr).

Five '75 FTP's and five EPA Highway Cycles were run on the vehicle. No calibration changes were made to the vehicle for the first four tests. Results from these tests indicated that the fuel/air ratio had increased during the test program. The idle CO had been set at about 6% prior to delivery but read 7.8% after the fourth test. The idle rpm had dropped to 620 and upon increasing it to 680 (the normal setting) idle CO dropped to 5.7%. This was the calibration used for the fifth test. Maintaining a consistent idle CO has reportedly been a continuing problem with this system, no doubt because the carburetor was designed to run much leaner than required by this system.

The fuel used for the first three tests (three each of '75 FTP's and EPA Highway Cycles) was Indolene Clear, a standard unleaded test fuel. Indolene 30, a standard leaded fuel, was used for the remaining tests.

Test Results

Exhaust emissions data, summarized below, illustrate that the PPG-Questor vehicle achieved the levels required by the 1978 Federal emissions standards with no change in fuel economy compared to a 1974 Pinto wagon which was certified for sale in California (the test vehicle was originally sold in California).

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

	HC	CO	NOx	1972 Procedure Fuel Economy (Fuel Consumption)	1975 Procedure Fuel Economy (Fuel Consumption)
PPG-Questor vehicle - avg. of 5 tests	.10 (.06)	2.62 (1.62)	.16 (.10)	16.5 miles/gal (14.3 litres/100 km)	17.1 miles/gal (13.8 litres/100 km)
1974 Certification vehicle	1.4 (.87)	35 (22)	1.7 (1.1)	16.6 miles/gal (14.2 litres/100 km)	
1978 Federal emissions standards	.41 (.25)	3.4 (2.1)	.4 (.25)		

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1974 Pinto Squire
Emission control system - Questor Reverter System and PPG Lead Trap

Engine

type	4 stroke Otto Cycle, OHV, 4 cyl. in-line
bore x stroke	3.78 x 3.13 in/96.0 x 79.5 mm
displacement	140 in^3/2300 cc
compression ratio	9.4:1
maximum power @ rpm	not available (NA)
fuel metering	2 barrel Holley carburetor
fuel requirement	91 RON

Drive Train

transmission type	3 speed automatic
final drive ratio	3.40:1

Chassis

type	unitized construction, front engine, rear wheel drive, 2 door station wagon
tire size	175 SR 13
curb weight	NA
inertia weight	3000 lbs./1362 kg
passenger capacity	4

Emission Control System

basic type	thermal reactor, reduction catalyst. Total volume of Reverter System approximately 280 in^3/4590 cc. Replaces exhaust manifold.
reduction catalyst location	Reverter
substrate	Inconel 601
loading	1N 1013
thermal reactor location	Reverter
air injection	Stock
size pump	NA
drive ratio	NA
location	exhaust ports
additional features	lead trap, Safe Guard System, Normal Operating Temperature Control
durability accumulated on system	7000 miles/11,300 km

EPA Highway Cycle Mass Emissions
grams per mile
(grams per kilometre)

	HC	CO	NOx	Fuel Economy (Fuel Consumption)
PPG-Questor Vehicle - average of 5 tests	.00 (.00)	.50 (.31)	.89 (.55)	23.2 miles/gal (10.1 litres/100 km)

On the '75 FTP CO emissions were above the standards once, on the fourth test; after the calibration change CO was again below the standards. Fuel economy declined during each of the tests until the calibration change was made; then it increased to a level of the average of the first four tests (17.1 mpg). HC and NOx emissions were well below the standards on all tests. All results are presented in the Appendix of this report.

The vehicle stalled once shortly after the initial start of the first '75 FTP. It was restarted and performed satisfactorily for the remainder of the test. On the next four '75 FTP's the vehicle did not stall, but the driver had to give extra gas to keep it running during the first few seconds. Driveability was poor until after the first acceleration of each test; after that it was acceptable.

Conclusions

The PPG-Questor vehicle, with 7000 miles accumulated, met the 1978 Federal emission standards with no loss in fuel economy compared to 1974 models. The system would have to undergo further durability testing to determine if it is capable of meeting the standards at 50,000 miles, which would be necessary for certification.

Questor has been able to improve the fuel economy of the Reverter System during the past two years from an original 20% loss to the present state which shows no loss in fuel economy compared to a 1974 system. With further improvements in the NOx catalyst, heat management, and fuel metering more improvements in fuel economy are expected. The two major problem areas are in air management and fuel metering. The present system uses a stock air pump and carburetor, neither of which was designed for this system.

Appendix

Table I

'75 FTP Composite Results
Mass emissions, grams per mile
Fuel economy, miles per gallon

Test No.	HC	CO	CO_2	NOx	Fuel Economy
19-7586	.09	2.35	496	.16	17.7
9-7634	.03	1.56	509	.15	17.3
9-7648	.15	2.86	515	.15	17.1
19-7695	.16	3.52	542	.19	16.2
9-7747	.08	2.79	516	.17	17.1

Table II

'75 FTP Individual Bag Results
Mass emissions, grams per mile
Fuel economy, miles per gallon

	Bag 1 Cold Transient					Bag 2 Hot Stabilized					Bag 3 Hot Transient				
Test Number	HC	CO	CO_2	NOx	Fuel Economy	HC	CO	CO_2	NOx	Fuel Economy	HC	CO	CO_2	NOx	Fuel Economy
19-7586	.51	8.07	520	.35	16.6	.00	.71	492	.05	18.0	.07	1.15	486	.23	18.2
9-7634	.21	4.23	550	.34	15.9	.00	.89	505	.06	17.5	.04	.83	486	.19	18.2
9-7648	.69	7.42	549	.34	15.8	.00	1.69	518	.05	17.1	.07	1.66	484	.20	18.2
19-7695	.55	11.33	577	.45	14.9	.04	1.00	538	.05	16.4	.12	2.41	523	.25	16.8
9-7747	.37	9.06	547	.39	15.8	.00	1.09	513	.06	17.3	.08	1.29	497	.22	17.8

Table III

EPA Highway Cycle
Emissions results and fuel economy
Mass emissions, grams per mile
Fuel economy, miles per gallon

Test No.	HC	CO	CO_2	NOx	Fuel Economy
19-7586	.00	.17	370	.78	24.0
9-7634	.00	.44	383	.66	23.1
19-7648	.00	.38	340	.55	26.1
19-7695	.02	1.05	430	1.80	20.6
9-7747	.00	.45	388	.64	22.8