ANALYSIS OF THE RELATIVE EFFECTIVENESS OF DIFFERENT SHORT TESTS FOR 1980+ VEHICLES

DRAFT REPORT

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1. OVERVIEW OF TEST PROGRAM

The analysis of the effectiveness of different short tests is based on actual test data obtained from California. The database consists of 640 vehicles tested through late December 1994 at the Air Resources Board's Haagen-Smit Laboratory (HSL) in El Monte, California. The 640 vehicles are part of a random sample of 2,000 vehicles taken from a list of 2,000,000 vehicles which were due for biennial I/M testing and were garaged within a 25-mile radius of HSL. The list of vehicles was provided to ARB by the California Department of Motor Vehicles (DMV). The owners of the vehicles were notified of inclusion in the test program via a solicitation letter, which instructed them to bring the vehicle to HSL for testing. The letter also offered a list of incentives to the vehicle owners.

When a vehicle was brought into HSL for testing, it was put through a series of screening tests. First, the vehicle was inspected for safety and testability. If the vehicle was determined to be safe and testable (or could be repaired to such a state), it was then given an underhood inspection, including the assessment of evaporative emission control system accessibility. The vehicle engine was allowed to idle throughout the screening process and was turned off only if the underhood inspections required doing so.

Except for those vehicles which were given pre-test repairs, the testing sequence was to begin within 20 minutes of the vehicle's arrival at HSL. In the event that the screening process took longer than 20 minutes, the affected vehicles were to be given a "Second Chance" test (i.e., the first IM240 or ASM test was used as a conditioning test only, and the results from a second test were recorded). If more than 40 minutes elapsed prior to testing, affected vehicles were to be warmed up with on road driving. It is not known how many (if any) vehicles were given second chance tests, nor how many had to be warmed up with on road driving.

After completing the screening tests, accepted vehicles were tested in as close to "as received" condition as possible using the tank fuel. When necessary, tank fuel was supplemented with commercial gasoline or gasoline from HSL's underground storage tanks. Vehicles were then given ASM 2525, ASM 5015, and IM240 tests; vehicles with even test numbers had the ASM tests performed first, and odd numbered test vehicles had the IM240 test performed first. FTP tests, when performed, were administered after the ASM and IM240 tests. For this analysis, only the "as received" test data was utilized to compute the effectiveness of short tests. This analysis focused on only 1980+ vehicles featuring "closed loop" emission controls, although additional analysis may be performed in the future for oxidation catalyst equipped 1980+ vehicles and pre-1980 vehicles.

2. DESCRIPTION OF DATA AS RECEIVED

The emissions test results for the 640 vehicles tested through late December was "preliminarily screened" by ARB and provided on five diskettes. The first two diskettes contain data relating to ASM and IM240 repairs, and the third diskette contains Smog Check data on vehicles tested at ARB. The fourth diskette contains the IM240, ASM, and FTP test results, and the vehicle description data. The fifth diskette contains information on any pre-acceptance repairs performed, a list of the vehicles placed into the IM240 and ASM bins, and the cutpoints used to determine if a vehicle failed the IM240, ASM 25/25, or ASM 50/15 tests. As this phase of the task is an analysis of baseline emissions, the data files on the first three diskettes were not used.

The files on diskettes four and five that were used in this analysis are:

- FTPDKP.XLS - FTP results at baseline (as received) and after repair.

- IM240DKP.XLS - IM240 results at baseline and after repair.
- T1TEST.XLS - ASM 50/15 results at baseline and after repair.
- T2TEST.XLS - ASM 25/25 results at baseline and after repair.
- VEHDESC.XLS - vehicle description data.
- CUTPOINT.XLS - model year grouped cutpoints, by inertia weight, for ASM and IM240 tests.

The data processing was to be done in SAS, which does not have the capability to read Microsoft Excel (.xls) files. Therefore, the six files were converted into Dbase format (.dbf), which SAS can import. The first five files were converted to Dbase format without any alterations to their content, but the structure of the file containing the cutpoints had to be modified in Excel so that each record (i.e., line of data) in the file contained short test cutpoints for a single combination of vehicle type, model year group, and inertia weight class. The resulting file was then saved in Dbase format.

All six files were imported into SAS and merged to form one dataset. The five files that contain the test results and the vehicle description information were merged on the basis of the Vehicle Number and Project fields, the combination of which uniquely identify each vehicle in the program. The vehicles were grouped according to model year and vehicle type groups, both of which are based on similarities of certification standards. Passenger cars and light duty trucks were treated as one vehicle group, and medium duty vehicles (6000 to 8500 pounds gvw) and heavy duty trucks (over 8500 pounds) comprise the other two vehicle groups. The 640 vehicles for which vehicle information was supplied are listed in Table 1. Over 75 percent of the vehicles (488 of 640) are 1983 and later passenger cars and light trucks.

The short test cutpoints (i.e., the cutpoints for IM240, ASM 5015, and ASM 2525 tests) were merged onto each vehicle record by means of matching the vehicle model year, vehicle type, and vehicle inertia weight (rounded down to the nearest 100 pounds) to the

TABLE 1

DATA SET BY VEHICLE TYPE AS RECEIVED

MODEL YEAR GROUP	PASSENGER CARS & LIGHT DUTY TRUCKS	MEDIUM DUTY VEHICLES	HEAVY DUTY TRUCKS	TOTAL
Pre-1975	43	2	0	45
1975-76	12	2	0	14
1977-79	41	5	0	46
1980-82	42	0	0	42
1983-87	228	0	1	229
1988 +	260	0	4	264
TOTAL	626	9	5	640

appropriate short test cutpoint. As part of its data preparation, the ARB had appended to each record the FTP standards to which the vehicles were certified. Short test cutpoints for each of the three short tests are provided in Appendix A.

The FTP, IM240, ASM 5015, and ASM 2525 test results collected from the vehicles "as received" and prior to any test related repairs are referred to as the baseline test results. The baseline test results for each vehicle (prior to any cleanup of the dataset) were compared to the FTP standards and short test cutpoints to determine the FTP and short test pass/fail rates. These baseline results are shown for passenger cars and light trucks in Table 2, and for medium duty vehicles and heavy duty vehicles in Table 3. The results under the "Missing/Invalid" columns indicate that the HC, CO, or NO_x emissions for a vehicle were either not included in the dataset or were less than zero. (Apparently, some very low emissions were recorded as less than zero due to improper zero point calibrations of the test benches used to measure emissions during the short tests.)

3. DATA CLEANUP

As illustrated above, some of the baseline data were invalid and needed to be corrected or removed. Given the short time period in which the analysis was to be completed, it was not deemed practical to try to collect new test data to replace missing data or to redefine or reinterpret negative values, so these data points were eliminated from the analysis. Consequently, since the purpose of this study is to compare short test results with FTP results, if one or more short test results were incomplete or invalid, the vehicle was removed from the analysis dataset.

This phase of the analysis focused on 1980 and later vehicles with three way catalysts, which effectively eliminated all medium duty vehicles (all were pre-1980) and all heavy duty vehicles (none had FTP test results). Upon examination of the baseline dataset, many of the certification standards that ARB had appended to the vehicle data were

TABLE 2

FTP AND SHORT TEST RESULTS FOR PC AND LDT, AS RECEIVED

MODEL YEAR GROUP		FTP			IM240			ASM5015			ASM2525		
		MISSING/ INVALID	FAIL	PASS	MISSING/ INVALID	FAIL	PASS	MISSING/ INVALID	FAIL	PASS	MISSING/ INVALID	FAIL	PASS
Pre-75	N	17	26	0	1	21	21	2	13	28	4	9	30
	%	39.5	60.5	-	2.3	48.8	48.8	4.7	30.2	65.1	9.3	20.9	69.8
1975-1976	N	1	11	0	1	10	1	1	11	0	2	9	1
	%	8.3	91.7	-	8.3	83.3	8.3	8.3	91.7	-	16.7	75.0	8.3
1977-1979	N	4	37	0	0	33	8	1	23	17	1	25	15
	%	9.8	90.2	-	-	80.5	19.5	2.4	56.1	41.5	2.4	61.0	36.6
1980-1982	N	8	33	1	3	26	13	9	24	9	8	26	8
	%	19.0	78.6	2.4	7.1	61.9	31.0	21.4	57.1	21.4	19.0	61.9	19.0
1983-1987	N	65	157	6	8	118	102	18	111	99	0	2	3
	%	28.5	68.9	2.6	3.5	51.8	44.7	7.9	48.7	43.4	-	40.0	60.0
1988+	N	156	68	36	4	23	233	64	25	171	50	25	185
	%	60.0	26.2	13.8	1.5	8.9	89.6	24.6	9.6	65.8	19.2	9.6	71.2

TABLE 3

FTP AND SHORT TEST RESULTS FOR MDV AND HDT, AS RECEIVED

MODEL YEAR GROUP		FTP			IM240			ASM5015			ASM2525		
		MISSING/ INVALID	FAIL	PASS	MISSING/ INVALID	FAIL	PASS	MISSING/ INVALID	FAIL	PASS	MISSING/ INVALID	FAIL	PASS
MDV Pre-75	N	0	2	0	0	2	0	0	0	2	0	0	2
	%	-	100	-	-	100	-	-	-	100	-	-	100
MDV 1975-1976	N	0	2	0	0	2	0	0	1	1	0	2	0
	%	-	100	-	-	100	-	-	50.0	50.0	-	100	-
MDV 1977-1979	N	1	4	0	1	2	2	1	3	1	1	3	1
	%	20.0	80.0	-	20.0	40.0	40.0	20.0	60.0	20.0	20.0	60.0	20.0
HDT 1983-1987	N	1	0	0	1	0	0	1	0	0	1	0	0
	%	100	-	-	100	-	-	100	-	-	100	-	-
HDT 1988+	N	4	0	0	4	0	0	4	0	0	4	0	0
	%	100	-	-	100	-	-	100	-	-	100	-	-

found to be in error. Communications with ARB personnel through Sierra resulted in ARB providing a dataset with corrected certification standards, and Table 4 lists the FTP certification standards for the vehicles in the resulting analysis dataset. At this point in the cleanup process, the dataset included of 242 1980 and later passenger cars and light trucks that had valid test results for the FTP and all three short tests.

Next, the FTP emissions were regressed against the short test emissions in an effort to identify any vehicles whose short test emissions would grossly underpredict or overpredict FTP emissions. Several vehicles were identified as potential outlier vehicles using the criterion that the absolute value of the residual divided by the standard error of the residual was greater than 2.0. Further examination of these vehicles revealed that almost all were high FTP emitters for HC and CO, but were capable of passing a short test (i.e., they were likely to be "errors of omission"). It was decided that these vehicles should be retained in the analysis data set, since high cold start emissions.

Of greater concern was identifying those vehicles which had abnormally high emissions on only one of the short tests, which indicated that some transient malfunction had occurred during that test only. Such vehicles were likely to be short test false failures, or "errors of commission." Twenty-nine 1980 and later vehicles were found to have passed two short tests and failed one short test. The individual test results for each of these vehicles were then examined, and it was found that the majority had failed for one pollutant by a small percentage (less than 20 percent) of the short test cutpoint, or that they were moderate to high FTP emitters for one or more pollutants that had (correctly) failed one short test for the same pollutant.

Three vehicles (numbers 44, 117, and 294) were normal FTP emitters that had failed only one short test by 35 percent of the short test cutpoint or more. These vehicles were likely to have transient malfunctions that may not result in the vehicle failing a "second

TABLE 4
FTP STANDARDS, g/mile
PC & LDT, AS RECEIVED

MODEL YEAR	FUEL FEED	$HC/CO/NO_x$	N	PERCENT
1980-1982	MPI	0.39/ 7/ 0.7	1	0.4
1980-1982	MPI	0.41/ 7/ 0.7	2	0.8
1980-1982	MPI	0.41/ 9/ 1	2	0.8
1980-1982	Carb	0.5/ 9/ 1.5	1	0.4
1980-1982	Carb	0.39/ 7/ 0.7	3	1.2
1980-1982	Carb	0.39/ 9/ 1	1	0.4
1980-1982	Carb	0.41/ 7/ 0.7	4	1.7
1980-1982	Carb	0.41/ 9/ 1	2	1.8
1980-1982	TBI	0.41/ 7/ 0.7	1	0.4
1980-1982	TBI	0.41/ 3.4/ 1	1	0.4
1983-1987	MPI	0.5/ 9/ 1	2	0.8
1983-1987	MPI	0.39 7/ 0.4	1	0.4
1983-1987	MPI	0.39 7/ 0.7	20	8.3
1983-1987	MPI	0.39/ 9/ 1	5	2.1
1983-1987	MPI	0.41/ 7/ 0.4	1	0.4
1983-1987	MPI	0.41/ 7/ 0.7	17	7.0
1983-1987	MPI	0.41/ 3.4/ 1	5	2.1
1983-1987	Carb	0.5/ 9/ 1	5	2.1
1983-1987	Carb	1.7/ 18/2.3	1	0.4
1983-1987	Carb	0.39 7/ 0.4	2	0.8
1983-1987	Carb	0.39 7/ 0.7	29	12.0
1983-1987	Carb	0.39 9/ 1	17	7.0
1983-1987	Carb	0.39 9/ 0.7	1	0.4
1983-1987	Carb	0.41 7/ 0.7	8	3.3
1983-1987	Carb	0.41 9/ 1	3	1.2
1983-1987	Carb	0.41 3.4 1	3	1.2
1983-1987	TBI	0.39/ 7/ 1	1	0.4
1983-1987	TBI	0.39/ 7/ 0.7	13	5.4
1983-1987	TBI	0.39/ 9/ 1	2	0.8
1983-1987	TBI	0.41/ 7/ 1	1	0.4
1983-1987	TBI	0.41/ 7/ 0.7	5	2.1
1983-1987	TBI	0.41/ 3.4/ 1	1	0.4

TABLE 4
FTP STANDARDS, g/mile
PC & LDT, AS RECEIVED
(CONTINUED)

MODEL YEAR	FUEL FEED	HC/CO/NOX	N	PERCENT
Post 1987	MPI	0.5/ 9/ 1	8	3.3
Post 1987	MPI	0.39/ 7/ 0.4	19	7.9
Post 1987	MPI	0.39/ 7/ 0.7	5	2.1
Post 1987	MPI	0.39/ 9/ 1	4	1.7
Post 1987	MPI	0.39/ 9/ 0.4	4	1.7
Post 1987	MPI	0.41/ 7/ 0.4	1	0.4
Post 1987	MPI	0.41/ 7/ 0.7	1	0.4
Post 1987	MPI	0.41/ 9/ 0.4	1	0.4
Post 1987	MPI	0.41/ 3.4/ 1	3	1.2
Post 1987	Carb	0.39/ 7/ 0.4	1	0.4
Post 1987	Carb	0.39/ 7/ 0.7	3	1.2
Post 1987	Carb	0.39/ 9/ 1	1	0.4
Post 1987	Carb	0.41/ 7/ 0.4	1	0.4
Post 1987	Carb	0.41/ 7/ 0.7	3	1.2
Post 1987	TBI	0.5/ 9/ 1	7	2.9
Post 1987	TBI	0.39/ 7/ 0.4	6	2.5
Post 1987	TBI	0.39/ 7/ 0.7	4	1.7
Post 1987	TBI	0.39/ 9/ 1	2	0.8
Post 1987	TBI	0.41/ 7/ 0.4	1	0.4
Post 1987	TBI	0.41/ 7/ 0.7	3	1.2
Post 1987	TBI	0.41/ 3.4/ 1	3	1.2

chance" test, and therefore, would not be good candidates for including in an analysis of repair effectiveness. Therefore, these three vehicles were classified as "outliers".

A fourth vehicle also failed only one short test by a significant amount: Vehicle 88 failed the ASM 2525 CO test by 85 percent of the standard. Although this vehicle was a high FTP emitter, it was also classified as an "outlier" on the basis of its relatively low test scores on the IM240 and ASM 5015 test. Table 5 lists the four vehicles that were classified as outliers.

4. ANALYSIS DATASET

After the four outlier vehicles were removed, the dataset consisted only of vehicles with HC, CO, and NO_x test results for all four test types. At this point, certain model year groups were combined so that there would be sufficient vehicles in those groups to produce significant results Thus, 1980 to 1982 MPI and TBI vehicles were combined with the 1983 to 1987 MPI and TBI groups, respectively, and all carbureted vehicles were combined into one group.

Two additional vehicles were removed from the analysis dataset because their certification standards were significantly different from the other vehicles in the dataset. One vehicle had certification standards of 0.5 g/mi HC, 9.0 g/mi CO, and 1.5 g/mile NO_x, and the other had certification standards of 1.7 HC/18 CO/2.3 NO_x.

Finally, any vehicles that were certified to a nonmethane hydrocarbon (NMHC) standard of 0.39 g/mile were grouped with those vehicles that were certified to a 0.41 g/mi total hydrocarbon standard. Table 6, then, lists the certification standards of the 236 1980 and later vehicles in the analysis dataset, grouped by model year and fuel delivery system ("fuel feed"). The table shows that only 74 of the 236 vehicles (31 percent) with a complete set of test results are 1988 and later fuel injected vehicles. Further, only 48

TABLE 5

OUTLIER VEHICLES WITH POTENTIAL TRANSIENT MECHANICAL FEATURES

VEHICLE NUMBER	MODEL YEAR GROUP	FUEL SYSTEM	REASON FOR CLASSIFICATION
294	1983-1987	Carb	Normal FTP HC and NO_x, moderate FTP CO. Failed ASM NO_x only; 35% over cutpoint.
44	1988	MPI	Normal FTP HC, CO and NO_x. Failed ASM 25/25 NO_x only; 65% over cutpoint.
117	1988	Carb	Normal FTP HC, CO, and NO_x. Failed ASM 25/25 HC and CO; CO was 10 times cutpoint.
88	1983-1987	MPI	Moderate FTP HC and NO_x, high FTP CO. Failed ASM 25/25 CO only; 85% over cutpoint.

TABLE 6
FTP STANDARDS, g/mile
PC & LDT, AFTER CLEAN UP

MODEL YEAR	FUEL FEED	HC/CO/NO_x	N	PERCENT
1980-1987	MPI	0.5/ 9/ 1	2	0.8
1980-1987	MPI	0.41/ 7/ 0.7	39	16.5
1980-1987	MPI	0.41/ 9/ 1	7	3.0
1980-1987	MPI	0.41 3.4/ 1	5	2.1
Post 1980	Carb	0.5/ 9/ 1	5	2.1
Post 1980	Carb	0.41/ 7/ 0.4	4	1.7
Post 1980	Carb	0.41/ 7/ 0.7	47	19.9
Post 1980	Carb	0.41/ 9/ 1	24	10.2
Post 1980	Carb	0.41/ 9/ 0.7	1	0.4
Post 1980	Carb	0.41/ 3.4/ 1	3	1.3
1980-1987	TBI	0.41/ 7/ 1	2	0.8
1980-1987	TBI	0.41/ 7/ 0.7	19	8.1
1980-1987	TBI	0.41/ 9/ 1	2	0.8
1980-1987	TBI	0.41/ 3.4/ 1	2	0.8
Post 1987	MPI	0.5/ 9/ 1	8	3.4
Post 1987	MPI	0.41/ 7/ 0.4	22	9.3
Post 1987	MPI	0.41/ 7/ 0.7	6	2.5
Post 1987	MPI	0.41/ 9/ 1	4	1.7
Post 1987	MPI	0.41/ 9/ 0.4	5	2.1
Post 1987	MPI	0.41/ 3.4/ 1	3	1.3
Post 1987	TBI	0.5/ 9/ 1	7	3.0
Post 1987	TBI	0.41/ 7/ 0.4	7	3.0
Post 1987	TBI	0.41/ 7/ 0.7	7	3.0
Post 1987	TBI	0.41/ 9/ 1	2	0.8
Post 1987	TBI	0.41/ 3.4/ 1	3	1.3

vehicles (20 percent of the analysis dataset) are 1988 or later multipoint fuel injected vehicles.

5. ANALYSIS OF DATA

The ARB sample of vehicles that were subject to FTP testing what primarily those that failed either the ASM tests or the IM240 test. Hence the sample is heavily biased towards high emitters making it relatively difficult to evaluate the error of commission rate with any degree of statistical precision.

Initially, EEA has hoped to separate at the 1980-82 vehicles as a group due to the fact that they represent first generation closed-loop control technology. Unfortunately the total sample of 1980-82 vehicles with FTP tests was 17 vehicles, almost all of which were high emitters. As a result, 1980-1987 vehicles were treated as one group, and 1988+ vehicles as a second group (except for a few carburetted 1988+ that were combined with the 1980-1987 group). This sample was divided into normal moderate, and high emitters using the actual certification standards and moderate emitter cutpoints as defined below:

Pollutant	Certification Std	Moderate Emitter Cutpoint
HC	0.41 0.50 (LDT)	0.82 0.82
CO	3.4 7.0 9.0	10.5 10.5 13.5
NO_x	1.0 (LDT) 1.0 (PC) 0.7 (PC) 0.4	2.0 1.4 1.4 0.8

Based on these parameters the available sample of cars was divided into normal, moderate, and high emitters, classified on the basis of the highest emission level relative to the standard for any pollutant. Table 7 shows the distribution of the sample among the three emitter categories, by fuel system type. As can be seen, there are only 31 normal emitters in the sample, and 21 of these are in the 1988+ MPI group. Hence, the error of commission analysis is subject to large statistical uncertainty. The sample under the alternative moderate emitter cutpoints is larger, but still very small for some groups.

The tests were rated in three bases:

- Failure rates
- Excess Emissions Identified
- Errors of Commission

Both error of commission and excess emission identification rates were calculated at normal and moderate cutpoints. Cutpoints used for the short test varied HC, CO and NO_x cutpoints specified in Appendix A by +20, -20 and -40 percent for each pollutant. Analysis was performed only the same level of reduction (or increase) in HC, CO and NO_x cutpoints, and no attempt was made to optimize each cutpoint separately due to resource constraints. The cutpoints in Appendix A are labelled as "C", while the others are labelled as C+20, C-20, and C-40, respectively.

Failure Rates

The analysis of failure rates is presented first. In this case, the unique sample content should be recognized for its bias towards high emitters so that conventional numbers in the range of 20 to 30 percent cannot be expected. One measure of an "ideal" failure rate is a rate representing the fraction of high emitters in the sample. If there were no errors of commission, a failure rate equal to the ideal failure rate would be optimal.

Table 8 shows the "ideal" failure rates and at the four alternative cutpoints for the IM240, ASM 5015 and ASM 2525 tests. Since each car can only pass or fail the test, the standard error of the failure rate estimate is $(p \cdot f/n)^{0.5}$ where f is the failure rate, p

TABLE 7

SAMPLE BY EMITTER CATEGORY

MYR Group	Fuel System	Normal	Moderate	High	Total
1980-87	MPI	5 (9.43)	7 (13.21)	41 (77.36)	53
1988+	MPI	21 (43.75)	14 (29.17)	13 (27.08)	48
1980-87	TBI	1 (4.0)	1 (4.0)	23 (92.0)	25
1988+	TBI	3 (11.54)	12 (46.18)	11 (42.31)	26
1980+	CARB	1 (1.19)	12 (14.29)	71 (84.52)	84
	TOTAL	31	46	159	236

Percent of sample in parenthesis; rows add up to 100 percent. High emitters includes super emitters.

TABLE 8
FAILURE RATES (Percent of Sample)

Group	Test	Cutpoint Level			
		C + 20%	C	C - 20%	C - 40%
1980 - 1987 MPI	IM240	47.17	64.15	67.92	75.47
(Ideal Rate = 77.36)	ASM5015	47.17	54.72	67.92	75.47
	ASM 2525	47.17	56.60	64.15	71.70
1988 + MPI	IM240	8.33*	20.83	27.08	37.50
(Ideal rate = 27.08)	ASM5015	14.58	20.83	31.25	45.83
	ASM2525	12.50	25.00	31.25	33.33
1980 - 1988 TBI	IM240	56.00	72.00	76.00	92.00
(Ideal rate = 92.0)	ASM5015	56.00	64.00	76.00	80.00
	ASM2525	56.00	72.00	72.00	84.00
1988 + TBI	IM240	19.23	26.92	34.62	42.31
(Ideal rate = 42.31)	ASM5015	38.46*	46.15*	46.15	50.00
	ASM2525	23.08	30.77	38.46	57.69
(All) CARB	IM240	58.33	69.05	72.62	88.10
(Ideal rate = 84.52)	ASM5015	63.09	72.62	78.57	83.33
	ASM2525	61.90	72.62	80.95	86.90

* Statistically different rate from other short tests rates at 90% confidence.

the pass rate, and n the sample size. For a sample size of 50 vehicles and $p = f = 0.5$,* the sample standard deviation is 7%. Hence, failure rates for the MPI samples have a standard deviation of 6 to 7 percent, the TBI samples have standard deviation of 4 to 10 percent, while the CARB samples have a standard deviation of 4 to 5 percent.

Based on these observations, it can be easily concluded that all three tests show statistically similar failure rates and the variations in failure rates between tests seen at some cutpoint levels are associated with vehicles marginally above or below a specific cutpoint for a given test. Hence, all three tests should provide equivalent failure rates in the field, unless the error of commission rates are substantially different. However, the IM240 test appears to provide a slightly higher failure rate for the 1980-1987 vehicles while the ASM tests provide a slightly higher failure for the 1988+ vehicles.

<u>Excess Emission Identification Rates</u>

Total excess emissions are the emissions in excess of standards summed over all moderate and high emitters in the sample. Excess emission identification rates also must account for the unusual composition of the sample with its overweighting of high emitters. Table 9 shows that a very small fraction of total excess emissions is in the moderate emitter category for the 1980-1987 vehicles of all fuel system types. Given that the excess emissions are so heavily associated with the high emitters, it can be expected that all three tests report very high identification rates. The excess emissions shown in Table 9 are also indicative of the optimal excess emission identification rates for any short test.

Excess emissions identification rates are shown in Table 10, and a clear pattern among the pre-1988 and 1988+ vehicles is obvious. Direct statistical analysis of excess

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* This does not vary much with failure rates. For $f = 0.75$, $5 = 6.1\%$.

TABLE 9

PERCENT OF TOTAL EXCESS EMISSIONS AMONG HIGH EMITTERS IN SAMPLE

	HC	CO	NO_x
1980-87 MPI	97.69	98.93	96.28
1988+ MPI	95.05	97.42	83.62
1980-87 TBI	100.00	100.00	97.91
1988+ TBI	88.79	89.84	59.09
CARB (All)	99.60	99.29	96.77

TABLE 10 EXCESS EMISSIONS IDENTIFICATION RATES

	HC				CO				NOx			
	IM240	ASM5015	ASM2525	E-ASM	IM240	ASM5015	ASM2525	E-ASM	IM240	ASM5015	ASM2525	E-ASM
MPI 80-87												
C+20	78 53	73 28	71 31	77 21	82.79	77 97	80 82	81.74	67 51	60 47	63 60	68 99
C	90.18	77.16	78 74	82.22	92 94	83 87	81.74	87 15	82 14	65 99	74.12	77.68
C-20	92 27	84 02	80 78	85 79	95 40	89.71	82 65	89.71	84.14	77.08	81.78	85.7
C-40	94.39	87 40	84 22	88 03	96 44	92 50	86 77	92 69	93.12	91.17	88 64	93.42
MPI 1988+												
C+20	50 91	70.76	45.74	72.97	31.45	64 14	42 17	64.14	50.41	61.05	57 71	73 35
C	56.59	76 66	79 76	94 56	31 45	70 21	87 23	97.42	71.70	79.03	67.27	84 59
C-20	64.50	94 56	88 66	94 56	53 47	97 42	91 35	97.42	83 23	86 37	81.79	86 37
C-40	81.45	94 99	88 66	94 99	59 54	97 42	91 35	97.42	93 74	91.16	81.79	91.16
TBI 80-87												
C+20	81.85	71.27	73 39	82 09	76 90	82 84	69 70	87 9	82.14	79 14	68 54	82 09
C	88.72	78 60	79 76	91 66	91 57	85 93	78 84	91 7	90.11	82 09	94.70	94.73
C-20	91.65	88 17	88 12	91.66	92 50	89 74	78 84	91.7	94.13	94.73	94.70	94.73
C-40	96.69	93 99	93.15	96 69	97 28	93 07	84 41	97.28	99 80	94 73	96 80	96 83
TBI 1988+												
C+20	50 36	68 46	40 90	68 46	61 70	66 97	55 57	66.97	39.76	63 01	53.86	63.01
C	54 84	68.46	63 99	68 46	66 97	71 30	66 97	71.3	46 85	67 73	55 92	67 73
C-20	58.09	68 46	63 99	68 46	66 97	71 30	71 30	71.3	62 90	67 73	60 64	67.73
C-40	68.46	68.50	72 64	72.68	71.90	71 30	74 95	74 95	67.73	67 73	79 33	79 33
CARB (ALL)												
C+20	93.47	90.83	90 72	92 73	89 99	86 45	87 84	88 62	80 66	85.04	82 81	86 17
C	96.20	93 95	95 45	97 45	93 95	89 34	81.74	91.3	89 36	89 68	90 86	94 54
C-20	98 25	95 66	96 69	99.14	95 40	95 52	91 84	97 34	93 32	90.76	94.27	96 17
C-40	99.52	96 73	98 25	99 28	98 63	96 50	97 80	98 08	98 94	91 48	95 01	97.16

PERCENT OF TOTAL EXCESS ABOVE FTP STANDARD emissions identification rates is difficult as the variance depends on the underlying distribution of emissions, which is not log-normal due to the biased sample. Hence a non-parametric ranking test must be used. The ranking of that test is based on excess emission identification rate at 4 cutpoints by model year/fuel system group and is as follows for HC/CO:

	Rank 1	Rank 2	Rank 3
MPI, 1980-87	IM240 (8)	ASM5015 (6)	ASM2525 (6)
MPI, 1988+	ASM5015 (6)	ASM2525 (5)	IM240 (7)
TBI, 1980-87	IM240 (7)	ASM5015 (6)	ASM2525 (6)
TBI, 1988+	ASM5015 (6)	ASM2525* (4)	IM240 (5)
CARB (All)	IM240 (8)	ASM2525 (5)	ASM5015 (5)

These rankings are based on excess emission identification rates being higher in at least 5 of 8 HC and CO cutpoint combinations relative to the next lower rank test. The numbers in parenthesis refer to the number of times that particular test had the ranking under which it is listed. In general the ASM 5015 and 2525 tests are ranked relatively close together, but it appears that the IM240 test is superior for pre-1988 vehicles while the ASM tests are superior for 1988+ vehicles, an unexpected result. The rankings for NO_x emission identification rates are very similar except that the ASM5015 appears slightly worse than the ASM2525.

Table 11 shows the excess emission identification rates based on the "moderate" cutpoint (i.e. only high emitters contribute to excess emissions) and the ranking of the tests is unchanged from the above table, although the 5015 and 2525 tests provide near equivalent results in more cases. The excess emission identification rate is more consistent for similar model year groups, than by fuel system type. For the pre-1988 vehicles, the IM 240 test identifies 96 percent of both excess HC and excess CO emissions (±2 percent), and 94 percent of excess NO_x emissions at the base California

* 2 first place rankings.

TABLE 11· EXCESS EMISSIONS IDENTIFICATION RATES

MOD STDS	HC IM240	HC ASM5015	HC ASM2525	HC E-ASM	CO IM240	CO ASM5015	CO ASM2525	CO E-ASM	NOx IM240	NOx ASM5015	NOx ASM2525	NOx E-ASM
MPI 80-87												
C+20	88.04	80.45	78 14	83 97	86 83	81 27	84 11	84.57	77.40	66 23	72.63	73.71
C	96.48	82.79	84.84	87 18	96.17	86 86	84.57	90.16	86 49	68 75	82.66	85.18
C-20	97.57	87 41	84 99	88.27	97 90	91 88	84 91	91 88	86.49	78.31	88 00	90.1
C-40	98 45	88 52	86 33	88.52	98 26	93 96	88 34	100	96 36	95 44	94 26	96 36
MPI 1988+												
C+20	64 13	80 79	50 25	80.79	18 18	70 50	46 57	70 5	79 06	87 96	77 84	98 75
C	67 49	83 54	88 87	100	18 18	70 50	100 00	100	89 85	98 75	81 98	98 75
C-20	69.87	100 00	97 25	100	46 57	100 00	100 00	100	94 61	98 75	98 75	98 75
C-40	77 84	100 00	97 25	100	46 57	100 00	100 00	100	100 00	98 75	98.75	98 75
TBI 80-87												
C+20	89 81	77.10	78.14	85 76	79 62	90 46	73 93	92 96	90.61	84 93	72 09	85 43
C	92 91	83 04	85.42	94 85	94 27	91 81	79 23	93 88	93 95	85 42	98 87	98 87
C-20	94 84	92 13	92 06	94 85	94.27	92 73	79 23	93 88	96 61	98 87	98 87	98 87
C-40	97.53	95.92	94 75	97 53	97 89	94 27	98 61	97 89	100 00	98 87	98.87	98 87
TBI 1988+												
C+20	69 93	85 39	52 20	85 39	77 11	78 96	68 80	78 96	81 60	81 60	81 60	81 6
C	69 93	85.39	85 39	85 39	80 99	78 96	78 96	78 96	81 60	81 60	81 60	81.6
C-20	69.93	85.39	85 39	85 39	80 99	78 96	78 96	78 96	81 60	81 60	81 60	81 6
C-40	85 39	85.39	85 39	85 39	80 99	78 96	78 96	78 96	81 60	81 60	100 00	100
CARB (ALL)												
C+20	97 07	93 48	93 69	94 77	94 49	89 24	90 87	90 93	87 01	89 80	87.49	89 8
C	98 63	95.33	97 33	98 48	97 07	91 01	92 32	92 39	95 62	93 12	93 65	97.61
C-20	99 77	96 69	97.58	99 85	97 46	97 08	92.48	98 28	97 61	93 12	95.84	97 61
C-40	99 98	97 63	98 95	99 85	99 74	97 64	98 61	98 61	100 00	93.11	95 84	97 61

PERCENT OF TOTAL EXCESS FROM HIGH EMITTERS ONLY cutpoints, when defining excess emissions on the basis of high emitters only. In contrast the ASM tests identify about 87 percent of HC and 90 percent of CO for the same group of vehicles. NO_x emission identification rates are near equivalent to those for the IM240 test.

For 1988+ vehicles, the situation reverses, with the ASM tests showing significantly better results, especially for the vehicles with MPI fuel systems. However, the emission identification rates are significantly lower than those for pre-1988 vehicles.

EEA also examined the failure rates for super emitters, defined as vehicles exceeding NO_x standards by a factor of 4, or HC/CO standards by a factor of 10. There are 35 vehicles in the data base that would be classified as super emitters, and more than half of these are due to their high NO_x emissions, as shown below:

Number of Super Emitters

	Reason for Classification	
Fuel System	High HC/CO	High NO_x
MPI, 1980-87	4	4
MPI, 1988+	0	1
TBI, 1980-87	2	6 (1 with High HC)
TBI, 1988+	0	1
CARB (All)	9	10 (1 with High HC)
Total	15	22 (2 with High HC)

Cars certified to a 0.4 NO_x standard could be classified as super emitters if their emissions exceed 1.60/mi for NO_x. Both 1988+ vehicles classified as super emitters on the basis of their NO_x emissions are certified to the 0.4 NO_x standards, with one at 1.84 g/mi and the other 2.83 g/mi. Two other super emitters are also super NO_x emitters relative to the 0.4 standard, one a 1984 MPI vehicle at 3.92 g/mi and the other a 1986 vehicle at 1.74 g/mi. These vehicles would not be classified as super emitters under a 1 g/mi NO_x standard, and only 1 vehicle would qualify as a super emitter under a 0.7 g/mi NO_x standard.

Nevertheless, the IM/240 test fails all super emitters at California cutpoints. Both ASM short tests curiously pass one HC/CO super emitter, a carburetted 1985 vehicles with FTP emissions of 2.54 HC/81.42 CO/0.49 NO_x. Each ASM test also passes one super NO_x emitter; the ASM 5015 passes a 1985 carburetted vehicle at 2.95 g/mi NO_x while the ASM 2525 passes the 1986 vehicle at 1.74 g/mi (a car certified to a 0.4 NO_x standard, described above). Hence, the ASM test super emitter identification rate for HC/CO super emitters is 93.3 percent, and is 90.9 percent for NO_x super emitters. Because of the relatively small sample, these values are not statistically different from the 100 percent identification rate observed for the I/M 240.

Tables 10 and 11 also shows the excess emission identification rates for the case of vehicles failing either one of the ASM tests. While this increases the error of commission rates, it does help the ASM excess emission identification rates for 1980-1987 vehicles. Although the conclusion regarding ranking for the IM240 vis-a-vis either-ASM test are not changed, the combined set of ASM tests are almost equivalent to the IM240 for the pre-1988 vehicles, and are significantly better than the IM240 test for the 1988+ vehicles, in terms of excess emissions identification rates.

Errors of Commission

Errors of commission are those vehicles that would fail a short test but pass the FTP. The ARB has adopted a second definition, to include vehicles failing a short test that are moderate emitters. Typically, the error of commission rate, using either definition, is the errors of commission normalized by the total failure rate or by the total sample. Due to the biased sample in this study, the rate as normally defined is not very meaningful.

Errors of commission (in absolute number of vehicles) can be defined with some statistical significance for only vehicles in the 1988+ MPI group, as all other groups contain five or fewer normal emitters. The 1988+ MPI group contains 21 normal emitters and the errors of commission at the four different cutpoints are listed below.

	IM240	ASM5015	ASM2525
C + 20	0	0	0
C	1	0	1
C - 20	1	0	2
C - 40	2	5	3

Conversion to a error of commission rate will be very misleading since the sample is so heavily biased towards failing vehicles. In this case of the 1988+ MPI group, 4.76 percent of all FTP normal emitters fail the IM 240 at California cutpoints. The standard deviation of this rate is ± 4.647; hence it is possible to have a zero sample error of commission and not be different from the 4.76 percent rate at 90 percent confidence. The errors of commission for the ASM5015 and ASM2525 are statistically similar at C + 20%, C, and C-20%, but the ASM 5015 has a significantly different error of commission rate at C-40%.

All other groups had five or fewer normal emitters, and the uncertainties surrounding the sample error of commission rate is very large. Nevertheless, among the entire sample of 10 normal emitters in all groups other than 1988+ MPI, these was only one error of commission. This vehicle was an error of commission at all cutpoints examined for IM240 and ASM5015, but was an error of commission only at the C-40% cutpoint on the ASM2525 test.

Using the ARB definition of error of commission, it is possible to examine the number of errors of commission for all groups except the 1983-87 TBI group which had only 2 vehicles under the moderate emitter cutpoint. Table 12 lists the errors of commission using this revised definition. The IM240 error of commission rate is almost identical to the ASM error of emission rates at "C" cutpoints for pre-1988 vehicles, but is higher for the 1988+ MPI group and lower for the 1988+ TBI group. None of these differences are statistically significant; across the entire set of 1980+ vehicles, the ASM2525 and IM240 have similar error of commission rates, whole the ASM5015 has a slightly higher rate. At the California cutpoints, the errors of commission divided by the total number of normal and moderate emitters is 14.3 percent for the IM240, 15.58 percent for the ASM5015, and 10.35 percent for the ASM2525.

In order to derive the error of commission rate for an unbiased sample the failure rates of (normal + moderate) emitters and the failure rate of high emitters must be calculated separately. Due to the inadequacy of the sample at the model year group/fuel system level, we have analyzed all 1988+ vehicles together, and these failure rates are listed in Table 13. An unbiased total sample failure rate can then be used to derive the percent of high emitters in the unbiased sample. For the IM 240 test, this is done as follows at the California cutpoint for the short test.

(Normal + Moderate) Emitter Failure Rate	=	0.1428
High Emitter Failure Rate	=	0.7295
Unbiased Sample Failure Rate	=	0.3130

If the percent of high emitters in the unbiased sample is "x", then

$$0.7295\,x + 0.1428\,(1-x) = 0.313$$

$$x = 28.98\%$$

TABLE 12

ERRORS OF COMMISSION (Alternative)
NORMAL + MODERATE EMITTERS

Group	Cutpoint	IM240	ASM5015	ASM2525	E-ASM*
MPI, 1983-1987	C + 20	2	0	2	2
	C	2	2	2	2
(N = 12)	C-20	3	5	4	5
	C-40	3	5	5	6
MPI 1988+	C+20	0	0	1	1
	C	4	1	2	3
(N=35)	C-20	6	3	4	5
	C-40	7	10	5	12
TBI 1988+	C+20	1	4	2	4
	C	2	6	2	6
(N = 15)	C-20	4	6	4	6
	C-40	5	7	8	9
CARB (All)	C+20	1	1	1	1
	C	3	3	2	3
(N=13)	C-20	3	4	4	5
	C-40	6	6	6	9
All 1980+	C+20	4	5	6	8
	C	11	12	8	14
(N=77)	C-20	16	18	16	21
	C-40	22	28	25	37

* E-ASM is failing either ASM.

TABLE 13

FAILURE RATE BY EMITTER CATEGORY ACROSS ALL GROUPS
(as percent of sample in category)

Cutpoint	IM 240	ASM 5015	ASM 2525
Normal + Moderate Emitters			
C + 20	5.19	6.49	7.79
C	14.28	15.58	10.29
C - 20	20.78	23.38	20.78
C - 40	28.57	36.36	32.46
High Emitters			
C + 20	58.49	65.40	61.00
C	72.95	72.95	76.10
C - 20	77.36	81.76	81.13
C - 40	90.56	86.16	86.79

Hence the error of commission rate is

$$E_c = \frac{0.1428\ (1-x)}{0.313}$$

$$= 32.4\% \text{ (based on failed vehicles)}$$

or 10% (based on the total sample)

Similarly for the ASM 5015

E_c = 28.7% (or 10.18% based on total sample)

and for the ASM 2525

E_c = 29.7% (or 10.15% based on total sample)

These values appear very high, and were re-evaluated at C+20% cutpoints. Based on the same set of calculations we can find that for the IM 240.

E_c = 14.0% (based on failed vehicle)

= 3.4% (based on total sample)

The E_c based on failure rate is nearly identical for all three tests, because the ASM tests have higher errors of commission and a higher overall failure rate, so that the ratio of the two does not vary. Based on the total sample, the E_c is 4.2% for the ASM 5015, and 5.1% for the ASM 2525. These differences are not statistically significant, but non-parametric tests show that across all cutpoints the IM 240 does have a lower error of commission rate than the ASM 5015 that is significant at the 90 percent confidence level.

Conclusions

Analysis of the data provided by ARB from a sample of cars tested on the FTP, IM240 and ASM 5015/2525 tests allowed comparisons of short test effectiveness. However, the sample was heavily biased towards high (FTP) emitters so that firm conclusions could not be reached on errors of commission.

Short tests were rated on the failure rate, excess emission identification rate, and error of commission rate. The test were examined at the California short test standards as well as standards 20% percent higher, and 20 and 40 percent lower than those specified by California. The findings are as follows:

- All three short tests demonstrate statistically equivalent failure rates at all cutpoints examined. However, the IM240 yields a slightly higher failure rate on pre-1988 vehicles, while the ASM tests yields a slightly higher failure rate on 1988+ vehicles. These differences are not statistically significant, except at isolated cutpoint/test combinations.

- Excess identification rates are also equivalent for all three short tests. A non-parametric test using short test rankings by excess emissions identification rates indicates that the IM240 is better on pre-1988 vehicles, while the ASM test perform better on 1988+ vehicles.

- Due to the very small sample of normal emitters, no conclusions regarding errors of commission are possible. If an alternative error rate is defined on the basis of normal or moderate emitters failing a short test, a pooled sample of all vehicles shows the IM240 to have a nearly identical error of commission rate to the ASM2525, which in turn has a slightly lower rate than the ASM5015 at each of the four cutpoints examined. Non-parametric tests indicate that the latter finding is statistically significant.

- At California cutpoints, the actual error of commission rates appear very high, using a combined analysis of the unbiased and biased samples. The error of commission (E_c) rate is about 30 percent if calculated as a fraction of all failures, and 10 percent if calculated as fraction of all cars tested. If cutpoints are relaxed by 20 percent, than E_c falls to 24 percent of all failed vehicles or 3.4 percent of the total. This finding could have a very significant impact on the actual cutpoints used in any program, and the resultant excess emission identification rate.

APPENDIX A

List of Cutpoints
Used By California On
The Short Tests

TABLE A-1

Predicted cutpoints for 1981 and newer model year vehicles at 2.5% EC

PASSENGER CARS

INERTIA Weight (lb	HYDROCARBONS IM240 (g/mi)	ASM5015 (ppm)	ASM2525 (ppm)	CARBON MONOXIDE IM240 (g/mi)	ASM5015 (%)	ASM2525 (%)	OXIDES OF NITROGEN IM240 (g/mi)	ASM5015 (ppm)	ASM2525 (ppm)
1750	0.97	119.02	114 74	23.30	0.67	0.65	1.99	1223.99	1105.07
2000	0.97	105 64	101 89	23.30	0.59	0.57	1.99	1074.99	970.94
2100	0.97	101 18	97 61	23.30	0.57	0.55	1.99	1025.32	926.23
2200	0.97	97.13	93.72	23.30	0.55	0.53	1.99	980.17	885.58
2300	0.97	93.42	90.17	23.30	0.52	0.51	1.99	938.95	848.47
2400	0.97	90.03	86.91	23.30	0.50	0.49	1.99	901.16	814.45
2500	0.97	86.91	83.92	23.30	0.49	0.47	1.99	866.39	783.15
2600	0.97	84 03	81.15	23.30	0.47	0.45	1.99	834.30	754.26
2700	0.97	81.36	78 59	23.30	0.46	0.44	1.99	804.59	727 51
2800	0.97	78.88	76.21	23.30	0.44	0.43	1.99	776.99	702.67
2900	0 97	76 58	74.00	23.30	0.43	0.41	1.99	751.30	679.55
3000	0.97	74.43	71.93	23.30	0.42	0.40	1.99	727.33	657.96
3100	0.97	72.41	70.00	23.30	0.40	0.39	1.99	704.90	637.77
3200	0 97	70 52	68.18	23.30	0.39	0.38	1.99	683.87	618.84
3300	0.97	68.75	66.48	23.30	0.38	0.37	1.99	664 12	601.05
3400	0.97	67.08	64 88	23.30	0.37	0.36	1.99	645.52	584.32
3500	0.97	65 51	63 37	23.30	0.36	0.35	1.99	627 99	568 54
3600	0 97	64 02	61 94	23.30	0.36	0.34	1.99	611.44	553 63
3700	0 97	62.62	60 59	23.30	0.35	0.34	1.99	595.78	539 54
3800	0.97	61.28	59.31	23.30	0.34	0.33	1.99	580.94	526.18
3900	0 97	60.02	58.10	23.30	0.33	0.32	1.99	566.87	513.51
4000	0.97	58.82	56.95	23.30	0.33	0.32	1.99	553.50	501.47
4100	0.97	57.68	55 85	23.30	0.32	0.31	1.99	540.78	490 02
4200	0.97	56.59	54.81	23.30	0.31	0.30	1.99	528.66	479.11
4300	0.97	55.55	53.81	23.30	0.31	0.30	1.99	517.11	468.72
4400	0.97	54.56	52 86	23.30	0.30	0.29	1.99	506.09	458.79
4500	0.97	53 62	51.95	23.30	0.30	0.29	1.99	495 55	449.31
4600	0.97	52.71	51 08	23.30	0.29	0.28	1.99	485.47	440.24
4700	0.97	51.85	50 25	23 30	0 29	0.28	1.99	475 83	431.55
4800	0.97	51.02	49.46	23 30	0.28	0 27	1.99	466.58	423 23
4900	0.97	50 22	48.69	23.30	0 28	0.27	1.99	457.71	415.24
5000	0.97	49.46	47.96	23.30	0.27	0.26	1.99	449.20	407.58
5250	0.97	47.67	46.25	23.30	0.26	0.26	1.99	429.33	389.69
5500	0.97	46.05	44.69	23.30	0.25	0.25	1.99	411.27	373 43
6000	0.97	43.21	41.96	23.30	0.24	0.23	1.99	379.66	344.98
6500	0.97	40.81	39.66	23.30	0.22	0.22	1.99	352.92	320 90
7000	0 97	38.75	37.68	23 30	0.21	0.21	1.99	330.00	300 27

TABLE A-1

Predicted cutpoints for 1975--1980 model year vehicles at 2.5% EC

PASSENGER CARS

	HYDROCARBONS			CARBON MONOXIDE			OXIDES OF NITROGEN		
INERTIA Weight (lb	IM240 (g/mi)	ASM5015 (ppm)	ASM2525 (ppm)	IM240 (g/mi)	ASM5015 (%)	ASM2525 (%)	IM240 (g/mi)	ASM5015 (ppm)	ASM2525 (ppm)
1750	1.45	172.09	158.21	20.27	0.92	0.61	5.13	4100.95	4278.62
2000	1.45	152.08	139.93	20.27	0.82	0.54	5.13	3588.33	3743.79
2100	1.45	145.41	133.84	20.27	0.78	0.52	5.13	3417.46	3565.52
2200	1.45	139.35	128.30	20.27	0.75	0.50	5.13	3262.12	3403.45
2300	1.45	133.81	123.25	20.27	0.72	0.48	5.13	3120.29	3255.47
2400	1.45	128.74	118.61	20.27	0.69	0.46	5.13	2990.27	3119.83
2500	1.45	124.07	114.35	20.27	0.66	0.45	5.13	2870.66	2995.03
2600	1.45	119.76	110.41	20.27	0.64	0.43	5.13	2760.25	2879.84
2700	1.45	115.76	106.76	20.27	0.62	0.42	5.13	2658.02	2773.18
2800	1.45	112.06	103.38	20.27	0.60	0.40	5.13	2563.09	2674.14
2900	1.45	108.61	100.23	20.27	0.58	0.39	5.13	2474.71	2581.93
3000	1.45	105.39	97.29	20.27	0.56	0.38	5.13	2392.22	2495.86
3100	1.45	102.38	94.54	20.27	0.55	0.37	5.13	2315.05	2415.35
3200	1.45	99.55	91.96	20.27	0.53	0.36	5.13	2242.70	2339.87
3300	1.45	96.90	89.53	20.27	0.52	0.35	5.13	2174.74	2268.97
3400	1.45	94.40	87.25	20.27	0.50	0.34	5.13	2110.78	2202.23
3500	1.45	92.05	85.10	20.27	0.49	0.34	5.13	2050.47	2139.31
3600	1.45	89.82	83.07	20.27	0.48	0.33	5.13	1993.52	2079.88
3700	1.45	87.72	81.15	20.27	0.47	0.32	5.13	1939.64	2023.67
3800	1.45	85.73	79.33	20.27	0.46	0.31	5.13	1888.59	1970.42
3900	1.45	83.84	77.61	20.27	0.45	0.31	5.13	1840.17	1919.89
4000	1.45	82.04	75.97	20.27	0.44	0.30	5.13	1794.16	1871.90
4100	1.45	80.33	74.41	20.27	0.43	0.30	5.13	1750.40	1826.24
4200	1.45	78.71	72.92	20.27	0.42	0.29	5.13	1708.73	1782.76
4300	1.45	77.15	71.50	20.27	0.41	0.28	5.13	1668.99	1741.30
4400	1.45	75.67	70.15	20.27	0.40	0.28	5.13	1631.06	1701.72
4500	1.45	74.26	68.86	20.27	0.40	0.27	5.13	1594.81	1663.91
4600	1.45	72.91	67.62	20.27	0.39	0.27	5.13	1560.14	1627.74
4700	1.45	71.61	66.44	20.27	0.38	0.27	5.13	1526.95	1593.10
4800	1.45	70.37	65.30	20.27	0.38	0.26	5.13	1495.14	1559.91
4900	1.45	69.18	64.22	20.27	0.37	0.26	5.13	1464.62	1528.08
5000	1.45	68.03	63.17	20.27	0.36	0.25	5.13	1435.33	1497.52
5250	1.45	65.36	60.74	20.27	0.35	0.24	5.13	1366.98	1426.21
5500	1.45	62.94	58.52	20.27	0.33	0.24	5.13	1304.85	1361.38
6000	1.45	58.69	54.64	20.27	0.31	0.22	5.13	1196.11	1247.93
6500	1.45	55.10	51.36	20.27	0.29	0.21	5.13	1104.10	1151.94
7000	1.45	52.02	48.55	20.27	0.28	0.20	5.13	1025.24	1069.66

TABLE A-1

Predicted cutpoints for 1974 and earlier model year vehicles at 2.5% EC

PASSENGER CARS

	HYDROCARBONS			CARBON MONOXIDE			OXIDES OF NITROGEN		
INERTIA Weight (lb	IM240 (g/mi)	ASM5015 (ppm)	ASM2525 (ppm)	IM240 (g/mi)	ASM5015 (%)	ASM2525 (%)	IM240 (g/mi)	ASM5015 (ppm)	ASM2525 (ppm)
1750	5.83	593.79	583.45	65.63	4.26	6.11	5.67	5367 26	4998.40
2000	5.83	521.07	512.02	65.63	3.75	5.37	5.67	4696.36	4373.60
2100	5.83	496.83	488.21	65.63	3.58	5.12	5.67	4472.72	4165.33
2200	5.83	474.79	466.57	65.63	3.42	4.89	5.67	4269.41	3976.00
2300	5.83	454.67	446.80	65.63	3.28	4.69	5.67	4083.79	3803.13
2400	5.83	436.23	428.68	65.63	3.15	4.50	5.67	3913.63	3644.67
2500	5.83	419.26	412.02	65.63	3.03	4.32	5.67	3757.08	3498.88
2600	5.83	403.59	396.63	65.63	2.92	4.16	5.67	3612.58	3364 31
2700	5.83	389.09	382.39	65.63	2.81	4.01	5.67	3478.78	3239.70
2800	5.83	375.62	369.16	65.63	2.72	3.88	5.67	3354.54	3124.00
2900	5.83	363.08	356.84	65 63	2.63	3.75	5.67	3238.87	3016.28
3000	5.83	351 38	345.35	65.63	2.55	3.63	5.67	3130.90	2915.73
3100	5 83	340 43	334 59	65.63	2.47	3.52	5.67	3029.91	2821 68
3200	5.83	330.17	324 51	65.63	2.40	3.41	5.67	2935 22	2733.50
3300	5.83	320.53	315.04	65.63	2.33	3.31	5.67	2846.28	2650 67
3400	5 83	311.45	306.13	65.63	2.27	3.22	5 67	2762.56	2572.71
3500	5.83	302.90	297.73	65.63	2.21	3.13	5 67	2683.63	2499 20
3600	5.83	294 82	289.79	65.63	2 15	3.05	5.67	2609.09	2429.78
3700	5.83	287.17	282.28	65.63	2.09	2.97	5 67	2538 57	2364 11
3800	5.83	279.93	275.17	65.63	2.04	2.90	5.67	2471.77	2301.89
3900	5 83	273.06	268.42	65.63	1.99	2.83	5.67	2408.39	2242.87
4000	5 83	266.54	262.01	65.63	1.95	2.76	5.67	2348 18	2186.80
4100	5.83	260.33	255.91	65.63	1.90	2.69	5 67	2290.91	2133.46
4200	5.83	254.41	250.11	65.63	1.86	2.63	5.67	2236.36	2082.67
4300	5 83	248.78	244.57	65.63	1.82	2.58	5.67	2184.35	2034 23
4400	5 83	243.40	239.28	65.63	1.79	2.52	5.67	2134.71	1988.00
4500	5 83	238.25	234.23	65.63	1 75	2.47	5.67	2087 27	1943.82
4600	5.83	233.34	229.40	65.63	1.71	2.42	5.67	2041.89	1901.57
4700	5.83	228.63	224.78	65.63	1.68	2.37	5.67	1998.45	1861.11
4800	5.83	224.11	220.34	65.63	1.65	2.32	5.67	1956.81	1822 33
4900	5.83	219.78	216.09	65.63	1.62	2.28	5.67	1916.88	1785.14
5000	5.83	215.63	212.01	65.63	1.59	2.24	5.67	1878.54	1749.44
5250	5.83	205.93	202.48	65.63	1.52	2.14	5.67	1789.09	1666.13
5500	5.83	197.12	193.83	65.63	1.46	2.05	5.67	1707.77	1590.40
6000	5.83	181.69	178.67	65.63	1.35	1.89	5.67	1565.45	1457.87
6500	5.83	168.64	165.85	65.63	1.26	1.76	5 67	1445.03	1345.72
7000	5.83	157 45	154.86	65 63	1.18	1.64	5.67	1341.82	1249 60

TABLE A-1

Predicted cutpoints for 1980 and earlier model year vehicles at 2.5% EC

MEDIUM DUTY VEHICLES

INERTIA Weight (lb	HYDROCARBONS IM240 (g/mi)	HYDROCARBONS ASM5015 (ppm)	HYDROCARBONS ASM2525 (ppm)	CARBON MONOXIDE IM240 (g/mi)	CARBON MONOXIDE ASM5015 (%)	CARBON MONOXIDE ASM2525 (%)	OXIDES OF NITROGEN IM240 (g/mi)	OXIDES OF NITROGEN ASM5015 (ppm)	OXIDES OF NITROGEN ASM2525 (ppm)
4900	5.83	219.78	216.09	65.63	1.62	2.28	5.67	1916.88	1785.14
5000	5.83	215.63	212.01	65.63	1.59	2.24	5.67	1878.54	1749 44
5100	5.83	211.64	208.09	65 63	1.56	2.20	5.67	1841.71	1715 14
5200	5.83	207.80	204.32	65.63	1.53	2.16	5.67	1806.29	1682.15
5300	5.83	204.10	200.69	65.63	1.51	2.12	5.67	1772.21	1650.42
5400	5.83	200.54	197.19	65.63	1.48	2.08	5.67	1739.39	1619.85
5500	5.83	197.12	193.83	65.63	1.46	2.05	5.67	1707 77	1590.40
5600	5.83	193.81	190.58	65.63	1.43	2.01	5.67	1677.27	1562.00
5700	5.83	190.62	187.45	65.63	1.41	1.98	5.67	1647.84	1534.60
5800	5.83	187.54	184.42	65.63	1.39	1.95	5.67	1619.43	1508.14
5900	5.83	184.57	181.50	65 63	1.37	1.92	5.67	1591.99	1482.58
6000	5.83	181.69	178 67	65.63	1.35	1.89	5.67	1565.45	1457.87
6100	5.83	178.91	175.94	65.63	1.33	1.86	5.67	1539.79	1433 97
6200	5.83	176.22	173.30	65.63	1.31	1.83	5.67	1514.95	1410.84
6300	5.83	173.61	170.74	65.63	1.29	1 81	5.67	1490.91	1388 44
6400	5.83	171.08	168 26	65.63	1.27	1.78	5.67	1467.61	1366.75
6500	5.83	168.64	165.85	65.63	1 26	1.76	5 67	1445.03	1345.72
6600	5.83	166.26	163.52	65.63	1.24	1.73	5.67	1423.14	1325 33
6700	5.83	163.96	161.26	65 63	1 22	1.71	5.67	1401.90	1305 55
6800	5.83	161.73	159.07	65.63	1.21	1.68	5.67	1381.28	1286 35
6900	5.83	159.56	156 93	65.63	1.19	1 66	5 67	1361 26	1267 71
7000	5.83	157 45	154.86	65.63	1.18	1.64	5.67	1341.82	1249.60
7100	5.83	155.40	152.85	65.63	1.16	1.62	5.67	1322.92	1232.00
7200	5.83	153.41	150.89	65.63	1.15	1.60	5.67	1304.54	1214.89
7300	5.83	151.47	148.99	65.63	1.14	1.58	5.67	1286.67	1198.25
7400	5.83	149.59	147 14	65.63	1.12	1.56	5.67	1269.29	1182.05
7500	5.83	147.75	145.34	65.63	1.11	1.54	5 67	1252.36	1166.29
7600	5.83	145.97	143.58	65 63	1.10	1.52	5 67	1235.88	1150.95
7700	5 83	144.23	141.88	65.63	1.08	1.51	5 67	1219.83	1136.00
7800	5.83	142.53	140.21	65 63	1.07	1.49	5 67	1204 19	1121.44
7900	5.83	140.88	138.59	65.63	1.06	1.47	5.67	1188.95	1107.24
8000	5.83	139.27	137.01	65.63	1.05	1.45	5.67	1174.09	1093.40
8100	5.83	137.70	135.46	65.63	1.04	1.44	5.67	1159 59	1079.90
8200	5.83	136.16	133.96	65.63	1.03	1.42	5.67	1145.45	1066.73
8300	5.83	134.67	132.49	65.63	1.02	1.41	5.67	1131.65	1053.88
8400	5.83	133.21	131.05	65.63	1 01	1.39	5.67	1118.18	1041.33
8500	5 83	131.78	129.65	65.63	1.00	1.38	5.67	1105 02	1029 08