An Evaluation of Three Honda Compound Vortex Controlled Combustion (CVCC) Powered Vehicles

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Background

This fall the Honda Motor Company of Japan announced publicly that they had developed an engine featuring Compound Vortex Controlled Combustion (CVCC), which would meet the Federal emission requirements for model year 1975 without after-treatment devices such as thermal reactors or catalysts. Honda also submitted a detailed report of their testing program on this engine to EPA as part of their annual status report. To confirm what appeared to be a substantial breakthrough in emission control technology, EPA contacted the Honda Motor Company and offered to conduct confirmatory tests on a vehicle in the Ann Arbor laboratory. Honda accepted the EPA offer and delivered three vehicles for test on December 6, 1972.

Vehicles Tested

All three of the vehicles supplied by Honda were equipped with essentially the same version of the Compound Vortex Controlled Combustion (CVCC) engine. Minor differences included the manufacturing processes used (sand vs. die casting) and differences in control linkages. Each engine was a water cooled in-line four cylinder with an overhead cam. Displacement was 1,948 cc (119 CID). Manufacturer rated maximum horsepower was 65 (DIN) @ 5000 rpm.

The CVCC engine burns a heterogeneous air-fuel mixture. In concept it is similar in some respects to the more well-known 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 prechamber.

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. The smallest venturi of the three barrel carburetor used on the engine supplies a rich mixture to each prechamber. The other two venturis supply the engines main chambers with a very lean mixture. Combustion is initiated in the prechambers 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 drawing of the engine and a schematic of the combustion system appears in Figure 1.

2. Hot start 1972, 2-bag FTP @3000 pound test weight.

3. Steady state tests @ idle, 15, 30, 45 & 60 mph.

The 1975 FTP was used to determine gaseous emissions, particulate emissions, and fuel economy at the vehicle's standard test weight of 2000 pounds. Testing for HC, CO, CO_2, NOx, and aldehydes was done in the Ann Arbor laboratory. Particulate testing was done at Dow Chemical in Midland, Michigan.

Particulate levels were also determined using the hot start 1972 FTP as were the HC, CO, CO_2, and NOx levels. One of the hot start tests was run at the 3000 pound test weight to determine the influence of vehicle weight on exhaust emissions and fuel economy with the CVCC engine.

Gaseous emissions (HC, CO, CO_2, and NOx) and fuel economy were determined during steady state operation at idle, 15, 30, 45, and 60 mph. Particulates were measured at 60 mph.

The Dow particulate procedure simulates an air quench of the vehicle's exhaust gas by routing the exhaust into a 15 7/8 inch diameter tube where it is diluted to a 500 cfm flow. Twenty-seven feet downstream of the tailpipe samples are pulled from the diluted exhaust through fiberglass filters, millepore filters and an Anderson Impactor. While the Dow procedure is not an "official" or standard particulate test, it does allow us to compare particulate emission levels from different vehicles using a common procedure.

A description of the Federal Test Procedure for exhaust emission testing is enclosed (Attachment I).

Test Results

Results are summarized in Tables I, II, III, and IV. Table I lists the results on the 1975 Federal Test Procedure for all three vehicles. The first test (not reported) on the low mileage car #3652 was aborted due to a binding choke linkage which was immediately repaired. All other tests on all three vehicles met the levels required for 1975 easily. NOx levels were less than one-third the 1975 requirement. About a 50% further reduction in NOx would be required for 1976 NOx levels, but it should be noted that EGR was not used on these vehicles. Honda representatives made it clear that the three cars supplied to EPA were 1975 model year prototypes only, with no modifications to improve NOx emissions.

Table IV summarizes the particulate testing results. Results obtained on three other vehicles using conventional engines are shown for comparison. The data indicates that the particulate emissions from the Honda vehicle are essentially the same as from conventional engines using equivalent fuels.

Although not reported in the Tables, the low mileage vehicle was also tested for aldehyde emissions using a wet chemical technique. The formaldehyde level of the exhaust was too low to be accurately determined with the procedure used. The CVCC exhaust aldehyde level is much lower than the conventional engine, apparently less than .01 grams per mile.

The driveability of the CVCC powered vehicles was evaluated on the road and there were no problems encountered. The engine was very responsive and the acceleration was very strong. Honda reported quarter-mile acceleration times of 17.8 seconds. The vehicles easily maintained expressway speeds with adequate passing power in reserve.

Conclusions

1. All three Honda CVCC vehicles tested repeatedly met the emission levels required for 1975. The lowest emitter of the three had completed the 50,000-mile AMA durability run without incident.

2. There does not appear to be a significant fuel economy or driveability penalty associated with the engine.

3. There is apparently adequate cushion in the emission levels at the 2000-pound test weight to also meet the 1975 levels with a 50% heavier vehicle.

4. There is no particulate emission or smoke problem associated with the CVCC engine.

5. There is no aldehyde emission problem associated with the CVCC engine.

6. Additional NOx control will be required to reach the 1976 levels but the vehicles tested did not employ devices or special calibration for NOx control.

7. The CVCC engine achieved lower emission levels than any other gasoline fueled engine without after-treatment ever tested by EPA.

Table I

Honda CVCC Powered Vehicle
1975 Federal Test Procedure
(emission data in grams per mile)

	Test Number	HC	CO	NOx	'75 FTP mpg	'72 FTP mpg
Low Mileage Car #3652	16-0109	.20	2.06	.75	22.0	20.9
	16-0114	.15	1.96	.83	22.4	21.5
	16-0117	.16	2.28	1.06	21.9	20.6
	16-0118	.21	2.24	.86	22.1	20.9
	16-0122	.19	2.05	.94	22.1	20.9
	AVERAGE	.18	2.12	.89	22.1	21.0
50,000 Mile Car #2034	16-0106	.19	1.73	.65	21.1	20.0
	16-0110	.25	1.73	.57	22.2	19.7
	16-0115	.26	1.70	.64	21.0	19.8
	16-0116	.26	1.85	.73	20.8	19.5
	AVERAGE	.24	1.75	.65	21.3	19.8
Low Mileage Back-up Car #3606	16-0123	.23	2.00	1.03	20.7	19.5
1975 Federal Standards		.41	3.40	3.1		
1976 Federal Standards		.41	3.40	.40		

Table III

Honda CVCC Vehicle #3652

Steady State Emission Levels
and Fuel Consumption
(emission data in grams per mile except for the idle mode where data is reported in grams per minute)

MODE	HC	CO	NOx	MPG
Idle	.06	.23	.02	*
15 mph cruise 2nd gear	.08	1.92	.44	21.0
30 mph 3rd gear	.01	.67	.50	29.2
45 mph cruise 4th gear	.007	.41	.75	32.1
60 mph cruise 4th gear	.005	.36	.645	33.0

*idle fuel consumption = 228.6 minutes/gallon or 12.5 grams per minute.