An Evaluation of Two Honda Automobiles Powered by 91 CID Stratified Charge CVCC Engines

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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 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.

This evaluation of two Honda Compound Vortex Controlled Combustion (CVCC) vehicles is the third opportunity for ECTD to report on the emission and fuel economy performance of vehicles incorporating the stratified charge engine that Honda Motor Company of Japan announced publicly in the fall of 1972. Results of tests conducted by EPA on three "Civic" vehicles powered by 119 CID (1950 cc) versions of the CVCC engine were reported in TAEB report number 73-11. The 1975 FTP emission values for the first cars tested were:

Hydrocarbons (HC) 0.21 gm/mi (.13 gm/Km)
Carbon Monoxide (CO) 1.96 gm/mi (1.22 gm/Km)
Oxides of Nitrogen (NOx) 0.81 gm/mi (.50 gm/Km)

After their earlier work on four cylinder engines and subcompact cars Honda adapted the CVCC process to a larger engine and vehicle combination to demonstrate that the CVCC concept would successfully reduce emissions on full-size American cars. A 350 CID Chevrolet V-8 engine was modified and installed in a Chevrolet Impala. After Honda reported achievement of the 1977 Statutory Standards, an EPA confirmatory test program was conducted during late summer of 1973 (see Report No. 74-13). The average 1975 FTP emission values for this testing were:

Hydrocarbons (HC) 0.25 gm/mi (.16 gm/Km)
Carbon Monoxide (CO) 2.98 gm/mi (1.85 gm/Km)
Oxides of Nitrogen (NOx) 1.23 gm/mi (.76 gm/Km)

In September of 1973 EPA requested the loan of a CVCC powered Civic for use in comparison tests between various stratified charge, Diesel, and conventional engined vehicles. In response to this request two vehicles were provided by Honda for an indefinite period of time. This report covers the first series of in-house evaluations of the vehicles loaned by Honda for the comparison program. Further testing and comparisons with other vehicles will be drawn in future EPA reports.

<u>Vehicles Tested</u>

Both vehicles tested were front wheel drive Honda Civic sedans powered by 90.8 CID versions of the CVCC engine. One vehicle was equipped with the 4-speed manual transmission, the other an automatic transmission. Neither vehicle was representative of the 1975 production Honda Civic because they had been calibrated by Honda to achieve the 1977 statutory standards of .41 HC, 3.4 CO and 2.0 NOx. The cars are described in detail in the Vehicle Description sheets (Tables 1 and 2). Figure 1 is a photograph of the manual transmission Honda CVCC Civic tested and Figure 2 is a top view photograph of that vehicle's engine with the air cleaner removed.

The CVCC engine burns a heterogeneous air-fuel mixture and in this respect is similar to the stratified charge engines of Ford (PROCO) and Texaco (TCCS). While the Ford and Texaco engines use direct cylinder fuel injection to obtain charge stratification, the Honda CVCC engine obtains stratification with the use of a separately carbureted prechamber. The CVCC is classified as a "small volume" prechamber. The prechamber is just large enough to provide a jet of flame to ignite the main chamber in which the bulk of the combustion takes place.

Two separate intake valves are used on each cylinder of the CVCC engine. One valve is located in the prechamber and the other in the main chamber. One small barrel of the three barrel carburetor used on the CVCC engine supplies a rich mixture to each prechamber. The other two barrels supply the main combustion chambers with a

Table 1

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1974 Honda Civic CVCC with manual transmission

Emission control system - pre-chamber stratified charge with engine modifications

Engine

type	4 stroke pre-chamber, stratified charge, spark ignited, single over head camshaft in-line 4 cyl.
bore x stroke	2.91 x 3.41 in. (74.0 x 86.5 mm)
displacement	90.8 cu. in. (1488 cc)
compression ratio	8.1:1
maximum power @ rpm	53 hp (39.5 kW) @ 5000 rpm
fuel metering	carbureted 3 venturi downdraft 2 venturi for combustion chamber 1 venturi for pre-chamber
fuel requirement	indolene clear (96 RON) used octane requirement not determined

Drive Train

transmission type	manual 4 speed
final drive ratio	4.73:1

Chassis

type	front transverse mounted engine, front wheel drive, 4 door unitized body
tire size	6.00 S 12-4PR
curb weight	1,640 lb. (745 kg)
inertia weight	2,000 lb. (907 kg)
passenger capacity	4

Emission Control System

basic type	pre-chamber stratified charge, positive crankcase ventilation

Table 2

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1974 Honda Civic CVCC with automatic transmission
Emission control system - pre-chamber stratified charge with engine modifications

Engine

type	4 stroke pre-chamber, stratified charge spark ignited, single over head camshaft in-line 4 cyl.
bore x stroke	2.91 x 3.41 in. (74.0 x 86.5 mm)
displacement	90.8 cu. in. (1488 cc)
compression ratio	8.1:1
maximum power @ rpm	53 hp (39.5 kw) @ 5000 rpm
fuel metering	carbureted 3 venturi downdraft 2 venturi for combustion chamber 1 venturi for pre-chamber
fuel requirement	indolene clear (96 RON) used octane requirement not determined

Drive Train

transmission type	2 speed automatic
final drive ratio	4.12:1

Chassis

type	front transverse mounted engine, front wheel drive, 4 door unitized body
tire size	6.00 S 12-4PR
curb weight	1,660 lb. (755 kg)
inertia weight	2,000 lb. (907 kg)
passenger capacity	4

Emission Control System

basic type	pre-chamber stratified charge, positive crankcase ventilation

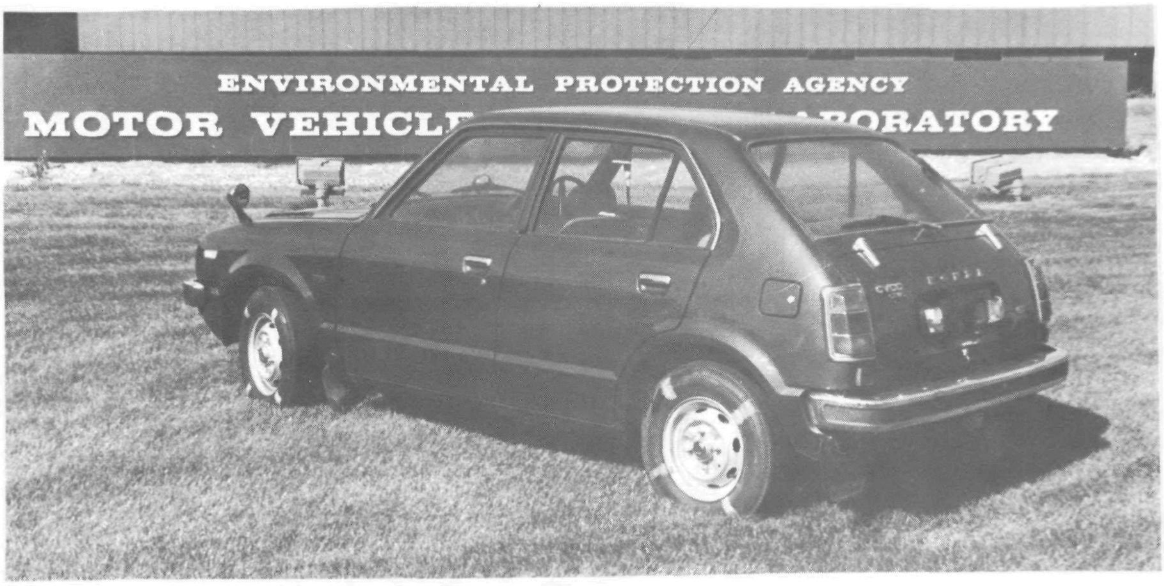
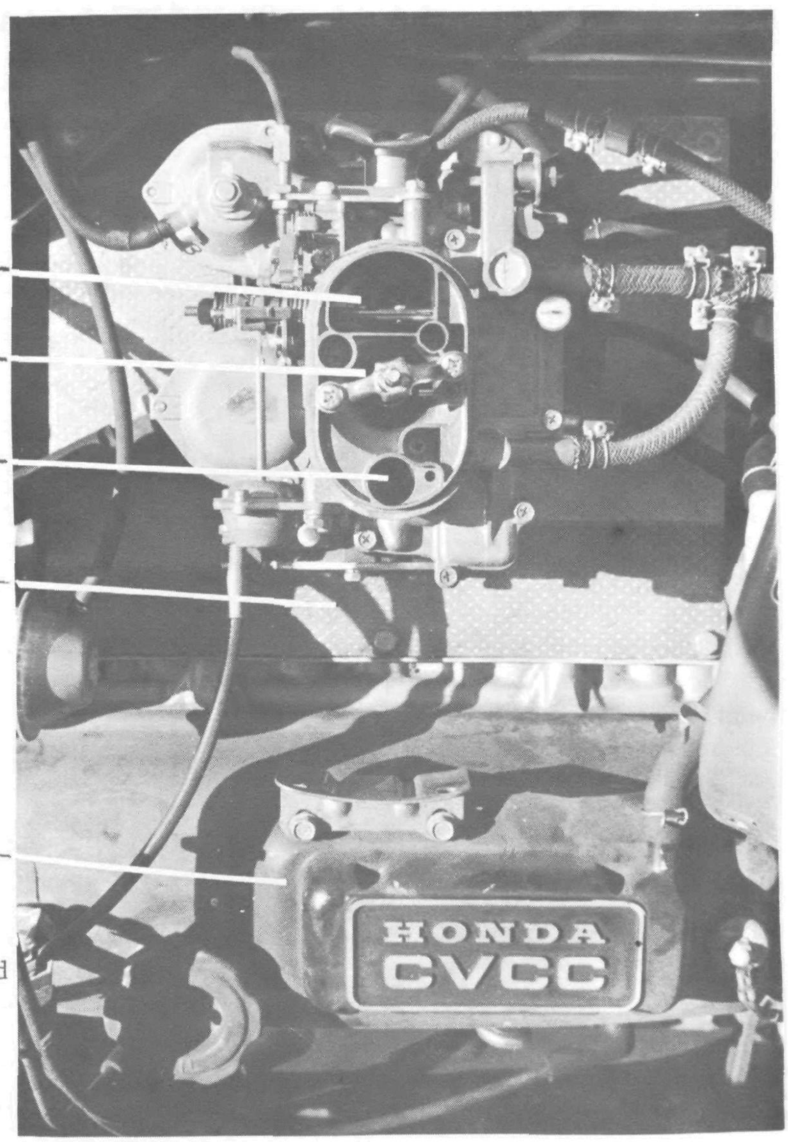


Figure 1. Honda CVCC Civic with Manual Transmission



Main chamber carburetor
primary venturi

Main chamber carburetor
secondary venturi

Prechamber carburetor
venturi

Heat shield

Valve cover

Figure 2. Top View of Engine
with Air Cleaner Removed

very lean mixture. Combustion is initiated in the prechamber with a conventional ignition system and spark plugs (one plug per prechamber). As the burning gases expand from the prechamber, they ignite and burn the lean mixture present in the main chamber. A schematic of the combustion system appears in Figure 3.

The overall air-fuel ratio of the CVCC engine is significantly leaner than stoichiometric. Conventional engines cannot generally be operated as lean because of the difficulty in consistently igniting homogeneous mixtures leaner than about 18:1 A/F. Ignition is easily achieved in the CVCC engine by locating the spark plug in the fuel rich prechamber. The very lean overall operation is conducive to low CO emissions because the high availability of oxygen facilitates the conversion of CO to CO_2. The combination of adequate oxygen and temperature in the main chamber is the essential factor in controlling HC emissions.

NOx formation is a function of air ($N_2 + O_2$) availability and temperature. The initial portion of the combustion in the CVCC engine occurs in the very rich region of the prechamber where the air availability is low, keeping NOx formation low. By the time the combustion has progressed to the main chamber, where there is high air availability, NOx formation stays low since the temperature has dropped because of expansion and the lean conditions.

No "add-on" type emission control systems such as catalysts, air injection, or exhaust gas recirculation (EGR) were used on the test vehicles but the exhaust manifolds are sized to promote post-cylinder HC oxidation.

Test Procedures

Exhaust emission tests were conducted according to the 1975 Federal Test Procedure ('75 FTP), described in the Federal Register of November 15, 1972, and the EPA Highway Cycle Test (HWC), described in the EPA Recommended Practices for Conducting Highway Fuel Economy Tests. Both of these tests are conducted on a chasses 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.

As received by EPA each vehicle had only been driven approximately 100 miles. After the initial tests were run both vehicles were taken to a test track for accumulation of 4000 miles under AMA durability conditions before any additional testing was performed.

Test Results

1975 FTP tests results for both vehicles are given in table 3. Highway cycle results are given in table 4. It is evident from

HONDA
CIVIC CVCC ENGINE

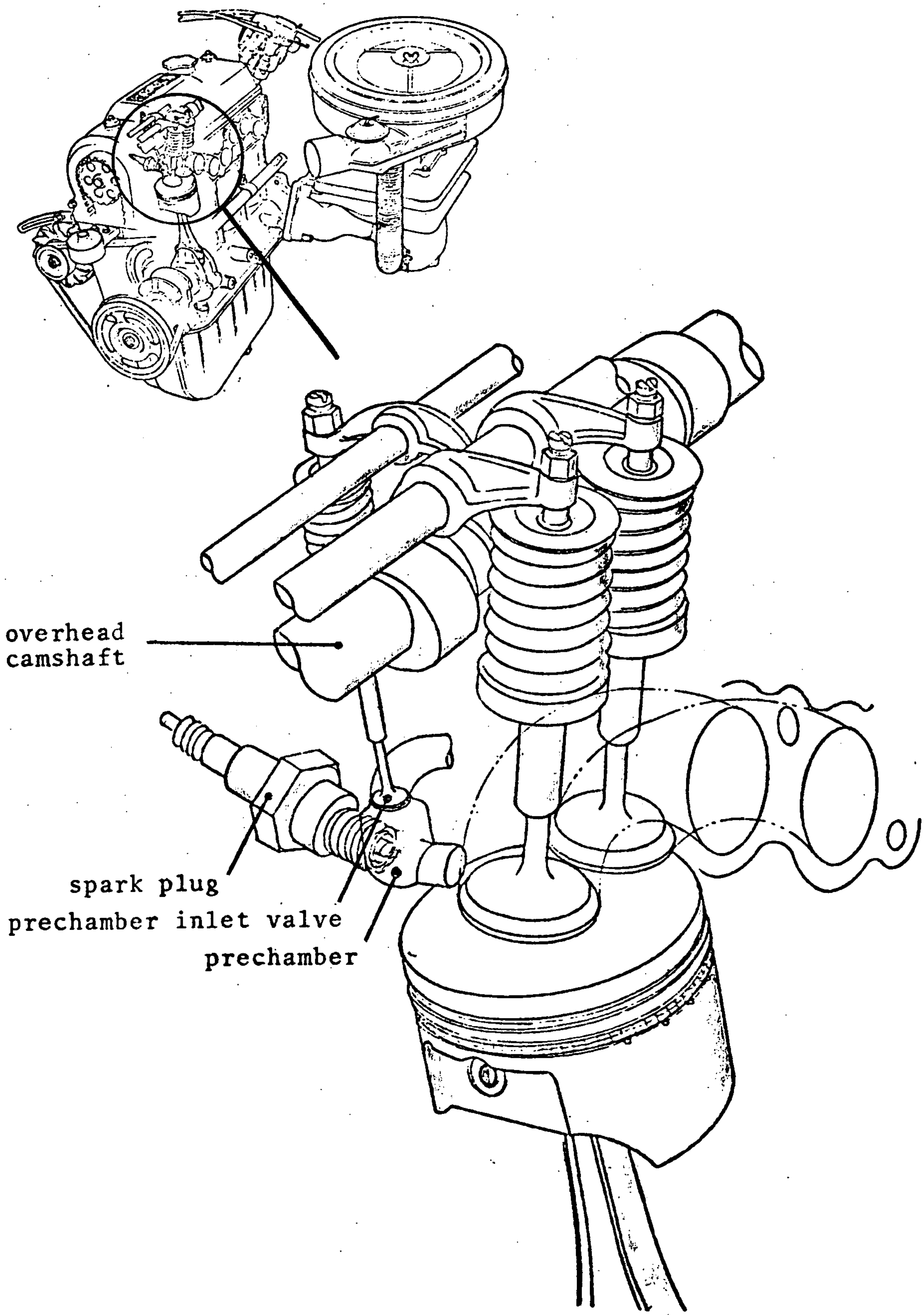


Figure 3

table 3 that emission levels just under the 1977 statutory standards can be achieved with the standard transmission vehicle. The CO results for the automatic transmission vehicle were slightly over the 3.4 g/mi 1977 statutory standard for CO.

Table 4 results indicate approximately 32% better fuel economy was achieved on the highway driving cycle than on the urban cycle. This fuel economy difference is within the range of results which have been seen for conventional engine powered vehicles.

Tables 3 and 4 reflect results using two different sets of tires. After the 4000 mile break-in at the Dana test track the front tires of both vehicles were worn out due to the tightness and surface roughness of the Dana track. A new set of four tires was purchased. The tires selected were radial ply (size 155 SR12); being the same size offered as on option by Honda. These were mounted on one vehicle and the stock (size 6.00 S12-4PR) bias ply rear tires of each vehicles were combined as a set for the other vehicle. Upon testing the vehicle with the radial tires a significant loss in fuel economy was observed. The tires were suspect and the vehicles were retested with the stock tires which showed improved fuel economy. Upon comparison of the new radial tires with the stock tires it was found that the radials were approximately one inch smaller in diameter. Increased fuel usage probably resulted from an effective increase in axle ratio resulting from the small diameter tires, and from increased tire flexure caused by the geometric relationship between the smaller diameter tires and the fixed roller spacing of the dual roller Clayton dynamometers used for testing. The influence of tire flexture on dynamometer loading is probably most noticeable for vehicles with less than 13" wheels as is the case for the Civic. Tables 3 and 4 also compare the emission and economy values of the two CVCC prototypes to the values obtained on 1975 production versions of the Honda Civic. The CVCC production cars calibrated to higher emission levels demonstrated fuel economy that was nearly identical to the lower emission prototypes. The conventional engine powered Civic vehicles had almost double the HC and CO levels of the low emission prototypes. Urban economy for the conventional engine powered vehicles was only 3% better than the prototype CVCC's. Highway fuel economy was 5% better for the conventional engine.

Conclusions

The standard transmission model Honda CVCC Civic demonstrated the ability to meet the 1977 statutory emission levels of 0.41 HC, 3.4 CO, and 2.0 NOx. The automatic transmission model met the 1977 HC and NOx levels, but exceeded the CO level by approximately .5 grams/ mile. Fuel economies of these two vehicles were essentially the same as those of the 1975 Honda CVCC Civic certification cars. Thus it appears that calibrating to the more stringent 1977 emission levels has not significantly degraded fuel economy from the 1975 model year.

As the maximum mileage of these vehicles as tested was around 4000 miles, the ability to maintain the 1977 calibrations with higher mileage accumulation has yet to be determined.

A 10% decrease in the '75 FTP fuel economy was observed when the standard bias ply tires were replaced with the optional radial ply tires. The reasons for this are not certain, but the smaller diameter of the radial and its interaction with the chassis dynamometer rolls are suspected.

TABLE 3
1975 FTP Composite Results

		Mass Emissions grams/mile (grams/kilometre)			Fuel Usage miles/gallon (litres/100 kilometres)
		HC	CO	NOx	
Manual Transmission Test Car, 1500 cc CVCC engine, 2000 IW	Initial tests, 100 miles w/bias ply tires	.37 (.23)	2.91 (1.81)	1.44 (0.89)	26.3 (8.94)
	After 4000 miles, w/bias ply tires	.39 (.24)	2.97 (1.85)	1.30 (0.81)	26.4 (8.91)
	After 4000 miles, w/radial tires	.36 (.22)	3.48 (2.16)	1.32 (0.82)	23.3 (10.1)
Automatic Transmission Test Car, 1500 cc CVCC engine, 2000 IW	Initial tests, 100 miles w/bias ply tires	.42 (.26)	3.80 (2.25)	1.83 (1.14)	24.1 (9.76)
	After 4000 miles, w/bias tires	.40 (.25)	4.58 (2.85)	1.72 (1.07)	24.5 (9.60)
	After 4000 miles, w/radial tires	.39 (.24)	3.96 (2.46)	1.73 (1.08)	22.2 (10.6)
1975 Honda Certification Cars w/bias ply tires	CVCC w/manual trans.	.55 (.34)	4.34 (2.69)	1.25 (.78)	27.5 (8.55)
	CVCC w/auto trans.	.51 (.32)	4.79 (2.98)	1.10 (.68)	24.2 (9.72)
	1200 cc conventional engine w/manual trans.	.81 (.50)	6.67 (4.14)	1.40 (.87)	28.0 (8.40)
	1200 cc conventional engine w/auto trans.	.61 (.38)	6.00 (3.73)	1.91 (1.19)	24.5 (9.60)
Federal standards	1975 49-state	1.5 (.93)	15.0 (9.3)	3.1 (1.9)	
	1975 California	.9 (.56)	9.0 (5.6)	2.0 (1.2)	
	1977	.41 (.25)	3.4 (2.1)	2.0 (1.2)	
	1978	.41 (.25)	3.4 (2.1)	0.40 (.25)	

TABLE 4
EPA Highway Cycle Results

	Mass Emissions grams/mile (grams/kilometre) HC	CO	NOx	Fuel Usage miles/gallon (litres/100 kilometres)
1500 cc Manual trans CVCC				
w/bias ply tires	.02 (.01)	.66 (.41)	1.47 (.92)	36.5 (6.46)
w/radial ply tires	.01 (.01)	.67 (.42)	1.49 (.93)	34.8 (6.76)
1500 cc Auto trans CVCC				
w/bias ply tires	.02 (.01)	.50 (.31)	1.75 (1.09)	30.4 (7.74)
w/radial ply tires	.02 (.01)	.61 (.38)	1.76 (1.09)	30.3 (7.76)
1975 Honda certification cars (w/bias ply tires)				
1500 cc CVCC manual trans				38.4 (6.13)
1500 cc CVCC, auto trans				28.8 (8.17)
1200 cc conventional engine w/manual trans				40.0 (5.88)
1200 cc conventional engine w/auto trans				30.0 (7.84)

APPENDIX

Individual Bag Results

Test #	Vehicle	Tire Type	Hydrocarbon Bag 1 g/mi	Hydrocarbon Bag 2 g/mi	Hydrocarbon Bag 3 g/mi	Carbon Monoxide Bag 1 g/mi	Carbon Monoxide Bag 2 g/mi	Carbon Monoxide Bag 3 g/mi	Carbon Dioxide Bag 1 g/mi	Carbon Dioxide Bag 2 g/mi	Carbon Dioxide Bag 3 g/mi	Oxides of Nitrogen Bag 1 g/mi	Oxides of Nitrogen Bag 2 g/mi	Oxides of Nitrogen Bag 3 g/mi	Fuel Economy Bag 1 mpg	Fuel Economy Bag 2 mpg	Fuel Economy Bag 3 mpg
21-90	Std.Tran.	Bias ply	0.82	0.15	0.45	3.90	2.75	2.48	332.4	344.2	304.9	1.83	1.07	1.86	26.0	25.4	28.6
16-4859	"	"	0.89	0.10	0.28	4.22	2.36	1.90	315.8	332.8	284.8	1.62	0.96	1.59	27.3	26.3	30.7
16-4880	"	"	0.97	0.11	0.71	5.16	2.68	3.17	344.4	364.7	312.9	1.70	1.03	1.62	25.0	24.0	27.7
15-4471	"	Radial	1.07	0.11	0.32	6.25	2.67	1.57	360.0	403.0	336.8	1.58	0.97	1.57	23.8	21.8	25.9
15-4450	"	"	0.83	0.10	0.45	5.16	3.07	3.28	370.2	387.8	336.4	1.70	1.06	1.65	23.3	22.6	25.9
15-4422	"	"	0.93	0.11	0.45	5.16	2.82	3.33	364.9	405.1	330.5	1.62	1.10	1.60	23.6	21.6	26.3
21-91	Auto Tran.	Bias	1.19	0.15	0.35	6.41	2.91	3.54	369.1	378.6	320.7	2.37	1.50	2.04	23.2	23.1	27.1
15-4857	"	"	0.95	0.13	0.52	12.32	2.37	2.99	365.5	363.3	325.8	2.21	1.40	1.98	22.9	24.1	26.7
15-4470	"	Radial	1.08	0.13	0.36	5.82	3.41	3.61	412.1	404.9	355.1	2.07	1.41	2.09	20.9	21.6	24.5