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A Preliminary Examination of the Repeatability of the Heavy-Duty Transient Dynamometer Emission Test

by

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NOTICE

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The purpose of this report is to briefly examine the repeatability of the new Heavy-Duty (HD) transient test procedure based upon the limited test experience gained to date.

The first two HD 1969 baseline engines have been tested on the proposed 1983 MY transient test procedure. This procedure involves the use of a modified DC electric dynamomter at the EPA Motor Vehicle Emissions Laboratory in Ann Arbor, Michigan. Emissions were analyzed by the CFV-CVS (constant flow venturi - constant volume sampler) technique. The CVS was rated at 1500 SCFM.

The heavy-duty transient procedure is a new test procedure, and a preliminary estimate of the accuracy of the test results gathered to date (April 28, 1978) were of paramount interest in evaluating the test procedure. The accuracy of these results would be subject to two basic types of errors. Errors due to lack of precision, commonly referred to as repeatability, and errors due to offset, usually considered bias errors. As shown in Table 1, the precision errors appear to be quite good for the complexity of the test procedure, and the amount of experience with the equipment. The bias errors are mainly equipment calibration errors, and are not quite as good as the precision errors. However, the accuracy of the data presented is considered adequate for the initial stages of the baseline program. An ongoing effort will attempt to minimize both precision and bias errors during the baseline program.

Table 1

Average Coefficient of Variation

	HD Tests (g/BHP-hr)	Typical LDV REPCA (g/mile)
HC	13.4%	5.7%
CO	6.5%	6.0%
NOx	4.4%	4.4%

The specific coefficients of variation are listed in Table 2. As shown, the variability of the HD transient procedure compares favorably with results obtained on the LDV transient procedure, which is quite pleasing this early in the program. However, it should be emphasized that these values are only average values, and in some instances the variation for an individual engine or vehicle can be quite high.

In order to investigate the source of the variability, the coefficients of variation for the hot start portion of the heavy-

Table 2

Coefficient of Variation
($s/\bar{x}$)

A. HD Cold Soak Emission Test (g/BHP-Hr)
(cold start + hot start)

	BHP-hr	BSHC	BSCO	BSNOx
1. 225 CID				
Dyno cal. "A"	1.5%	9.6%	5.5%	4.1%
Dyno cal. "B"	3.9%	4.8%	6.4%	4.9%
2. 392 CID				
Dyno Cal. "B"	6.2%	25.9%	7.7%	4.2%

B. HD Hot Portion (g/BHP-Hr)
(hot start only)

	BSHC	BSCO	BSNOx
1. 225 CID			
Dyno cal. "A"	9.8%	5.1%	4.5%
Dyno cal. "B"	3.6%	5.6%	4.9%
2. 392 CID			
Dyno Cal. "B"	27.6%	9.2%	3.5%

C. LDV FET (g/mile)

	HC	CO	NOx
1. Production Catalyst Vehicle			
Dyno A	5.9%	47.3%	3.3%
Dyno B	6.1%	26.2%	4.1%
Dyno C	10.0%	31.1%	5.1%
2. REPCA Non-Catalyst Vehicle			
Dyno A	5.6%	5.9%	4.1%
Dyno B	6.3%	5.5%	4.6%
Dyno C	5.3%	6.5%	4.4%

duty test were computed. These data (Table 2A and B) indicate that there is essentailly no difference in terms of emission variability between the hot portion and the total test. This result is not surprising since the weighting factor for the hot start portion for these tests was 0.875 versus 0.125 for the cold start portion.* Therefore, it is assumed that most of the variability can be attributed to the repeatability of each segment. It is suspected that the starting segment of each portion has the greatest variability. A more detailed analysis may be undertaken in the future to verify this assumption.

The emission measurement accuracy discussed so far, deals only with errors due to random variability for a given set of conditions. Another source of errors in emission results are bias errors. An example of a bias error would be the testing of an LDV with an incorrect power absorber setting. It would be expected that the emission results would have equivalent variability regardless of the power absorber setting, but, only one group of data would be correct, the data taken with the correct power absorber setting.

This analogy applies to the heavy-duty transient test as well. Only, the heavy-duty test has many more parameters that must be measured to assure the correct power setting. As in the light-duty test, most bias errors can be corrected with proper calibration.

During these tests, two different calibrations were used. The difference between calibration "A" and calibration "B" was that the engine operating speed was increased from the values in calibration "A" to values slightly over the reference speed in the test cycle. The control system was adjusted in this manner because calibration "A" generally had a negative error in speed which resulted in a measured cycle horsepower-hour approximately 10% below the reference horsepower-hour. The speed adjustment was overcompensated slightly, and the change resulted in calibration "B" operating the engine approximately 14% above the reference or correct horsepower-hour. Although this change did not significantly affect the repeatability, it did affect the emission levels (see Table 3).

Based on the difference between calibration "A" and "B" in inegrated BHP-Hr over cycle, the following observation can be stated; for the tests on the 225 CID Chrysler engine, every 1% change in cycle BHP-Hr resulted in approximately a 2% change in

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* Note: Since this report was prepared, the hot/cold weighting factor has been changed based upon final analysis of the CAPE-21 data base - see EPA Technical Report No. HDV 78-04, "Transient Cycle Arrangement for Heavy-Duty Engine and Chassis Emissions Testing", by C. France, June 1978.

Table 3

Test Results
Cold Start Weighting = .125
Hot Start Weighting = .875

Cold Soak Emission Test

	BHP-hr	BSHC	BSCO	BSNOx
1. 225 CID				
Dyno Cal. "A"	10.95	6.68	52.24	9.66
Dyno Cal. "B"	13.96	3.96	47.59	8.58
2. 392 CID				
Dyno Cal. "B"	19.39	11.83	206.17	3.91

BSHC, a 0.375% change in BSCO, and a 0.5% change in BSNOx. Although no similar LDV data are available for REPCA at MVEL in Ann Arbor for comparison, the variation in emissions relative to BHP-Hr changes from this HD engine seem acceptable.

The International Harvester 392 CID engine was operated only with speed calibration "B". However, the IHC engine had more difficulty in following the torque cycle than the Chrysler engine. Thus, the cycle power developed by the IHC engine was approximately 6% below the reference power. Because the IHC engine did not meet the statistical criteria for torque, it is most likely that that engine will be retested.

From this discussion of bias errors, it is obvious that bias errors do occur during testing. The effect of these bias errors influence the emission test results in two important ways. Initially, the engine is operated at an incorrect power setting. The magnitude and direction of the error in the engine emissions due to operating the engine at an incorrect power setting would generally be unknown. Possibly more important though, is that the test results in grams/horsepower-hour would be computed with a horsepower-hour value that is different than the reference or cycle horsepower-hour. The magnitude and direction of this effect is easily computed by knowing the operating horsepower-hour and the reference horsepower-hours.

To some degree bias erros due to operating the engine at an incorrect power setting, and bias errors due to dividing by a different horsepower-hour value must be accepted. No machine will ever be perfect. However, errors of this type can be minimized by continuing to emphasize accurate calibration of the equipment.

The actual emission results from each individual test on the two engines are given in Tables 4 and 5. Additional examination of the repeatability of the HD transient dynamometer emission test will be performed as more test data become available.

Table 4

Engine Description:

MFG: Chrysler S/N: FW225R2994032

CID: 225 Rated BHP: 94

Type: L-6 Rated RPM: 3556

Cold Start Weighting = .125

Hot Start Weighting = .875

Maintenance Requirements/Problems:

Tune-up prior to BLT-1

Rebuild Carburetor After BLT-7

10-Hour Cold Soak Test Results:

			(g/BHP-Hr)		(lb/BHP-Hr)	
Test No.	Dyno Cal.	HC	CO	NOx	BSFC	BHP-Hr
BLT-1	"A"	6.08	55.61	10.00	.821	10.767
BLT-2	"A"	6.31	49.04	9.74	.655	10.894
BLT-4	"A"	6.77	50.95	9.23	.650	10.967
BLT-5	"A"	7.54	53.34	—	.627	11.154
BLT-7	"B"	5.12	50.00	9.12	.597	13.551
BLT-8	"B"*	3.74	46.33	9.00	.574	14.488
BLT-9	"B"*	4.05	45.50	8.57	.554	14.011
BLT-11	"B"*	4.08	51.04	8.16	.576	13.394
		A B*	A B*	A B*		
$\overline{x}$		6.68 3.96	52.24 47.59	9.66 8.58		
s		.64 .19	2.86 3.02	.39 .42		

4-Hour Cold Soak Test Results:

Test No.	Dyno Cal.	HC	CO	NOx	BSFC	BHP-Hr
BLT-3	"A"	6.17	48.11	9.19	.640	11.016
BLT-6	"A"	6.83	51.75	9.36	.618	11.110
BLT-10	"B"*	4.23	49.74	9.20	.591	14.140

* plus carburetor rebuild.

Table 5

Engine Description:

MFG: IHC S/N: V392 658417
CID: 392 Rated BHP: 159
Type: V-8 Rated RPM: 3527
Cold Start Weighting = .125
Hot Start Weighting = .875

Maintenance Requirements/Problems:

Tune-up prior to BLT-1
Replaced faulty coil wire after BLT-4

10-Hour Cold Soak Test Results:

		(g/BHP-Hr)			(lb/BHP-Hr)	
Test No.	Dyno Cal.	HC	CO	NOx	BSFC	BHP-Hr
BLT-1	"B"	15.96	200.30	3.68	.795	21.153
BLT-3	"B"	—	—	—	—	—
BLT-5	"B"	12.22	191.86	4.02	.825	18.941
BLT-7	"B"	8.93	203.87	4.04	.819	18.958
BLT-8	"B"	10.22	228.64	3.89	.868	18.506
$\bar{x}$		11.83	206.17	3.91		
s		3.07	15.81	.17		

4-Hour Cold Soak Test Results:

Test No.	Dyno Cal.	HC	CO	NOx	BSFC	BHP-Hr
BLT-2	"B"	8.80	172.10	4.02	.756	19.805
BLT-4	"B"	—	—	—	—	—
BLT-6	"B"	8.41	193.90	4.29	.817	19.098