Analysis of Invalid Emission Testing in the California Smog Check Program

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Table of Contents

List of Tables

List of Figures

Analysis of Invalid Emission Testing in the California Smog Check Program

1. Summary

Emissions measurements reported by licensed automotive repair dealerships participating in the California motor vehicle inspection and maintenance (I/M) program (called "Smog Check") have been compared to measurements made on the same vehicles at the California Air Resources Board (ARB) laboratory. Based on an experimental program under which 1,100 defective vehicles were taken to randomly selected repair facilities (called "Smog Check stations") by ARB employees posing as ordinary motorists, the Smog Check station emission test results appear to be invalid for about 17.5% of the vehicles. This is the fraction of defective vehicles for which the lower readings reported by Smog Check stations cannot be explained by test-to-test variability. These vehicles usually failed the emission standards at ARB after reportedly passing the standards at the Smog Check station.

Although the computer-controlled emissions analyzers used in the California program are designed to minimize the occurrence of erroneous emission measurements, there are several ways in which invalid results can be recorded. One technique, referred to as "clean piping", involves measuring the emissions from a known clean vehicle and reporting the results as if they were obtained from another vehicle. Another technique involves partially removing the sampling probe from the tailpipe to dilute the exhaust sample enough to get the vehicle to pass the test without exceeding the dilution thresholds programmed into the analyzer. Temporarily increasing idle speed is a technique used on some vehicles. Specific techniques that may have been used on the vehicles involved in the ARB experimental program are unknown.

All of the vehicles in the experimental program should have failed a properly conducted Smog Check test, and most of them did fail the first test conducted at a randomly selected Smog Check station. However, some of the vehicles returned from the Smog Check stations with idle emission test results that were substantially different from the results of a confirmatory test conducted by ARB. On average, the vehicles showing the greatest discrepancy between the last test at the Smog Check station and the retest at ARB had significantly higher Federal Test Procedure (FTP) and idle emissions during the initial (pre-Smog Check) testing at ARB. The final test results reported by the Smog Check stations indicate that idle emissions were reduced to the same level as other vehicles, presumably due to the effect of repairs. However, based on ARB's test results before and after the Smog Check, no significant change in either FTP or idle emissions actually occurred. The lack of an FTP emission reduction is consistent with the conclusion that the

idle emission reduction reported by the Smog Check station was not the result of any actual repairs.

Figures 1 and 2 highlight the differences between the vehicles for which ARB's test was much higher than the last Smog Check test and the vehicles for which the last Smog Check test was confirmed by ARB's test. As shown in Figure 1, in cases where the last Smog Check test was confirmed by ARB, CO emissions were reduced substantially. Based on the Before and After Smog Check tests conducted by ARB, idle CO emissions were reduced from 1.63% to 0.73%, a 55% reduction. As shown in parentheses, FTP emissions were reduced from 3.86 g/mi HC, 40.5 g/mi CO, and 2.20 g/mi NOx to 2.67 g/mi HC, 32.7 g/mi CO, and 1.92 g/mi NOx, reductions of 31% for HC, 19% for CO, and 13% for NOx.

Figure 2 shows a radically different trend for the vehicles with a large discrepancy between the results reported by the Smog Check station and the results measured by ARB after Smog Check. Not only were the idle CO emissions higher to begin with (3.0%), the idle emissions after the vehicle was returned to ARB from the Smog Check station were actually higher (3.36%). In contrast, the Smog Check stations reported that the idle CO emissions were reduced to 0.69%. As shown in parentheses, FTP emissions before Smog Check - 7.41 g/mi HC, 64.6 g/mi CO, and 2.00 g/mi NOx - were substantially higher than for the other vehicles. After return from the Smog Check station, emissions had been reduced by only 10% for HC, 0% for CO, and 11% for NOx.

Figure 1

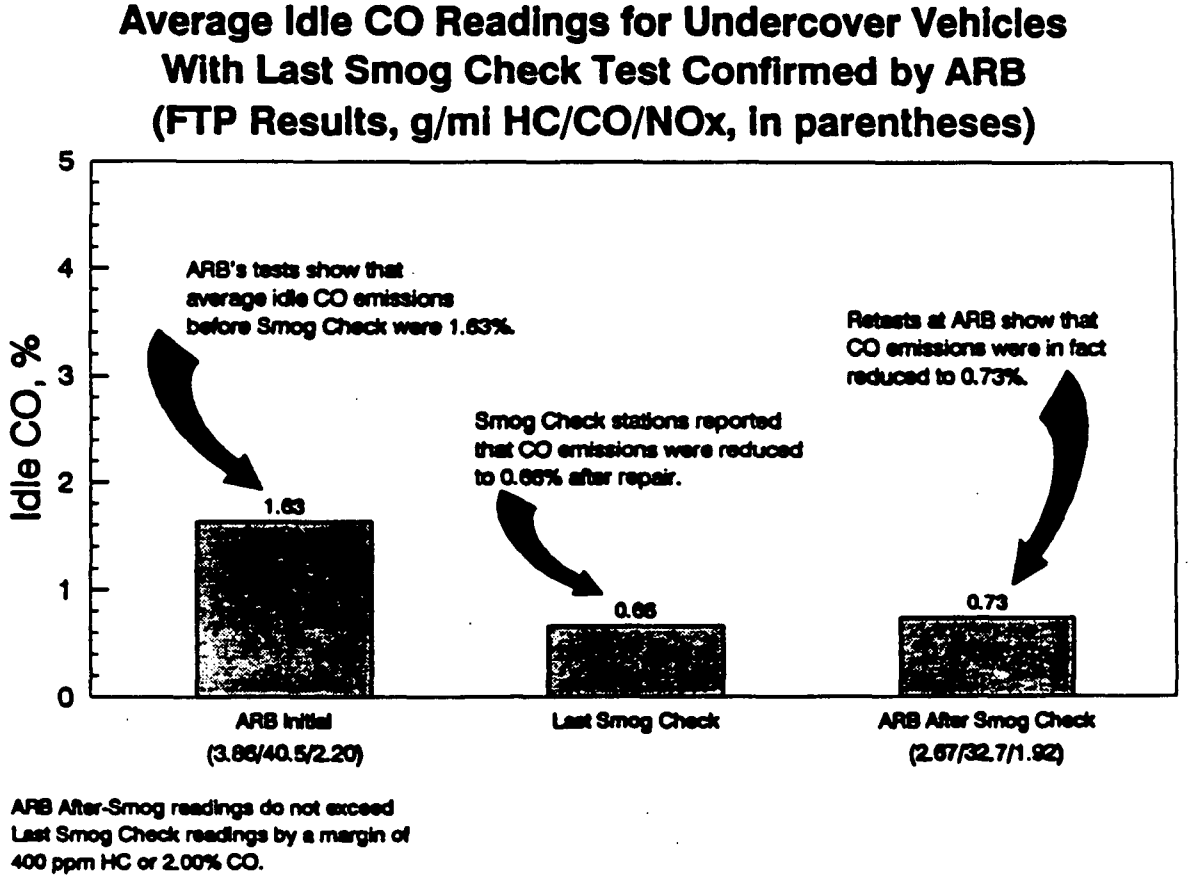
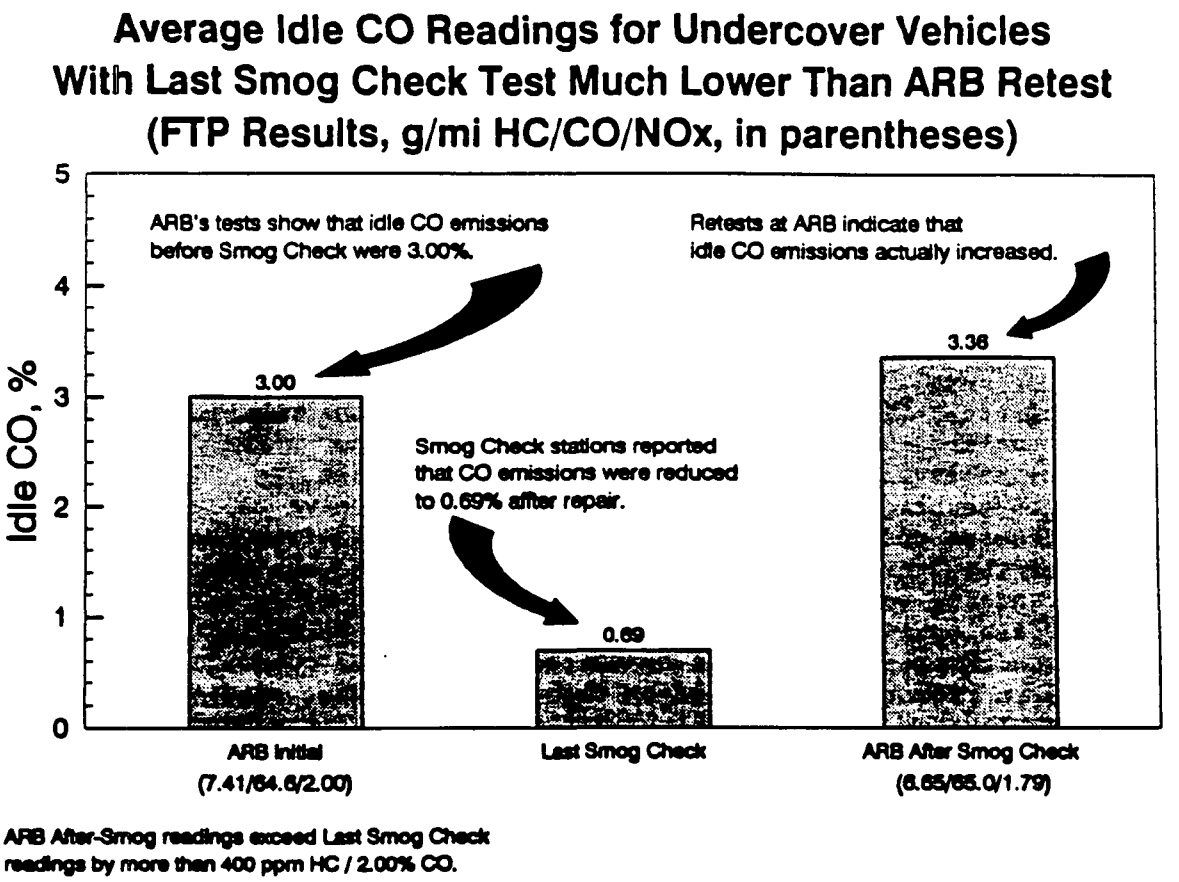


Figure 2



Because the occurrence of apparently invalid emission testing was determined to be proportional to the emissions of vehicles, it is estimated that invalid testing reduces the benefits of the Smog Check program by at least 30% for hydrocarbons and 39% for carbon monoxide. NOx emissions are not significantly affected. These estimates do not account for any additional loss in benefits that might be associated with testing of vehicles owned by motorists who are regular customers of the facility that performs the Smog Check. (In this study, the vehicles were taken to randomly selected facilities not familiar with either the driver or the vehicle.) The estimated reduction in benefits appears to validate EPA's discount for I/M programs that allow vehicles to be tested in the same facility that is responsible for repairing vehicles that fail the test.

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2. Introduction

Deliberate falsification of test results to get vehicles through the California I/M (Smog Check) program has been positively identified in previous investigations by the California Bureau of Automotive Repair (BAR). One form of test falsification is commonly referred to as "clean-piping", which involves measuring the emissions from a known clean vehicle and reporting the results as if they were obtained from another vehicle. Other forms of falsifying the emission test results include partially removing the sampling probe from the tailpipe to deliberately dilute the sample enough to cause the vehicle to pass the test but not exceed the dilution limits specified by BAR. Another technique involves temporarily increasing the idle rpm. The net effect of such techniques is that vehicles that should have failed the test do not receive additional repairs and the emissions after Smog Check are higher than they should be. The extent to which such testing techniques are reducing the effectiveness of the California I/M program has not been previously quantified. The comprehensive evaluation of the Smog Check program that was conducted during 1992 quantified the emission reductions achieved by the program without specifically addressing the extent to which invalid test results reduced program effectiveness.* That evaluation program involved the testing of 1,100 defective vehicles that were taken to randomly selected repair facilities (called "Smog Check stations") by ARB employees posing as ordinary motorists.

One indication of a possible problem with the validity of the test results from Smog Check stations is that the idle emission rates of vehicles stopped during random roadside inspections are higher than the idle emission results obtained for the same vehicle during the prior I/M test.** Some have attributed this difference in emissions to action that motorists have taken, e.g., restoring vehicles to a defective condition almost immediately after passing an I/M test. However, a preliminary analysis of data from the 1,100 vehicle ARB test program indicated that the correlation problem between roadside inspection results and Smog Check station test results exists before the vehicle is ever returned to the motorist after it passes a Smog Check test. As shown in Figure 3, average idle emissions for the vehicles were 76 ppm HC during their last test at a Smog Check station (which was typically the after-repair test) before they were returned to ARB. When retested at ARB, the actual idle emissions (196 ppm) were more than 100% higher. Figure 4 shows similar results for the idle CO emission measurements.

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* "Evaluation of the California Smog Check Program and Recommendations for Program Improvements, Fourth Report to the Legislature," California I/M Review Committee, February 16, 1993.

** D.R. Lawson, "Passing the Test - Human Behavior and California's Smog Check Program," Air & Waste, Vol. 43, December 1993.

Figure 3

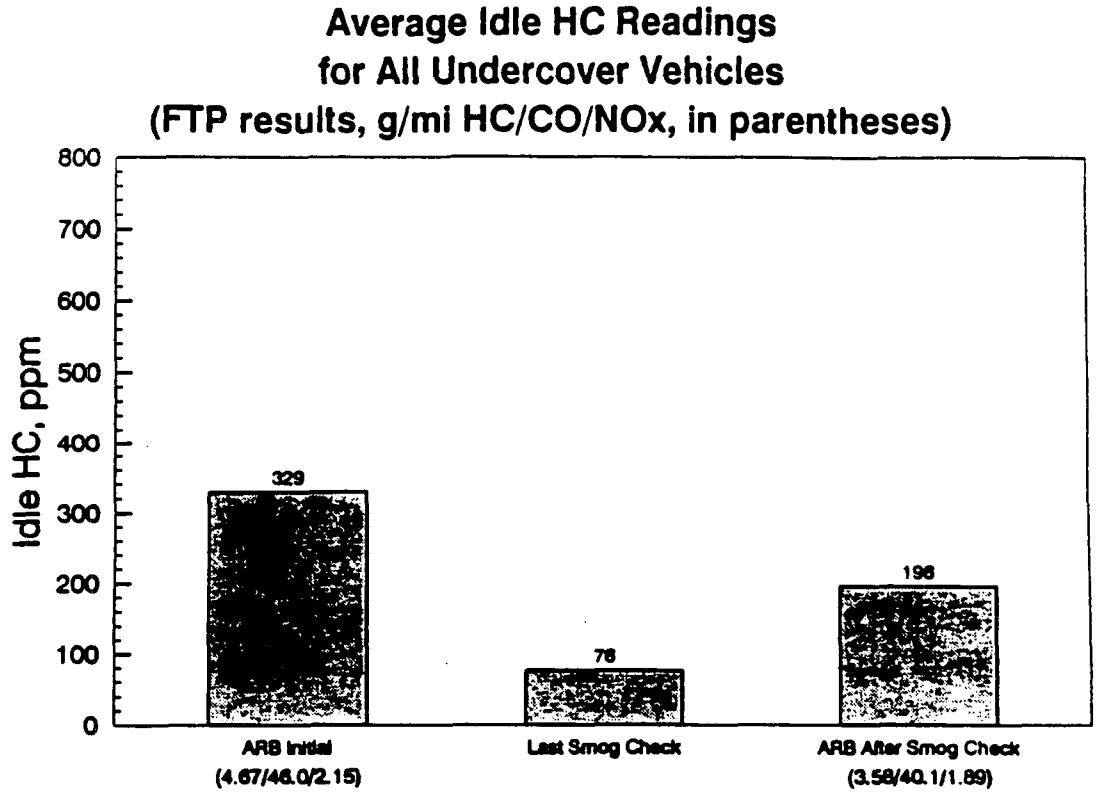
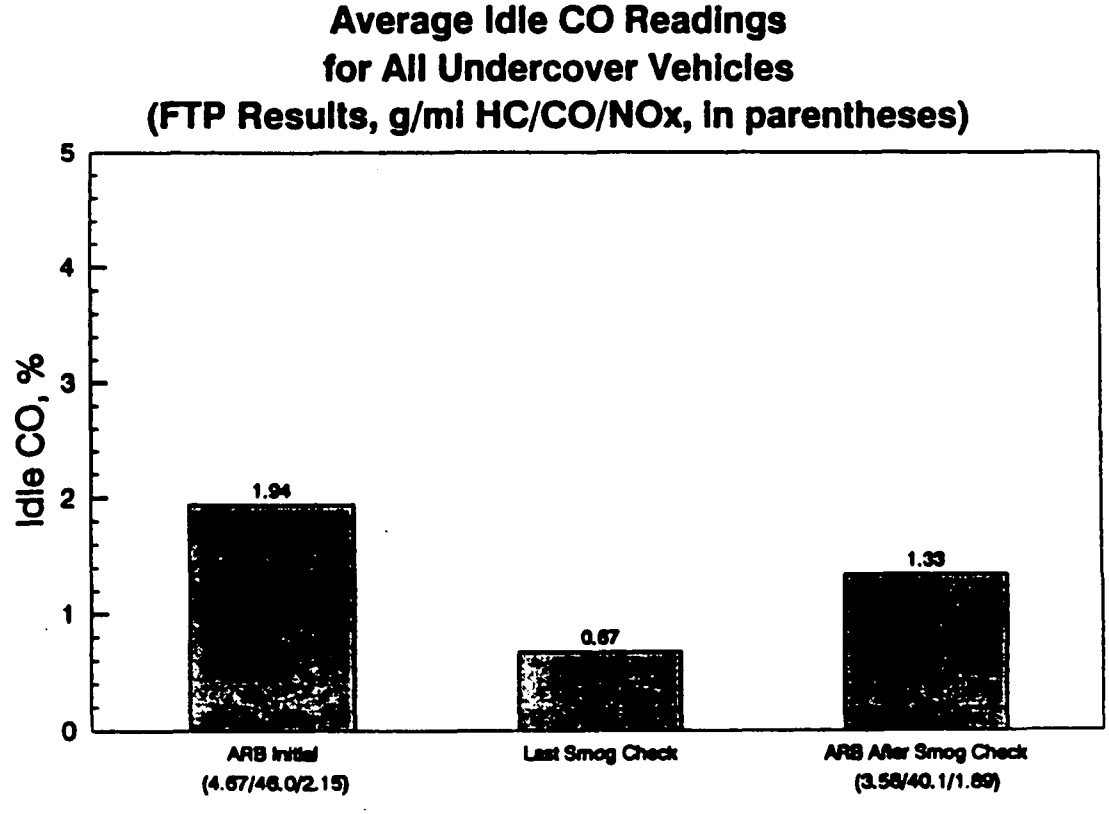


Figure 4



Task 2 of Work Assignment 2-01 of Sierra's support contract with EPA (Contract No. 68-C1-0079) requested the performance of a more detailed analysis of the data collected by ARB during the 1,100 vehicle undercover program to determine the extent to which fraud or testing error might be causing the true emissions of vehicles to exceed the results reported by Smog Check stations.

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3. Analysis of I/M Evaluation Data

To determine the frequency of invalid exhaust measurements and to determine the effects of such measurements on I/M program benefits, it is necessary to have a robust sample of data from vehicles that have gone through the Smog Check program and have been tested before and after the process. In addition to the mass emissions tests before and after Smog Check using the Federal Test Procedure (FTP), independent measurements of emissions at idle and 2500 rpm are needed for comparison with the results reported by Smog Check stations. The 1,100-car undercover test program conducted by ARB for the 1992 Smog Check evaluation provided the required data base. The undercover program test/repair sequence was as follows:

0) Screening Smog Check tailpipe test at ARB contractor

1) Baseline Smog Check visual/functional inspection and tailpipe test at ARB laboratory

2) Baseline FTP at ARB laboratory

3) Baseline (Initial) Smog Check visual/functional inspection and tailpipe test at Smog Check station

4) After-Repair Smog Check visual/functional inspection and tailpipe test at Smog Check station

5) After-Smog Check visual/functional inspection and tailpipe test at ARB Laboratory

6) After-Smog Check FTP at ARB laboratory

Analysis of I/M Test Variability

The initial focus of the analysis effort was based on the presumption that invalid exhaust measurements could be determined by comparing concentration readings from the last (or After-Repair) Smog Check tailpipe test (Step 4 above) with those from the test conducted when the vehicle returned to the ARB laboratory (Step 5 above). If the ARB After-Smog readings on a particular vehicle were sufficiently higher than the vehicle's Last Smog Check readings, then it could be said that the vehicle had apparently been tested in an invalid manner in the Smog Check shop. In this context, however, the determination of what "sufficiently higher" should be requires consideration of the normal variability associated with site-to-site and test-to-test variation.

To determine the expected variation in tailpipe readings from one site to another, the readings from the Initial test at the ARB laboratory (Step 1) were compared with those from the Screening facility (Step 0).

Since the operator of the Screening facility knew that ARB would be conducting confirmatory tests, there was no reason to suspect that there would be any bias deliberately induced during the testing process at the Screening facility.

The distribution of the differences in the readings (ARB Initial test minus Screening test) is presented in Figures 5 and 6, for Idle HC readings and Idle CO readings, respectively. The differences appear to be normally distributed, with about as many positive as are negative. A similar examination was made of the differences between the ARB After-Smog test and the last Smog Check test, which was the test on which the vehicle would receive its certificate of compliance. The distributions of those HC and CO differences (ARB After-Smog test readings minus last Smog Check test readings) are presented in Figures 7 and 8, respectively.

Estimation of Invalid Test Results

Figures 7 and 8, when compared with Figures 5 and 6, show a bias toward positive difference values, that is, they show that more of the ARB After-Smog readings were higher than the last Smog Check readings, rather than being normally distributed with similar numbers higher and lower. One example will illustrate this apparent bias: Referring to Figure 8, on 12.5% of the sample, the ARB After-Smog Idle CO reading was higher by more than 2.00% CO than the Idle CO reading on the last test at a Smog Check shop. In the more normally distributed differences in readings between the ARB Initial test and the Screening test, the difference was greater than 2.00% on only 4.3% of the sample, as shown in Figure 6.

The bias in the comparison of ARB After-Smog readings can be seen more clearly in Figures 9 and 10. These show, for HC and CO respectively, the ARB After-Smog minus Last Smog Check differences plotted as bars against a line plot of the more normally distributed ARB Initial minus Screening test results. Comparing ARB results with the Screening test, 23.1% of the vehicles had HC emissions at least 50ppm higher when measured at ARB. 17.1% of the vehicles had CO emissions at least 0.25% higher.* In contrast, comparing ARB results with the last test at a Smog Check station, 39.3% of the vehicles had HC emissions at least 50ppm higher when measured at ARB and 34.6% of the vehicles had CO emissions at least 0.25% higher. The ARB vs. Smog Check distribution is skewed toward higher readings at ARB by 16.2% of the sample in the case of idle HC and 17.5% of the sample in the case of idle CO. These comparisons indicate that a minimum of 17.5% of the vehicles had higher emissions in the after-Smog Check test at ARB than can be explained by test-to-test variability.

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* The 50 ppm HC and 0.25% CO tolerance were used to eliminate consideration of test result differences due to the accuracy of the analyzers used in BAR-approved Test Analyzer Systems. The BAR analyzers have an HC accuracy of 30-80 ppm and CO accuracy of 0.15-0.4% on the mid- and high-range.

Figure 5

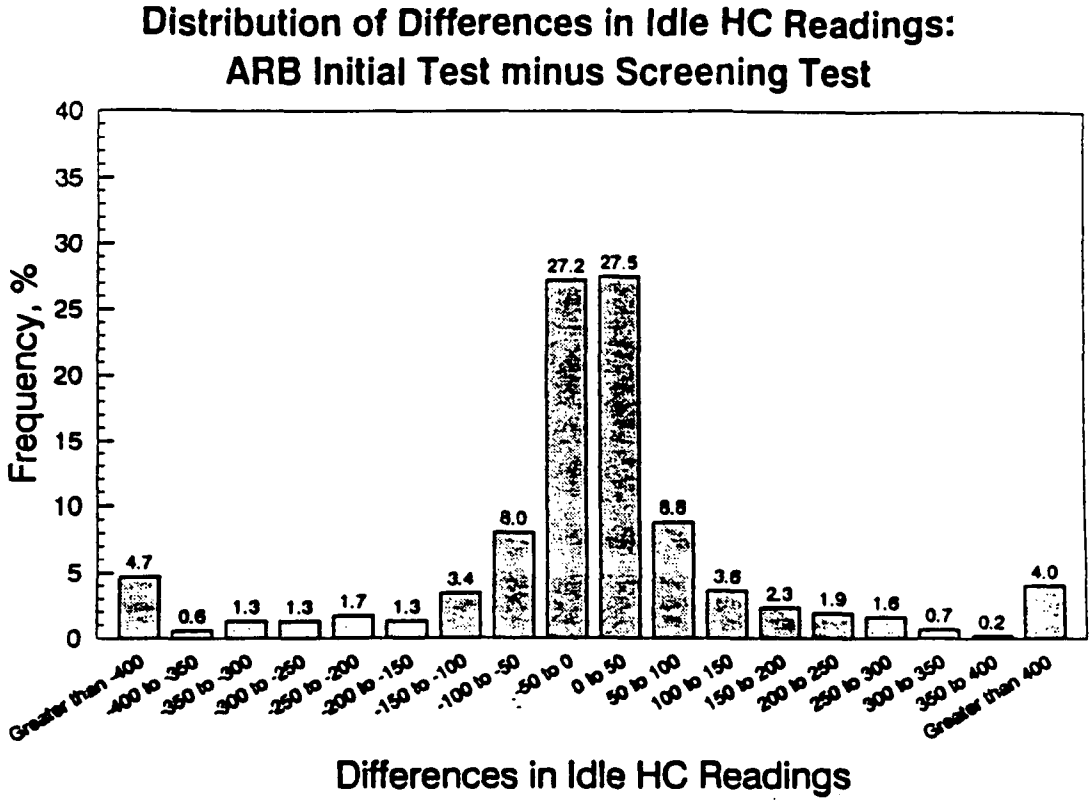


Figure 6

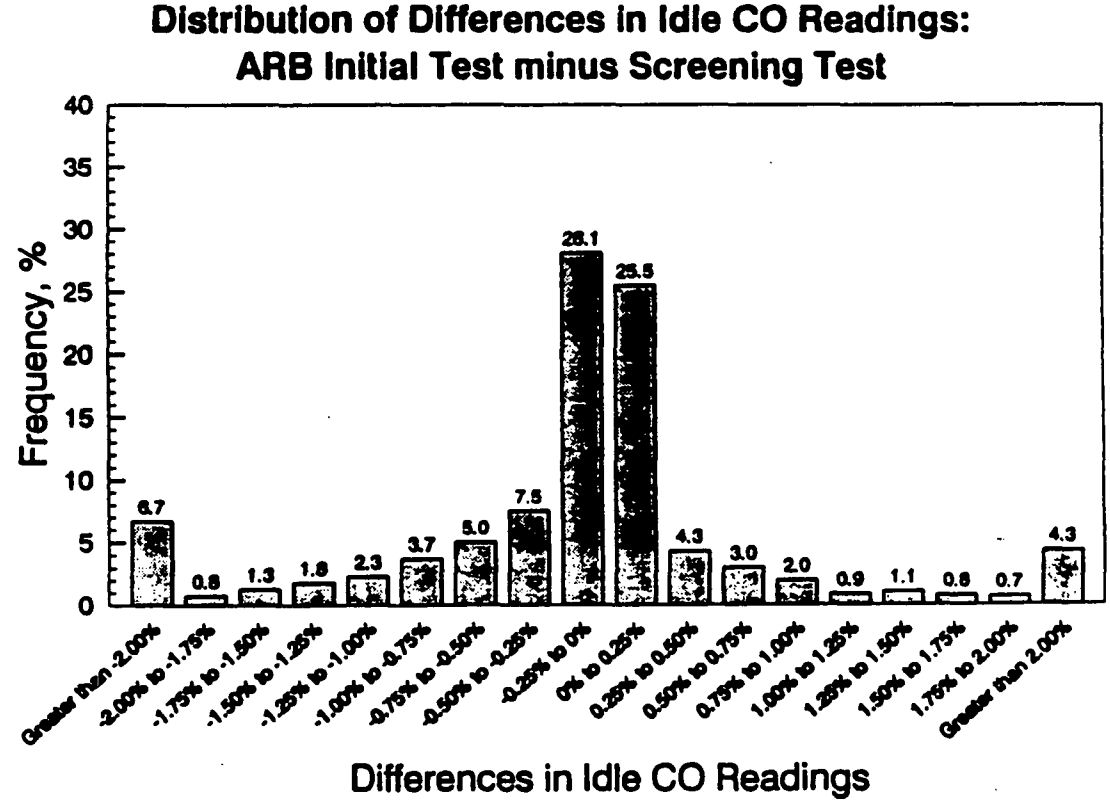


Figure 7

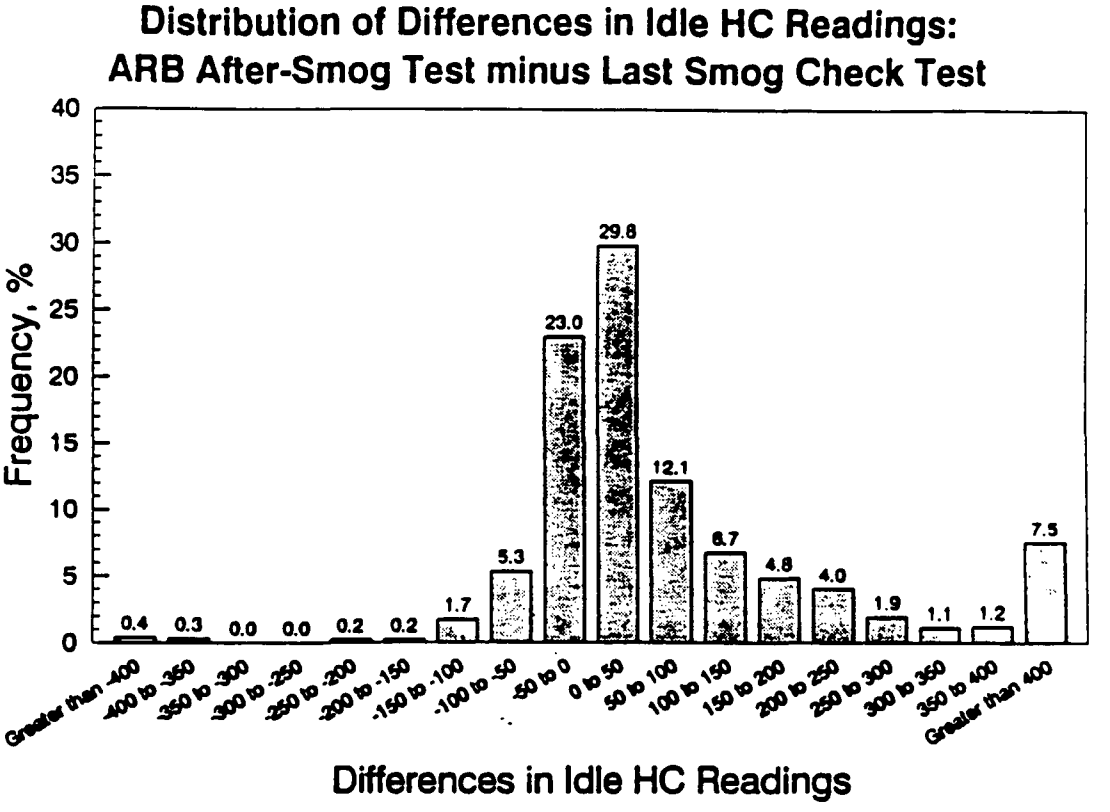


Figure 8

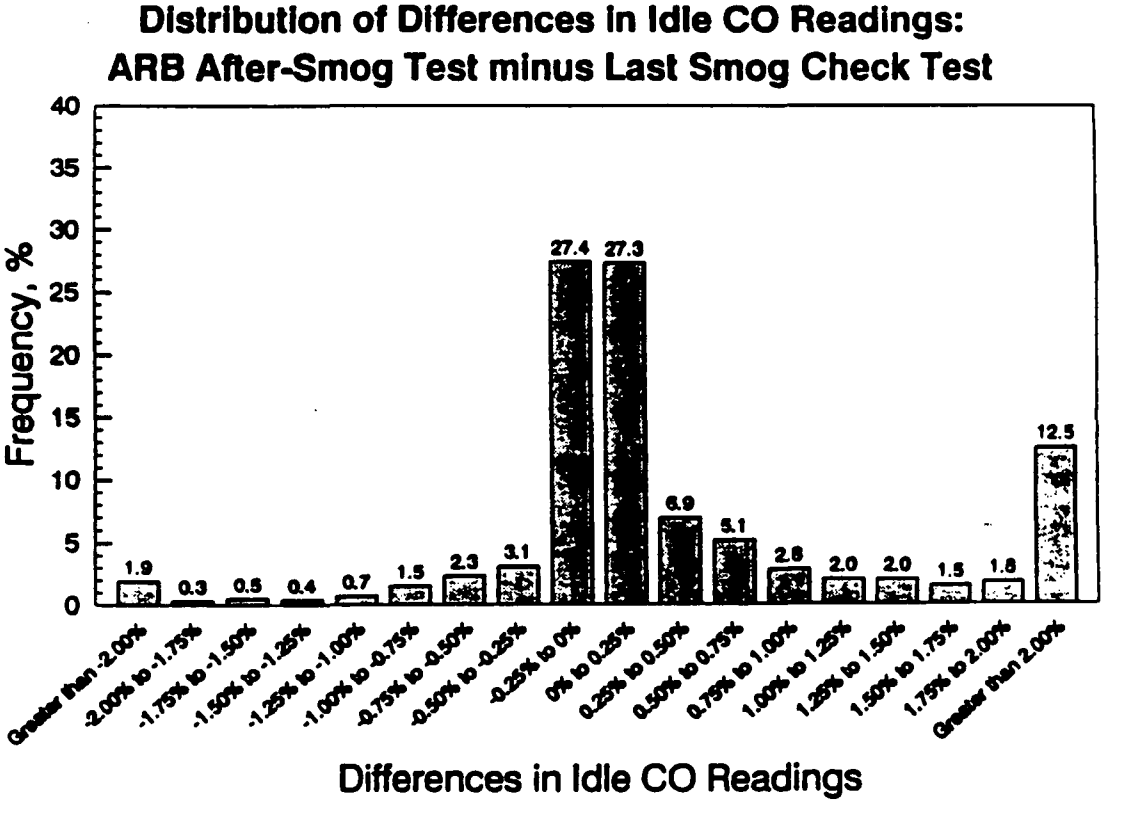


Figure 9

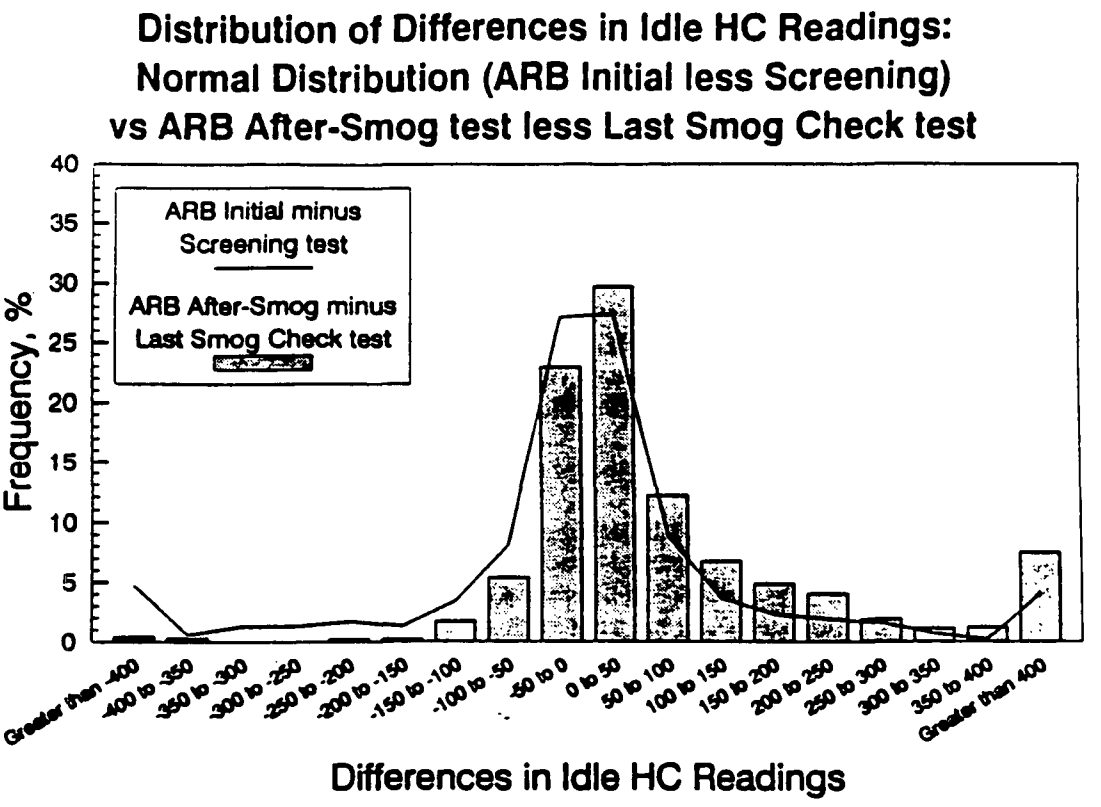
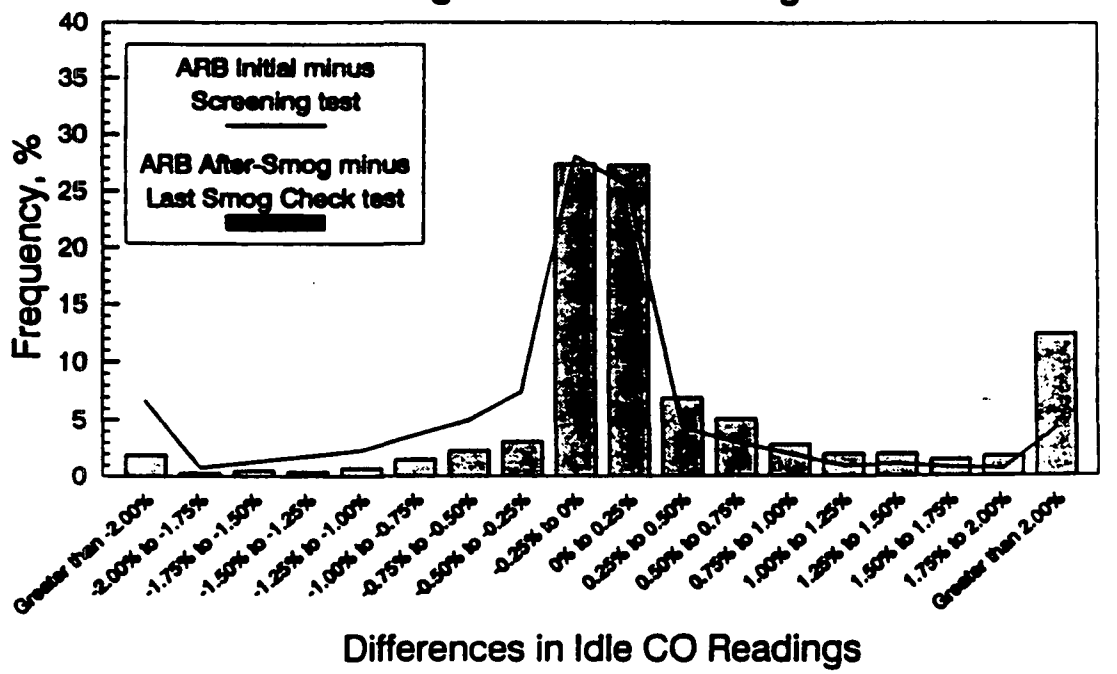


Figure 10



Because the increased frequency of higher measurements at ARB is not restricted to extreme differences, it is difficult to separate those vehicles that were improperly tested from vehicles that were higher at ARB due only to site-to-site/test-to-test variability. In addition, in cases where the differences between ARB's measurements and the values reported by the Smog Check station were relatively small, there is less concern about the loss in potential emission benefits associated with the improper or falsified test results. For that reason, the analytical approach focused on those vehicles where the ARB After-Smog Check readings were more than 400 ppm HC or 2.00% CO higher than the "Last Smog Check" reading. Basing the analysis on this level of difference was somewhat arbitrary because there was no level of difference which cleanly divided the vehicles into those with high variability and those with invalid results reported by the Smog Check station. However, as described below, the analytical approach used accounted for the fact that some of the vehicles with differences exceeding the 400 ppm/2.00% criteria were expected to have been properly tested.

Based on the comparison between ARB and Screening Facility test results (as shown earlier in Figures 1 and 2), a total of 7.8% of the vehicles would have been expected to have idle test results at ARB that exceeded their Smog Check test results by more than 400 ppm HC or 2.0% CO. When both idle and 2500 rpm emission tests (used on 1980 and later models) are considered, a total of 9.4% of the vehicles would have been expected to have test results at ARB that exceeded their Smog Check test results by more than 400 ppm HC or 2.0% CO. Because 20.4% of the undercover vehicles exceeded these margins, 11.0% of the vehicles exceeded the 400 ppm/2.0% margins and have apparently invalid test results, based on this analysis. Expressed another way, 54% (11.0÷20.4) of the vehicles that exceed the 400 ppm/2.0% margins are projected to have invalid test results.

Characteristics of Vehicles Based on ARB/Smog Check Correlation

In the undercover car test program were a total of 1,027 vehicles that received a Last Smog Check test (at a Smog Check shop) and a subsequent Smog Check test (After-Smog test) at the ARB laboratory. Of these, 209, or 20.4%, exceeded the 400 ppm HC or 2.00% CO exhaust measurement difference criterion. In the remainder of the analysis, vehicles for which the last ARB test exceeded the Last Smog Check test by more than the 400 ppm/2.0% margins are referred to as "Suspect" vehicles because, as explained above, 54% of them are projected to have invalid test results. Of these 209 vehicles, 96.7% Passed the Last Smog Check test and then Failed the After-Smog test at the ARB laboratory. In cases where the ARB test results did not exceed the Last Smog Check results by the 400 ppm/2.0% margins, some invalid testing is also suspected to have occurred; however, these vehicles are collectively referred to as "Other" vehicles or vehicles for which ARB test results and Last Smog Check test results are in reasonable agreement.

All 1,027 vehicles were not suitable for an analysis intended to address the effects of potentially invalid testing on the effectiveness of the California I/M program. Only 831 vehicles received a Last Smog Check

test and an ARB After-Smog test, plus a Smog Check tailpipe test in Baseline condition at ARB's laboratory, and an Initial test at a Smog Check shop (Steps 1, 3, 4, and 5), and received FTP mass emissions tests in Baseline (Step 2) and After-Smog Check conditions (Step 6). ARB retesting after the return of the undercover vehicles from the Smog Check stations indicated results exceeding those reported by the Smog Check station by 400 ppm HC or 2.0% CO in 22.9% (190 out of 831) of the cases.

Idle emissions - Table 1 presents average Idle emissions concentrations of HC and CO measured during the tailpipe test portion of the Smog Check inspection. In cases where the ARB test after Smog Check and the Last Smog Check test were in reasonable agreement, the vehicles had roughly similar readings in both facilities: average HC readings were 75 ppm in the Last Smog Check test and 110 ppm in the After-Smog test at the ARB laboratory. The CO readings were also similar: the average Idle

Table 1

Smog Check Tailpipe Idle Emissions
From Undercover Vehicles
Before and After Smog Check Repair

Condition	Idle Emissions	
	HC, ppm	CO, %
ARB-Smog Check Results Agree:		
Initial (Baseline) Test at ARB	267	1.63
After-Smog Test at ARB	110	0.73
% Change, Initial (Baseline) to After-Repair	-58.8	-55.2
Initial (Baseline) Test at Smog Check	210	1.20
Last Test at Smog Check	75	0.66
% Change, Initial (Baseline) to After-Repair	-64.3	-45.0
ARB Results Much Higher:		
Initial (Baseline) Test at ARB	537	3.00
After-Smog Test at ARB	484	3.36
% Change, Initial (Baseline) to After-Repair	-9.9	+12.0
Initial (Baseline) Test at Smog Check	347	2.04
Last Test at Smog Check	81	0.69
% Change, Initial (Baseline) to After-Repair	-76.7	-66.2

reading of 0.66% in the Last test at the Smog Check shops is close to the average 0.73% recorded in the After-Smog test at the ARB laboratory. These vehicles also showed Initial (Baseline) to After-Repair Idle emission reductions of similar magnitudes in both the ARB lab and the Smog Check stations. Tailpipe HC readings, for instance, were reduced 58.8% in the ARB lab, and 64.3% in the Smog Check shop. Tailpipe CO reductions were also of the same order of magnitude, i.e., 55.2% in the ARB lab and 45.0% in the Smog Check shop.

For the "Suspect" vehicles (where the ARB test results were much higher), the results were significantly different, comparing both measured emissions concentrations and claimed reductions at the Smog Check shop with the actual reductions measured at the ARB laboratory. Referring still to Table 1, average Smog Check Last-Test HC was 81 ppm, but 484 ppm at ARB (After-Smog). Average Last-Test CO was 0.69% at Smog Check shops, but 3.36% at ARB. These readings are reflected in the disparity between claimed and actual emission reductions also. A reduction of 76.7% in Idle HC emissions was claimed to have been achieved at the Smog Check station, but the same tests conducted at ARB indicated that the HC reduction was only 9.9%. The CO situation is even worse: the Smog Check stations claimed to reduce emissions by 66.2%, but ARB tests indicated an actual emissions increase of 12.0%.

Figures 11 through 14 are the graphical presentations of the information provided in Table 1. Figures 11 and 12 are HC and CO readings, respectively, for vehicles where the ARB results are in reasonable agreement with the Last Smog Check test; Figures 13 and 14 present HC and CO for vehicles with ARB results exceeding the Last Smog Check test by more than the margins. In each figure, the tailpipe emissions concentrations are represented by vertical bars, arranged left to right in the order in which the tests were performed.

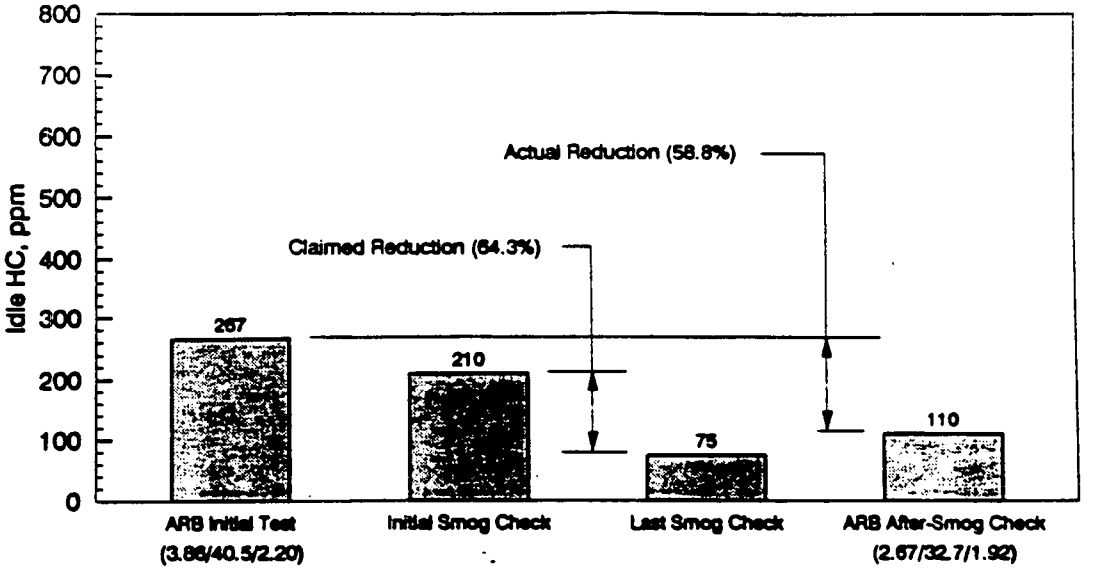
The charts make it clear that there was not much difference in the results reported by the Smog Check station regardless of whether the ARB results were in agreement with the Smog Check station results. However, tests conducted at the ARB laboratory tell another story. The "Suspect" vehicles had higher emissions from beginning to end than the other vehicles. The "Suspect" vehicles also emerged from the process with little or no reduction in their Idle emissions. Average Idle HC emissions were reduced about 10%, from 537 ppm to 484 ppm, and Idle CO emissions actually increased, from 3.00% to 3.36%.

Even though the other vehicles began the sequence of tests with lower average emissions, they still delivered significant emission reductions. As discussed earlier, and shown in the charts, when there was reasonable agreement between the ARB and Last Smog Check results, Idle emission reductions of 58.8% for HC and 55.2% for CO were observed comparing the ARB Initial Test (before Smog Check) with the After Smog Check ARB test.

Mass emissions - Table 2 below summarizes the mass emissions results, derived from tests conducted at ARB's El Monte laboratory using the 1975 Federal Test Procedure (FTP). The information presented in the table shows that when the ARB test results were much higher than the Last Smog Check test, the vehicles had higher mass emissions of HC and CO than the other vehicles. In addition, the reductions in mass emissions of HC and

Figure 11

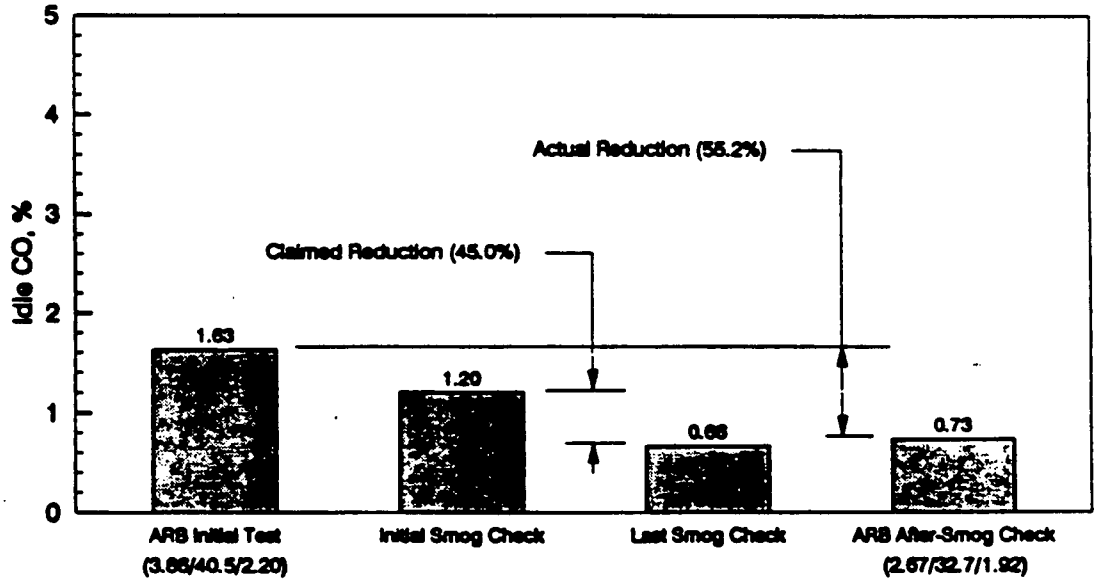
Average Idle HC Readings for Undercover Vehicles With Last Smog Check Test Confirmed by ARB (FTP Results, g/mi HC/CO/NOx, in parentheses)



ARB After-Smog readings do not exceed Last Smog Check readings by more than 400 ppm/2.00 %.
641 vehicles met the criteria.

Figure 12

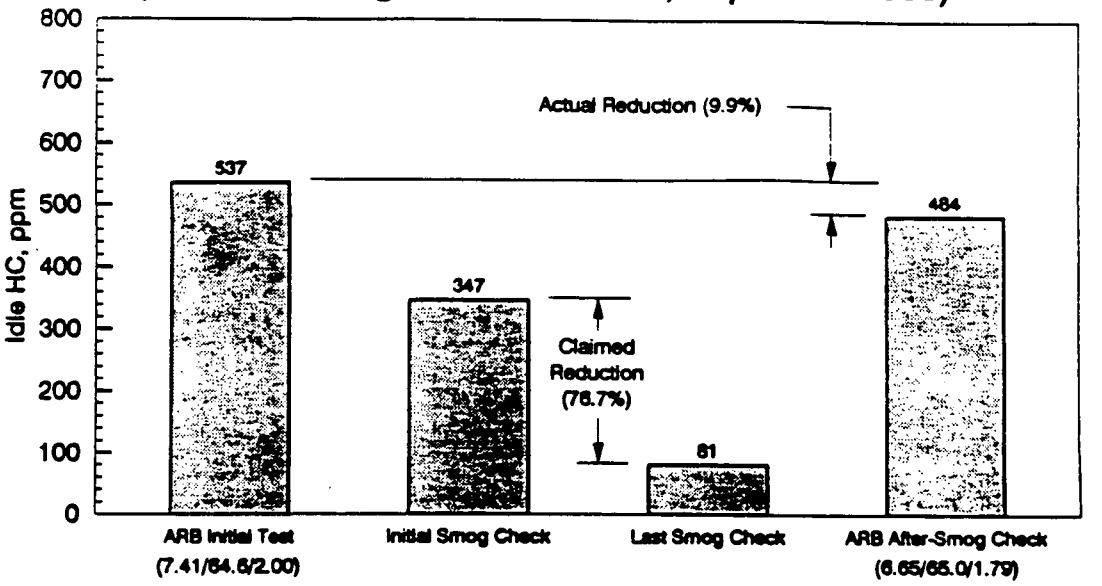
Average Idle CO Readings for Undercover Vehicles With Last Smog Check Test Confirmed by ARB (FTP Results, g/mi HC/CO/NOx, in parentheses)



ARB After-Smog readings do not exceed Last Smog Check readings by more than 400 ppm/2.00%.
641 vehicles met the criteria.

Figure 13

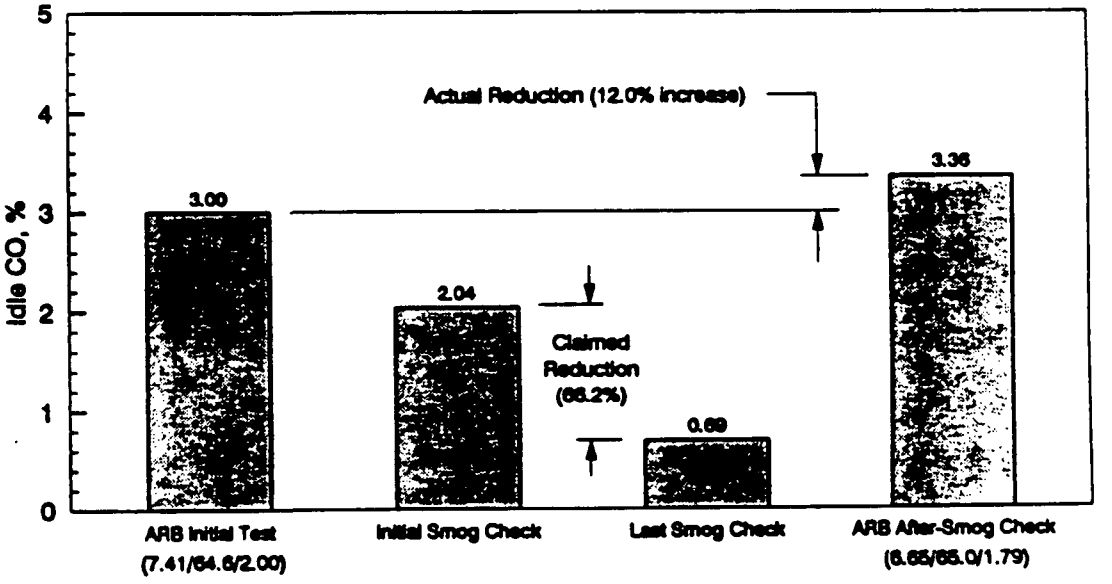
Average Idle HC Readings for Undercover Vehicles With Last Smog Check Test Much Lower Than ARB Retest (FTP Results, g/mi HC/CO/NOx, in parentheses)



ARB After-Smog readings exceed Last Smog Check readings by at least 400 ppm HC or 2.00% CO.
190 vehicles met the criteria.

Figure 14

Average Idle CO Readings for Undercover Vehicles With Last Smog Check Test Much Lower Than ARB Retest (FTP Results, g/mi HC/CO/NOx, in parentheses)



ARB After-Smog readings exceed Last Smog Check readings by at least 400 ppm HC or 2.00% CO.
190 vehicles met the criteria.

Table 2

FTP Mass Emissions From Undercover Vehicles
Before and After Smog Check Repair

Condition	Mass Emissions, g/mi		
	HC	CO	NOx
ARB-Smog Check Tests Agree:			
Initial (Baseline) Test at ARB	3.86	40.5	2.20
After-Smog Check Test at ARB	2.67	32.7	1.92
% Change, Initial (Baseline) to After-Smog	-30.8	-19.1	-12.7
ARB Test Results Much Higher:			
Initial (Baseline) Test at ARB	7.41	64.6	2.00
Last Test at ARB	6.65	65.0	1.79
% Change, Initial (Baseline) to Last Test	-10.3	+0.5	-10.5

CO for the vehicles that had much higher test results at ARB were less than the reductions achieved for the other vehicles. For example, average HC mass emissions were reduced by 30.8% for the vehicles for which the ARB and Last Smog Check results were in reasonable agreement, but by only 10.3% for the "Suspect" vehicles. The results are even more disparate for CO: mass emissions increased 0.5% on the "Suspect" vehicles, but were reduced an average of 19.1% for the other vehicles.

NOx mass emissions were reduced relatively little for both groups of vehicles. However, "Suspect" vehicles showed smaller reductions than the other vehicles.

Figure 15 presents the mass emissions results graphically. Note that the scale for CO emissions is on the right side of the chart.

Model Year Trends - The incidence of "Suspect" exhaust measurement as a function of vehicle model year was investigated in an attempt to determine whether any patterns were apparent. As shown in Figure 16, there appears to be only a weak correlation between the occurrence of "Suspect" emission measurements at Smog Check stations and model year (and therefore control technology).

Figure 16 shows that while the overall "Suspect" exhaust measurement rate was 20.4% (209 out of 1,027), it ranges from 8.3% among 1987 model year vehicles to 42.9% among 1970 model year vehicles. (None of the six 1989 models received "Suspect" exhaust measurements.) The average "Suspect" exhaust measurement rate for pre-1975 models is somewhat above the overall rate, at 30.05%. 1975-79 model year vehicles are obviously below the overall rate, the average for those five years being 13.7%.

Figure 15

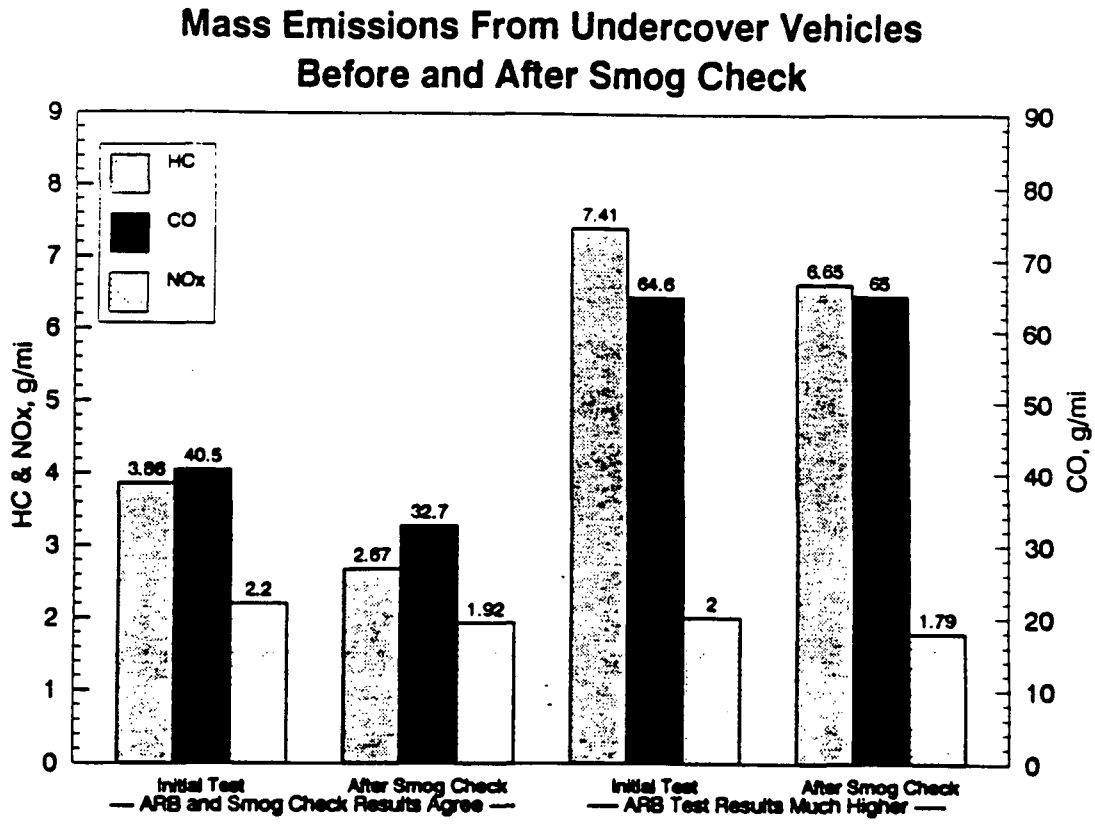
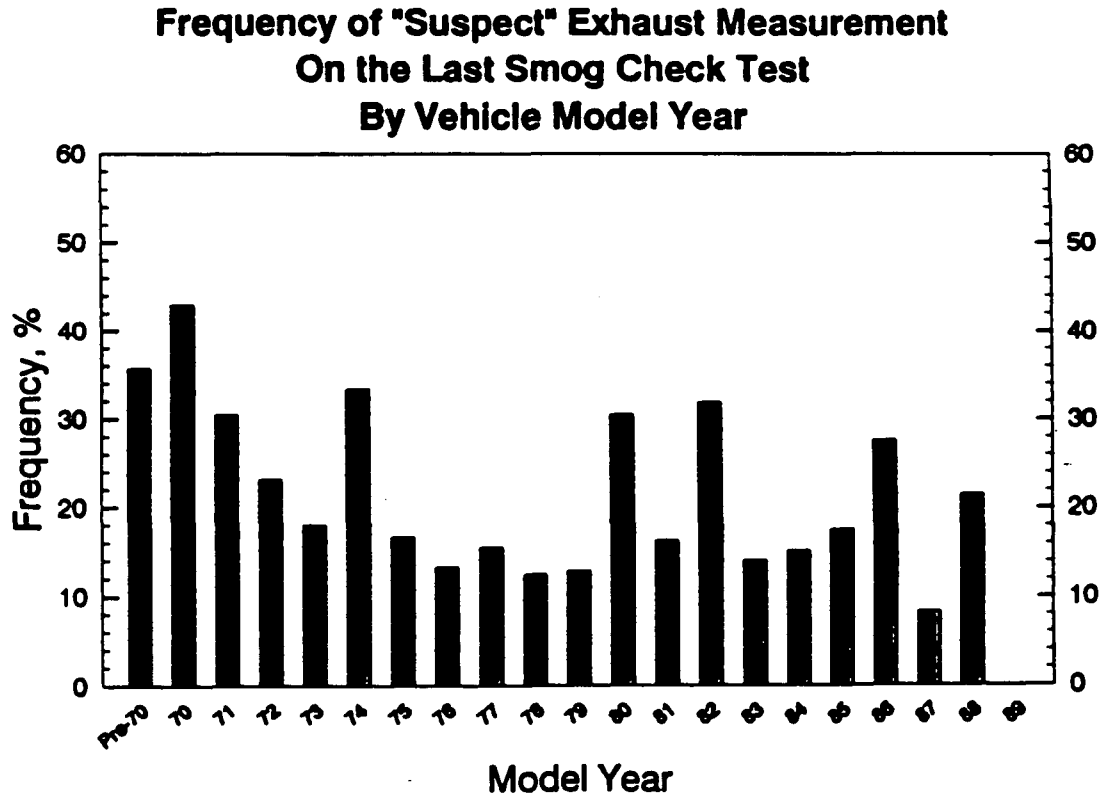


Figure 16



4. FTP Emissions Impact of Invalid Testing

To the extent that vehicles go unrepaired because of invalid test results, the benefits of the I/M program are diminished. A first-order approximation of the impact of invalid testing has been developed by randomly replacing the after-repair emission levels of 54% of the "Suspect" vehicles with the after-repair emission levels of the "other" vehicles (54% being the fraction of vehicles in the "Suspect" category that cannot be explained based on test-to-test variability)*. Tables 3-7 show the results of this analysis and the intermediate steps in the calculation.

Table 3 shows the FTP emissions by model year group and the VMT-weighted composite emissions before and after Smog Check for all of the undercover vehicles used in the analysis. As expected, the older vehicles are shown to have significantly higher emissions. The VMT-weighted emissions are close to the "Post-1979" average emissions because of the large fraction of the fleet represented by that category and the relatively high annual VMT rate for that category.

Table 3

Undercover Fleet – All Vehicle Emissions By Model Year Range							
		Mass Emissions (g/mi)					
		Before Smog Check			After Smog Check		
Model Year Range	Sample Size	HC	CO	NOx	HC	CO	NOx
Pre-75	167	9.91	70.94	2.76	7.31	66.11	2.50
75-79	238	4.34	48.20	2.51	3.51	42.88	2.14
Post-79	427	2.80	35.05	1.71	2.16	28.41	1.51
Weighted Composite		3.54	39.78	1.93	2.74	33.50	1.69

* This analytical approach deals with all vehicles that passed the I/M test because of invalid testing, not just those vehicles that initially failed the I/M test. The "Suspect" vehicles include vehicles that passed the initial I/M test. Under the ARB program, defective vehicles that initially passed were taken to a second Smog Check station. The results of those second chance tests have been ignored in this analysis.

Table 4 shows that the HC and CO FTP emissions of the vehicles where invalid testing is suspected were higher than average to begin with and not reduced nearly as much as the result of going through the Smog Check program. Table 5 shows the corresponding results for the other vehicles, which have significantly lower HC and CO FTP emissions to begin with and greater emission reductions due to I/M.

Table 4

Undercover Fleet - "Suspect" Vehicle Emissions By Model Year Range							
Model Year Range	Sample Size	Mass Emissions (g/mi) Before Smog Check			After Smog Check		
		HC	CO	NOx	HC	CO	NOx
Pre-75	61	12.20	77.55	2.74	10.96	76.97	2.57
75-79	43	7.77	85.07	2.18	7.34	84.23	1.90
Post-79	101	4.48	53.34	1.54	3.82	52.74	1.43

Table 5

Undercover Fleet - "Other" Vehicle Emissions By Model Year Range							
Model Year Range	Sample Size	Mass Emissions (g/mi) Before Smog Check			After Smog Check		
		HC	CO	NOx	HC	CO	NOx
Pre-75	106	8.59	67.14	2.77	5.22	59.85	2.47
75-79	195	3.59	40.07	2.58	2.67	33.77	2.19
Post-79	326	2.28	29.38	1.77	1.65	20.87	1.54

Table 6 shows the effect of randomly substituting the After Smog Check emission rates of the "other" vehicles for the After Smog Check emission rates of 54% of the vehicles suspected of passing due to invalid testing. Table 7 shows how the net emission reductions are affected by this substitution. With no substitution (using the results presented in Table 3), the emission reductions are 23% for HC, 16% for CO, and 12% for NOx. Randomly replacing the after-repair emission levels of 54% of

the "Suspect" vehicles with the after-repair emissions from the other vehicles increases the reduction in FTP emissions to 33% for HC and 26% for CO. NOx emission reductions decline slightly, from 12% to 11%. It should be noted that these emission reduction estimates are the single I/M cycle estimates for should-fail vehicles only. Coincidentally, the results are close to the overall benefits expected from the program after accounting for passing vehicles and the compounding of benefits caused by multiple program cycles.

Table 6

Undercover Fleet - With 54% of Randomly Selected "Suspect" Vehicles Repaired By Model Year Range							
Model Year Range	Should Fail VMT Frac	Mass Emissions (g/mi) Before Smog Check			After Smog Check		
		HC	CO	NOx	HC	CO	NOx
Pre-75	0.064	9.91	70.94	2.76	6.18	62.73	2.49
75-79	0.185	4.34	48.20	2.51	3.06	37.96	2.17
Post-79	0.751	2.80	35.05	1.71	1.89	24.34	1.53
Weighted Composite		3.54	39.78	1.93	2.38	29.32	1.71

Table 7

Mass Emission Reductions With and Without 54% of Randomly Selected "Suspect" Vehicles Repaired						
Model Year Range	Mass Emission Reductions (g/mi) With "Suspect" Vehicles Included			Mass Emission Reductions If 54% of "Suspect" Vehicles Eliminated		
	HC	CO	NOx	HC	CO	NOx
Pre-75	26%	7%	9%	38%	12%	10%
75-79	19%	11%	15%	30%	21%	14%
Post-79	23%	19%	12%	33%	31%	11%
Weighted Composite	23%	16%	12%	33%	26%	11%

Based on the results shown in Table 7, the overall benefits of the I/M program would be expected to increase by at least 1.43 times for HC and 1.63 times for CO if apparently invalid testing could be eliminated. Expressed in another way, invalid testing is estimated to cause a loss in I/M benefits of 30% for HC and 39% for CO.

The maximum benefits of eliminating invalid testing are expected to be higher than shown in Table 7 because this analysis only accounted for the benefits of failing and repairing vehicles for which the apparent falsification of results exceeded 400 ppm HC and 2.0% CO. Based on the analysis of test-to-test variability, 11% of the defective vehicles going through the I/M program are in this category. Based on the variability analysis discussed earlier, another 6.5% of the defective vehicles receive invalid test results in cases where the discrepancy between the reported results and the actual results does not exceed the 400 ppm HC/2.0% CO margins. The benefits of correctly failing and repairing these vehicles is probably somewhat less on a per-vehicle basis.

The computations summarized above have also been performed for two other substitution scenarios. Instead of randomly substituting results for the "Other" vehicles for 54% of the "Suspect" vehicles, we have also calculated what the effect would be of replacing the 54% dirtiest "Suspect" vehicles in each model year group. This might be considered an upper bound of what the effect of eliminating invalid testing might be. At the other end of the spectrum, we have also computed the results of replacing the 54% cleanest "Suspect" vehicles with the average emissions from the "Other" category. The "dirtiest" and "cleanest" vehicles were determined based on the sum of HC and NOx emissions plus CO emissions divided by seven (the standard averaging technique used by the California Air Resources Board). Tables 8 and 9 show the results for replacing the 54% dirtiest. Tables 10 and 11 show the results for replacing the 54% cleanest.

Table 8

Undercover Fleet - With the 54% Dirtiest of "Suspect" Vehicles Repaired By Model Year Range

Model Year Range	Should Fail VMT Frac	Mass Emissions (g/mi) Before Smog Check			After Smog Check		
		HC	CO	NOx	HC	CO	NOx
Pre-75	0.064	9.91	70.94	2.76	5.41	58.67	2.47
75-79	0.185	4.34	48.20	2.51	2.76	35.01	2.19
Post-79	0.751	2.80	35.05	1.71	1.70	21.71	1.52
Weighted Composite		3.54	39.78	1.93	2.13	26.54	1.70

Table 9

Mass Emission Reductions With and Without 54% Dirtiest "Suspect" Vehicles Repaired						
	Mass Emission Reductions (g/mi) With "Suspect" Vehicles Included			Mass Emission Reductions If 54% of "Suspect" Vehicles Eliminated		
Model Year Range	HC	CO	NOx	HC	CO	NOx
Pre-75	26%	7%	9%	45%	17%	10%
75-79	19%	11%	15%	36%	27%	13%
Post-79	23%	19%	12%	39%	38%	11%
Weighted Composite	23%	16%	12%	40%	33%	11%

Table 10

Undercover Fleet - With the 54% Cleanest of "Suspect" Vehicles Repaired By Model Year Range							
		Mass Emissions (g/mi)					
		Before Smog Check			After Smog Check		
Model Year Range	Should Fail VMT Frac	HC	CO	NOx	HC	CO	NOx
Pre-75	0.064	9.91	70.94	2.76	7.02	66.18	2.51
75-79	0.185	4.34	48.20	2.51	3.38	40.88	2.15
Post-79	0.751	2.80	35.05	1.71	2.07	26.86	1.54
Weighted Composite		3.54	39.78	1.93	2.63	31.97	1.71

Table 11

Mass Emission Reductions With and Without 54% Cleanest "Suspect" Vehicles Repaired						
	Mass Emission Reductions (g/mi) With "Suspect" Vehicles Included			Mass Emission Reductions If 54% of "Suspect" Vehicles Eliminated		
Model Year Range	HC	CO	NOx	HC	CO	NOx
Pre-75	26%	7%	9%	29%	7%	9%
75-79	19%	11%	15%	22%	15%	14%
Post-79	23%	19%	12%	26%	23%	11%
Weighted Composite	23%	16%	12%	26%	20%	11%

As shown in Table 9, replacing the 54% dirtiest vehicles increases the composite emission reductions from 33% to 40% for HC and from 26% to 33% for CO. NOx emission reductions are the same as in the random substitution case (11%). As shown in Table 11, replacing the 54% cleanest vehicles reduces the composite emission reductions to from 33% to 26% for HC and from 26% to 20% for CO. Again, NOx emission reductions are the same as in the random substitution case.

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