EPA-HONDA Emission Laboratory Correlation Study

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Abstract

A laboratory correlation program between the EPA Motor Vehicle Emission Laboratory (MVEL) and the new Ann Arbor Honda emission test laboratory has been completed. Statistical analysis of data from a 1976 Honda Civic CVCC tested for exhaust emissions and fuel consumption at two inertia settings indicate no differences in measured values of CO, CO_2, and calculated fuel consumption. A statistical difference exists between measured quantities of HC and NO_x.

1. Introduction

American Honda Motor Company, Inc. has recently completed construction and the facilities checkout of their light duty vehicle emissions test laboratory located at 3947 Research Park Drive, Ann Arbor. After one test cell became operational about mid-August 1975, American Honda requested that a laboratory to laboratory correlation program be conducted to locate and correct potential significant differences between test results from EPA and Honda.

On Friday, September 12, a vehicle was tested at the Honda Ann Arbor laboratory, and on Monday, September 15, the same vehicle and test sequence were used to gather emission and fuel economy data at the EPA-MVEL. The data gathered at these two test sites were then used for comparison purposes.

2. Test Design

2.1 Test Sequence

The laboratory correlation program consisted of hot start exhaust emission tests, EPA highway fuel economy tests, dynamometer coastdown checks, and static gas checks of HC, CO, CO_2, and NOx.

The test sequence, as repeated at each site, consisted of the following tests and checks:

1) @ 2000# IW 2 Hot-start LA-4 tests (2-bag)
   1 HFET
   Dynamometer coastdown checks

2) @ 2250# IW 2 Hot-start LA-4 tests
   1 HFET
   Dynamometer coastdown checks

3) Gas analysis of HC (propane), CO, CO_2, and NOx dilute concentrations. A total of 12 cylinders were analyzed at each laboratory.

2.2 Test Vehicle

The test vehicle was a 1976 model year Honda Civic CVCC, 1.5 litre, 5 speed manual transmission, equipped to measure and record torque and speed vs. time. The vehicle was tested at 2000 and 2250 pounds inertia. The fuel type used was Indolene 30. Honda supplied the driver for all tests at both laboratories.

2.2-1 Preconditioning:

All exhaust emission and fuel economy tests were hot start tests. The test vehicle was used to warm-up the dynamometer and set the correct value of indicated horsepower. The preconditioning consisted of 15 minutes at 30 mph, 3 minutes at 50 mph, and 1 minute at idle.

2.3 Facilities

2.3-1 Equipment: The vehicle was tested at the Honda Ann Arbor Laboratory using their light duty test cell (only one is operational at present) and analytical equipment. The test cell has temperature and humidity control.

At the EPA-MVEL in Ann Arbor, dynamometer 5, CVS 25C, and analytical train 21 were used for the correlation tests. A complete description of the Honda and EPA equipment is presented in Table 1.

2.3-2 Calibration: Analyzer, CVS, and dynamometer checks and calibration were performed in accordance with current Federal Register requirements. Honda and EPA propane recovery checks and chemiluminescent convertor efficiency checks were within acceptable guidelines.

3. Test Results

3.1 Emission and Fuel Economy Results

Test results are summarized in Table 2. Values for Y_{HT} (bag 1), and Y_{HS} (bag 2) have units of grams per phase. Composite values are computed in grams/mile. NOx results are reported as corrected values.

Table 1

TEST SITE INSTRUMENTATION

Analyzers	EPA #21	Honda
HC	Beckman 400 0-50, 100, 250 ppm H_2/N_2 fuel	Beckman 400 0-50, 100 ppm H_2/N_2 fuel
LCO	Bendix 8501 0-50, 500	Beckman 315B 0-200, 400, 800
HCO	Beckman 315A 0-1000, 2500	Beckman 315B 0-1000, 2000, 5000
CO_2	MSA 202 0-2.5, 5%	Beckman 315B 0-2.0, 4, 6%
NOx	TECO 10 0-100, 250	Beckman 951 0-100, 400
Analyzer Bench	Homebuilt	AESi
CVS	Aeronutronic Ford CFV	AESi PDP
Dynamometer	Clayton CTE-50 Flywheel Driven Inertia Simulation	Clayton CTE-50 Flywheel Driven Inertia Simulation
Driver's Aid	Varian, 5" FS = 60 mph 4"/min. Preprinted Trace	AESi, 5" FS = 60 mph 4"/min. Preprinted Trace
Computer	IBM 370, Off-line	NOVA/2

Table 2

Date		September 15				September 12			
Test Site		EPA-MVEL				HONDA-ANN ARBOR			
Inertia Weight lbs.		2000	2000	2250	2250	2000	2000	2250	2250
Baro. Press. mm Hg		747.3	747.5	747.5	747.5	737.1	737.1	737.1	737.1
Dry Bulb/Wet Bulb °C		22.2/15.5	22.5/15.5	22.2/15.5	22.7/15.8	22.8/16.7	23.9/16.7	22.8/16.1	22.2/16.1
Relative Humidity %		50	50	50	50	50	51	50	53
NOx Correction Factor		0.928	0.928	0.924	0.930	0.966	0.959	0.946	0.952
2 Bag LA-4 Test Hot Start									
Y_{HT} (g/phase)	HC	2.40	2.11	2.31	2.28	2.36	2.23	2.72	2.72
	CO	16.58	13.05	16.28	17.03	12.75	13.15	18.36	17.77
	CO_2	950.9	953.1	952.4	967.0	963.7	945.2	976.9	980.0
	NOx	7.53	7.60	7.88	8.22	7.84	8.41	9.16	8.81
Y_S (g/phase)	HC	2.96	2.86	2.95	2.95	3.24	3.24	3.31	3.18
	CO	13.07	12.95	13.68	13.97	12.72	12.85	13.94	13.55
	CO_2	1171.8	1195.2	1207.2	1198.5	1181.9	1173.0	1208.1	1177.9
	NOx	4.36	4.32	4.87	5.09	4.75	4.92	5.94	5.55
Y_{comp} (g/mi.)	HC	0.71	0.66	0.70	0.69	0.74	0.72	0.80	0.78
	CO	3.95	3.47	3.99	4.13	3.34	3.46	4.30	4.17
	CO_2	283.0	286.4	287.9	288.7	286.1	282.4	291.3	287.7
	NOx	1.58	1.59	1.70	1.77	1.67	1.77	2.00	1.91
LA-4 FE (mpg)		30.5	30.2	29.9	29.8	30.2	30.6	29.5	29.9
HFET (mpg)			40.0		39.1		39.2		38.5

Composite values of CO and CO_2 were repeatable and showed acceptable correlation at both inertia settings at the two test sites but Honda measured higher quantities of HC and NOx for all four emission tests. The calculated fuel consumption for both LA-4 and HFET cycles agreed well at both test sites.

3.2 Gas Cylinder Analysis

Twelve gas cylinders were analyzed on the same analytical systems that were used for emission testing. The analyses of the twelve concentrations of gases are presented as Table 3.

Only NOx analyses showed substantial deviation between Honda and EPA. The differences between determinations of NOx concentrations are also apparent when examining emission results.

3.3 Coastdown Checks

Dynamometer coastdowns were run at each inertia setting at both test sites. Differences in frictional horsepower losses were not significant. Torque requirements at six speed conditions were well within the range of torque variation observed during the 1975 EPA-MVMA Correlation Study.

Table 3

GAS ANALYSIS

Cylinder	Concentration (ppm) Nominal	EPA	Honda	$\frac{H-E}{E}$ x 100%
HC	25.1	24.3	24.9	+2.46
	73.2	72.9	74.0	+1.50
CO	86.0	82.2	81.0	-1.45
	450.0	451.3	440.0	-2.50
CO_2 (%)	0.65	0.664	0.645	-2.86
	1.31	1.287	1.300	+1.01
NOx	17.1	15.4	16.1	+4.54
	46.6	43.4	47.3	+8.98
	88.6	88.3	95.9	+8.60
	13.9	11.2	11.8	+5.35
	41.7	36.6	39.7	+8.46
	83.7	75.8	82.2	+8.44

4. Statistical Treatment

4.1 Emission and Fuel Economy Results

The mean values for HC, CO, CO_2, NOx and fuel economy results were examined to check for significant statistical differences between Honda and EPA. An independent "t" statistic was calculated for each pair of values at each inertia weight. At 2000 pounds inertia a statistically significant difference was observed at the 90% confidence level for measured values of HC and NOx, with Honda measuring 8% higher values of HC and NOx. At 2250 pounds inertia Honda measured 13% higher values of HC and NOx. Again, these differences were only significant at the 90% confidence level. No significant differences were apparent when examining CO, CO_2, and LA-4 and HFET fuel economy. Statistical analyses are summarized in Tables 4 and 5.

4.2 Discussion of Test Results

An examination of the EPA HC and CO results reveals a higher degree of variation among results at 2000 pounds inertia than at 2250 pounds inertia. There is no inherent reason for higher variability at the lower inertia setting. The high variability among EPA results is due to the high HC and CO values measured for test 1 at 2000 pounds inertia which can be traced to the bag 1 concentrations. At this time the high values for HC and CO cannot be accounted for and must be attributed to test-to-test variability. The bag 1 HC and CO data were closely examined

Table 4

STATISTICAL ANALYSIS

2000# IW

	HC	CO	CO_2	NOx	LA-4 MPG	FET MPG
EPA 1)	0.71	3.95	283.0	1.58	30.48	
2)	0.66	3.47	286.0	1.59	30.17	
						40.05
$\bar{x}$	0.685	3.710	284.70	1.585	30.325	
σ	0.035	0.339	2.40	0.007	0.219	
σ, % of $\bar{x}$	5.1	9.1	0.84	0.44	0.72	
HONDA 1)	0.75	3.34	286.1	1.67	30.21	
2)	0.73	3.46	282.4	1.77	30.59	
						39.18
$\bar{x}$	0.740	3.405	284.25	1.720	30.363	
σ	0.014	0.092	2.62	0.071	0.205	
σ, % of $\bar{x}$	1.9	2.7	0.92	4.13	0.68	
$\frac{(\bar{x}_H - \bar{x}_E)}{\bar{x}_E}$ 100%	+8.0	-8.2	-0.15	+8.5	+0.12	-2.3
t-statistic	+2.04	-1.25	-0.18	+2.69	+0.31	
t-value 99% C.L. 6.965	ND**	ND	ND	ND	ND	
95% C.L. 2.920	ND	ND	ND	ND	ND	
90% C.L. 1.886	D*	ND	ND	D	ND	

*Difference exists
**No Difference exists

Table 5

STATISTICAL ANALYSIS

2250# IW

	HC	CO	CO_2	NOx	LA-4 MPG	FET MPG
EPA 1)	.70	3.99	287.9	1.70	29.91	
2)	.69	4.13	288.7	1.77	29.82	
						39.13
$\bar{x}$	0.695	4.060	288.30	1.735	29.87	
σ	0.007	0.099	0.57	0.049	0.064	
σ, % of $\bar{x}$	1.0	2.4	0.19	2.82	0.21	
HONDA 1)	0.80	4.30	291.3	2.00	29.52	
2)	0.78	4.17	287.7	1.91	29.91	
						38.49
$\bar{x}$	0.790	4.235	289.5	1.96	29.78	
σ	0.014	0.092	2.546	0.064	0.222	
σ, % of $\bar{x}$	1.8	2.17	0.87	3.26	0.74	
$\frac{(\bar{x}_H - \bar{x}_E)}{\bar{x}_E}100\%$	+13.7	+4.3	+0.41	+13.0	-0.30	-1.6
t-statistic	+8.50	+1.83	+0.65	+3.86	-0.75	
t-value 99% C.L. 6.965	D*	ND**	ND	ND	ND	
95% C.L. 2.920	D	ND	ND	D	ND	
90% C.L. 1.886	D	ND	ND	D	ND	

* Difference exists
** No Difference exists

for transcription errors, span and zero set point errors, analyzer or CVS problems, and other possible errors, but none were located. Possible sources of test-to-test variability such as vehicle, driver, and ambient condition changes have likewise been examined and ruled out as the source of variability which would account for the differences in EPA bag 1 results for HC and CO.

It should be noted that the high degree of EPA CO variability (traceable to bag 1, test 1 results at 2000 pounds) did not result in a proven statistical difference between EPA and Honda, even at the 99% confidence level. The power of the "t" test is related to the accuracy of the estimated values of standard deviation for each sample. Higher values of sample standard deviation will result in lower calculated values of the "t" statistic and consequently a lesser chance of observing a significant difference between samples. A third test at each inertia setting is necessary if an accurate estimate of the standard deviation cannot be attained with two tests.

Differences in NOx can likely be attributed to the NOx analyzer or NOx calibration gases. Honda and EPA use different NOx analyzers, although both chemiluminescent analyzers are negative pressure reaction chamber types, and both analyzers have $NO_2 \rightarrow NO$ conversion efficiencies above 96%. The NOx calibration and span gases should be rechecked at each site. The discrepancies between NOx emission results are not likely to be due to dynamometer loading because CO_2 differences were negligible and dynamometer coastdowns and torque readings did not indicate differences in dynamometer power absorption characteristics.

The reasons for hydrocarbon differences are difficult to assess. They cannot readily be attributed to ambient effects such as temperature, humidity, and barometric pressure. Dry bulb temperatures and absolute humidity were nearly identical for both test sites but barometric pressure was 0.4 in. Hg higher during the tests at EPA. The 1975 EPA-MVMA Correlation Study[1] estimates the effects of changes in ambient test conditions in terms of changes in grams/mile for HC, CO, CO_2, NOx and fuel consumption. An 0.4 in. Hg change in barometric pressure may cause a change of 0.066 gm/mile of HC. However, it appears that this difference should not be entirely attributed to barometric pressure change because the effect of barometric pressure on CO and CO_2 is usually more pronounced than changes in HC levels, but neither CO or CO_2 show differences between test sites. No significant differences were observed between CO, CO_2, and fuel consumption measurements at the 99% confidence level.

5. <u>Conclusions</u>

1) CO, CO_2, and fuel economy results agree closely between EPA-MVEL and the Honda-Ann Arbor test laboratory.

2) HC and NOx emission measurements show disagreement between test sites. Honda measures 8% higher levels of HC and NOx at 2000 pounds IW and 13% higher levels of HC and NOx at 2250 pounds IW.

3) Differences in NOx readings are likely due to analyzer setup and/or errors in using calibration and span gases.

6. Recommendations

1) NOx analyzer operating parameters should be checked. Span gases should also be checked for errors in naming concentrations.

2) Testing at each site on more than one day would probably result in a greater change in ambient conditions. This would permit more accurate estimates of ambient correction factors to be made.

3) Honda should include this laboratory as part of the next JAMA correlation study.

References

1. Leiferman, M., and Wilson, G.; "1975 EPA-US MVMA Emission Laboratory Correlation Study", Environmental Protection Agency, Office of Air and Waste Management, Office of Mobile Source Air Pollution Control, Emission Control Technology Division.