Testing of a Plymouth Lean Burn Vehicle with an Oxidation Catalyst

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Background

Lean mixture combustion engines are attractive because of the low emissions and good fuel economy that are possible with a properly controlled lean burn engine. The addition of an oxidation catalyst should allow further improvements in emissions, driveability, and fuel economy. Chrysler Corporation has conducted research into engine operation at lean air-fuel ratios and is now planning to market lean burn vehicles. It also has extensively tested a lean burn vehicle with an oxidation catalyst.

The Emission Control Technology Division (ECTD) has recently tested (Report 75-16, 75-23, 76-7) several lean burn vehicles. However, none of these used a catalyst. Also, only one of the previous vehicles used systems that would possibly be marketed soon. ECTD, consistent with its interest in the evaluation of advanced automotive technology, requested a vehicle for testing. Chrysler Corporation made available a lean burn vehicle for emissions testing.

The Environmental Protection Agency receives information about many systems which appear to offer potential for emissions reduction or improvement in fuel economy 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 for the system, attempts are made to schedule tests at the EPA Emissions Laboratory at Ann Arbor, Michigan. The results of all such tests 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 of limited applicability. A complete evaluation of the effectiveness of an emission control system in achieving improvements on the 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 this 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.

Vehicle Description

The vehicle tested was a Plymouth Fury with 360 cubic inch (5899 cc), V-8 engine and a 3-speed automatic transmission. The vehicle was equipped with a Chrysler lean burn system with an oxidation catalyst. (The vehicle is described in detail on the following page.)

On this vehicle the lean burn system consisted of an induction system operating at an air to fuel ratio of about 18 to 1. Spark advance was electronically controlled. An oxidation catalyst was used for exhaust after-treatment.

The system used on this vehicle is not necessarily planned for production vehicles.

Test Procedures

Exhaust emissions tests were conducted according to the 1975 Federal Test Procedure ('75 FTP), described in the Federal Register of November 15, 1972 except that no evaporative emissions tests were conducted. Additional tests included the EPA Highway Fuel Economy Test (HFET), described in the Federal Register, Volume 39, Number 200, October 15, 1974 and steady state emissions tests.

These tests are conducted on a chassis dynamometer and employ the Constant Volume Sampling (CVS) procedure, which gives exhaust emissions of HC, CO, NOx and CO_2 in grams per mile. Fuel economy is calculated by the carbon balance method. The fuel used was Indolene unleaded 96 RON gasoline. All tests were conducted using an inertia weight of 4500 pounds (2041 kg) with a road load setting of 14.0 horsepower (10.4 kW) at 50 miles per hour (80.5 km/hr).

During these tests the vehicle was tested for sulfate emissions using the EPA sulfate procedures. A description of the procedure for measuring sulfate emissions and summary of the test results is given in the appendix.

Test Results

Exhaust emissions data, summarized below, showed that the Chrysler test car, using their lean burn system, was well within the levels of the 1977 Federal emissions standards at high mileage. However, the vehicle did not meet the statutory 1978 emission standards of .41 gm/mi HC, 3.4 gm/mi CO, .4 gm/mi NOx. Detailed results appear in the appendix to this report.

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1976 Plymouth Fury
Emission control system - Chrysler Lean Burn with Oxidation Catalyst

Engine

type	4 stroke, Otto cycle, V-8
bore x stroke	4.00 x 3.58 in./101.6 x 90.9 mm
displacement	360 cu. in./5899 cc
compression ratio	8.4:1
maximum power @ rpm	190 hp/142 kW
fuel metering	single 4 barrel carburetor
fuel requirement	regular unleaded, tested with 96 RON Indolene unleaded containing .03 percent sulfur

Drive Train

transmission type	3 speed automatic
final drive ratio	2.71:1

Chassis

type	unitized body/frame, front engine, rear wheel drive
tire size	GR 78 x 15
curb weight	4300 pounds
inertia weight	4500 pounds
passenger capacity	6

Emission Control System

basic type	lean combustion mixture, electronic spark advance monolith catalyst
durability accumulated on system	51,184 miles

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

	HC	CO	CO_2	NOx	Fuel Economy (Fuel Consumption)
Two Tests	.53 (.33)	3.97 (2.46)	803 (499)	1.62 (1.01)	10.9 miles/gal (21.5 liters/100 km)
1977 Federal Standards	1.5	15.0		2.0	

On the EPA Highway Cycle the results were:

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

	HC	CO	CO_2	NOx	Fuel Economy (Fuel Consumption)
Average of 2 tests	.28 (.17)	.44 (.27)	480 (298)	2.90 (1.80)	18.4 miles/gal (12.8 litres/100 km)

Steady state fuel economy results:

Speed mph (km/hr)	Fuel Economy miles/gal	(Fuel Consumption) litres/100 km
15 (24.1)	15.5	(15.2)
30 (48.3)	22.1	(10.7)
45 (72.4)	21.4	(11.0)
60 (96.6)	18.9	(12.4)

A comparison of the test vehicle's combined city/highway fuel economy with that of the 1976 certification Plymouth 360 (as published in the 1976 Buyer's Guide) showed that the test car had a fuel economy penalty of 7%. When compared to all vehicles in the same inertia weight class (4500 lbs) the test car showed a 15% fuel economy penalty.

	City/Highway Combined Fuel Economy miles/gal	(Fuel Consumption) litres/100 km
Plymouth Lean Burn (360 CID)	13.3	(17.7)
Plymouth 1976 Certification Vehicle (360 CID)	14.3	(16.5)
Average of all 4500 lb 1976 Vehicles (ave. 350 CID)	15.7	(15.0)

In calculating city/highway combined fuel economy, the urban fuel economy is weighted 55% and the highway fuel economy is weighted 45% to account for the 55/45 ratio of urban to rural mileage accumulation. The following equation is used:

$$MPG_{combined} = \frac{1}{\frac{.55}{MPG_{urban}} + \frac{.45}{MPG_{highway}}}$$

Sulfate emission test results are summarized in the appendix. The first test sequence showed sulfate levels of 31.2 mgpm over the sulfate cycle. The test was repeatable with a standard deviation of 4.3 mgpm. The second test sequence showed sulfate levels of 48.7 mgpm over the sulfate cycle. The test was repeatable with a standard deviation of 4.5 mgpm. The cause of this increase in sulfate emissions is not known. These sulfate levels are similar to EPA test results on catalyst vehicles with excess air.

For comparison, typical vehicle sulfate emission results as found in the EPA sulfate baseline study are:

Catalyst vehicles with excess air - about 30 mgm/mile H_2SO_4 (range 0.3-96)

Catalyst vehicles without excess air - about 17 mgm/mile H_2SO_4 (range 0.5-83)

3-way catalyst vehicles - 1 mgm/mile H_2SO_4

Non-catalyst vehicles - 1 mgm/mile H_2SO_4

The large range in sulfate levels is because the results are for vehicles using many different technologies and calibrated to different emission levels.

The vehicle had excellent driveability when it was driven on the road for a driveability evaluation.

Conclusions

At high mileage this Plymouth Fury equipped with a prototype lean burn system met the emission levels required by the 1977 Federal standards.

This system had a significant fuel economy penalty relative to conventional engines tested for 1976 emission standard certification in the same weight class. EPA has tested other lean burn vehicles meeting similar emissions levels, several of which had no fuel economy penalty.

Sulfate emission levels were found to be similar to catalyst vehicles with excess air.

Plymouth Lean Burn System with Oxidation Catalyst

Procedures used to measure sulfate emissions

1. The fuel was drained from the test vehicle. The vehicle was refueled with Indolene HO gasoline containing 0.03% sulfur by weight.

2. The vehicle was prepped by driving the vehicle over one LA-4 cycle to precondition the vehicle.

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

a) FTP
b) Sulfate Emissions Test (SET)
c) SET
d) HFET
e) SET
f) SET

Table A-1

75 FTP Mass Emissions
grams per mile

	Bag 1 Cold Transient					Bag 2 Hot Stabilized					Bag 3 Hot Transient				
Test Number	HC	CO	CO_2	NOx	Fuel Economy mpg	HC	CO	CO_2	NOx	Fuel Economy mpg	HC	CO	CO_2	NOx	Fuel Economy mpg
77-655	1.32	16.27	835	2.24	10.3	.33	.65	833	1.04	10.6	.52	2.04	760	1.70	11.6
77-756	1.14	13.46	822	2.72	10.5	.23	.82	850	1.24	10.4	.44	1.80	662	2.12	13.3

Table A-2

75 FTP Composite Mass Emissions
grams per mile

Test Number	HC	CO	CO_2	NOx	Fuel Economy (mpg)
77-655	.59	4.25	813	1.46	10.8
77-656	.48	3.69	793	1.78	11.1

Table A-3

EPA Highway Cycle Mass Emissions
grams per mile

Test Number	HC	CO	CO_2	NOx	Fuel Economy (mpg)
77-642	.27	.42	479	3.02	18.5
77-656	.29	.45	482	2.77	18.3

Table A-4

Steady State Mass Emissions
grams per mile

Test Number	Speed MPH	HC	CO	CO_2	NOx	Fuel Economy (MPG)
77-757*	Idle	.05	.06	147	.07	.83
77-758	15	.69	.34	571	.45	15.5
77-759	30	.85	.21	399	1.46	22.1
77-760	45	.18	.25	413	3.08	21.4
77-761	60	.17	.43	469	4.30	18.9

* grams per minute, gallons per hour.

Table A-5

Sulfate Procedure Emissions
grams per mile

Test Sequence 1

Test Type	HC	CO	CO_2	NOx	Fuel Economy (mpg)	H_2SO_4*	% Conversion
75 FTP (composite)	.53	5.37	791	1.81	11.1	35.2	15.7
Highway	.23	.61	493	3.14	17.9	43.0	30.8
Sulfate (avg. of 4)	.25	.73	556	2.87	15.9	31.2	19.8

Test Sequence 2

75 FTP (composite)	.49	4.03	772	2.28	11.4	23.9	10.9
Highway	.26	.61	508	2.55	17.4	60.7	42.3
Sulfate (avg. of 4)	.27	.62	557	2.24	15.9	48.7	31.0

* milligrams per mile