EPA-AA-TEB-80-5

Catalyst Effectiveness of High Mileage In-Use Vehicles

December 1979

by

Lois Platte

Test and Evaluation Branch
Emission Control Technology Division
Office of Air, Noise, and Radiation
United States Environmental Protection Agency

Catalyst Effectiveness of High Mileage In-Use Vehicles

There has been considerable speculation that fuel switching may have been a contributing factor to the increased ozone levels experienced in the Los Angeles area during the recent smog alert. The rationale for the speculation is that automobiles equipped with catalytic converters emitted increased hydrocarbons (which through photochemical reactions form ozone) because of the reduced effectiveness or deactivation of the catalyst caused by the use of leaded fuel. Many studies are being conducted to quantify the effect of such misfueling on the amount of pollutants emitted.

However, this paper focuses on another factor related to the reduced capacity of the catalyst which also is viewed by some as a contributor to the air quality problem. The problem is the suspected inadequate performance of the catalyst due to the effects of deterioration from aging or mileage accumulation. The "useful life" of light-duty vehicles has been defined as 50,000 miles or 5 years in Federal regulations. It is thought by some that the effectiveness of the catalyst on vehicles that are beyond their "useful life" is drastically reduced. The higher mileage vehicles may contribute to increased hydrocarbon levels since many catalyst equipped automobiles now on the road have reached the 5 year or 50,000 mile mark.

To address this issue, this paper will examine the catalyst effectiveness of relatively high mileage vehicles. Previous EPA surveillance studies of passenger cars have demonstrated that many in-use vehicles exhibit poor emission performance when compared to the applicable standards. The causes of the poor performance are misfueling, maladjustments and disablements, and inadequate maintenance of emission components. These factors may hinder or block the activity of the catalyst. Thus, the factors must be eliminated or corrected to determine how well the catalyst performs in reducing emissions. Several EPA programs have been conducted in which corrective maintenance was performed on in-use vehicles. The data collected in these programs will be reviewed in an effort to examine the catalyst performance of higher mileage vehicles that have been restored to a good maintenance state. Although the concern in the recent Los Angeles pollution episode is with hydrocarbons, the catalyst effectiveness will be discussed in terms of all three regulated exhaust pollutants.

It is a matter of debate as to whether or not EPA test vehicles have been subjected to misfueling. It is questionable whether a vehicle owner would voluntarily submit his car for emissions testing that was being conducted by EPA contractors if the owner had misfueled his vehicle. In fact, there is little indication that misfueled vehicles are recruited in the EPA test programs. Three pieces of information are collected in the program which may be used as indications of misfueling. There are (1) the lead content of the fuel in the vehicle when delivered for testing, (2) the condition of the fuel tank restrictor, and (3) the owner's response to a question concerning his use of leaded fuel. The information gathered on these three items indicates that misfueled vehicles are not recruited into the EPA test sample to any significant degree. Thus, for purposes of this study it can be assumed that the effects of emissions of misfueling are negligible if present at all.

The first program to be reviewed is the Restorative Maintenance Retesting of Passenger Cars in Detroit. A sample of 1976 and 1977 model year vehicles were retested over a period of one to one and a half years of in-use service. All the vehicles were equipped with oxidation catalysts. The accumulated mileage of these vehicles had not reached 50,000 at the final set of tests since the vehicles were less than 2 years old. Therefore, the data can't be used to directly address the issue of catalyst effectiveness of vehicles that have passed their "useful life" point. The data do show however the time trend on catalyst performance and indicate whether emission performance restorability deteriorates over time.

Thirteen 1976 model year vehicles were tested in the Detroit program at three different points in time. The average mileage of the 13 vehicles was approximately 9,800, 27,400, and 36,400 miles at the respective test points. The first retest was conducted after approximately one year of in-use service, while the second retest was conducted after an additional six months of operation. Six 1977 model year vehicles were retested once. At the first test the average mileage was approximately 2,600 miles. The second test was performed about six months later at an average mileage of approximately 19,800 miles.

At each test point, the vehicles underwent a series of restorative maintenance steps. Each step was followed by a FTP to measure the maintenance effect on reducing emissions. The maintenance steps followed in this program included the correction of maladjustments and disablements, the repair or replacement of defective parts, and a tune-up. A maintenance step was performed on a vehicle if the vehicle failed the emissions standards and required the maintenance performed in that step.

The test results are given in Figure 1 and 2 for the 1976 and 1977 model year Detroit vehicles respectively. The HC values given for the 1976 model year retests are affected by one vehicle that has HC measurements between 32 and 36 gm/mile depending upon the test sequence and set. These large HC measurements unduly affect the average because they are so excessive and the sample size is small. The dotted lines given in Figure 1 indicate the average HC levels without the excessive values.

The average HC and CO emissions of the restored vehicles return to high levels in the relatively short time interval between the sets of tests as is indicated by the results labeled test 1 in the figures. Yet the average as-received HC and CO emissions were reduced significantly in each test set following corrective maintenance. The average NOx values increased slightly for a few of the test sets. The percent of the vehicles that passed the standards increased from approximately 50% or less to at least 77% (which represents only 3 failing vehicles). The passing rates for each test are given in Table 1. Therefore, although there seems to be some deterioration in the catalyst during its "useful life," it functions well enough to control emissions to an acceptable level when the vehicle is restored to a good maintenance state.

Another test program was conducted to gather information on catalyst-equipped passenger cars which have exceeded their defined "useful life." A sample of eight St. Louis cars equipped with oxidation catalysts were tested in the program entitled Restorative Maintenance and Catalyst Replacement on Very High Mileage Cars in St. Louis. The test vehicles were sought to obtain a general sample of the popular domestic 1975 model cars with final selection based on odometer reading. The odometer values ranged from about 71,000 to 138,800 miles. The average mileage was 104,500.

The first phase of the program involved the usual restorative maintenance steps. Figure 3 displays the results of the maintenance actions in tests 1 through 3. Table 2 gives the corresponding percentages of the sample vehicles that pass the standards. Even though these vehicles are significantly beyond their defined "useful life," the final CO and NOx test results after corrective maintenance are well below the standard levels. The final average HC level, 1.94 gm/mi, is 23% greater than the HC standard but is significantly lower than the as-received emission level. The results suggest that the oxidation catalysts on very high mileage in-use vehicles are capable of controlling emissions relatively well.

The average emission levels of 300 catalyst equipped vehicles tested in a previous program (An Evaluation of Restorative Maintenance on Exhaust Emissions from In-Use Automobiles, SAE 780082) are displayed on Figure 3 as dotted lines. The 300 car fleet results have been included as a comparison to a set of restored vehicles tested at very low mileage (less than 12,000 miles). These values compared to the high mileage St. Louis vehicles results indicate that there is some deterioration in the capacity of the catalyst to control emissions as the vehicle ages and accumulates mileage.

The second phase of the St. Louis program involved the replacement of the high mileage catalyst on each of the eight test vehicles. A fourth FTP was performed following the replacement of the catalyst with a section of plain pipe to obtain "engine out" emissions. The average HC and CO "engine out" emissions are respectively 87% and 66% higher than the emission levels following corrective maintenance. This is shown by comparison of test 3 to test 4 results in Figure 3. The dramatic increase in emissions following the replacement of the catalyst with a section of pipe clearly indicates that the high mileage catalyst is capable of functioning in reducing HC and CO emissions.

Another FTP was performed following the installation of a new catalyst on each vehicle. The results are displayed as test 5 in Figure 3. With the new catalyst, the average HC and NOx levels of the eight vehicles were reduced to levels that were as low as the low mileage 300 car fleet. The average CO emissions of the St. Louis sample following catalyst replacement were not reduced to the level of the 300 car fleet. Nonetheless, the CO emissions of the new catalyst were comparable to those of the old catalyst when the vehicles were in a good maintenance state.

Two additional test programs were conducted that provide information on catalyst effectiveness in the Los Angeles area. The first program to be discussed is the Study of Exhaust Emissions from 1975-1979 Passenger Cars in Los Angeles (Contract No. 68-03-2590). A subsample of 50 vehicles were selected from the total test fleet for the performance of the restorative maintenance procedures. The 50 vehicles were selected with a preference for high mileage oxidation catalyst vehicles. Forty-one of the 50 vehicles subjected to restorative maintenance were 1975-1977 oxidation catalyst vehicles. The non-catalyst vehicles are not considered in this paper since the principal concern is with catalyst effectiveness.

The test results for the oxidation catalyst equipped vehicles from the Los Angeles program are given in Figure 4 and Table 3. Unlike the results given for the other test programs discussed in this paper, the average emission values are not reduced to a level less than the standard following the corrective maintenance. Each of the vehicles selected for maintenance in this program failed the standards on their as-received test. Because of this selection procedure, the sample is biased toward poor performance vehicles. However, the emission levels were significantly reduced following maintenance from the as-received levels.

The second Los Angeles area test program was conducted on 3-way catalyst vehicles. Since 3-way catalyst vehicles have been introduced only recently the test vehicles were not expected to have high mileage. The average mileage is less than 10,000 miles on these test vehicles. The sample is included to give an indication of emission performance of 3-way catalyst vehicles at the mileage accumulation stage at which they are currently operating.

The Los Angeles study is part of a larger program entitled the Study of Emissions of Passenger Cars in Six Cities (Contract No. 68-03-2774). The Los Angeles program involved the testing of 51 vehicles that underwent restorative maintenance. Each of these vehicles failed the standards on their as-received test. The maintenance steps are somewhat different from previous programs. The first maintenance action was the correction of "obvious" maladjustments and disablements of the type that are likely to be discovered in a quick visual underhood inspection. The second maintenance step involved the replacement of the O_2 sensor if it was found to be non-functional. The last two steps involved the usual steps of correction of maladjustments and disablements (those not found in the quick visual inspection) and finally correction of defective parts and/or a tune-up.

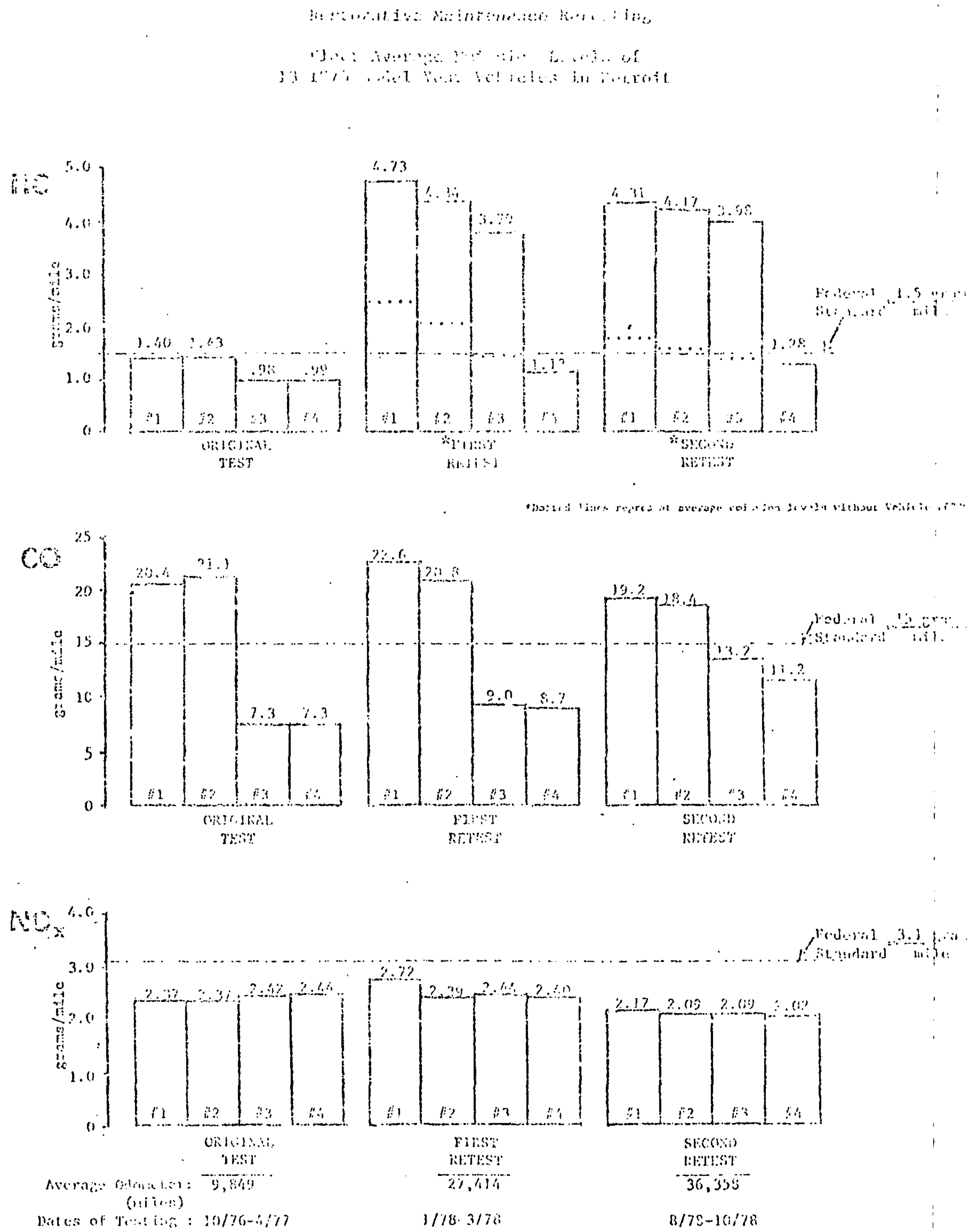
The average test results for the 3-way catalyst vehicles that had restorative maintenance are displayed in Figure 5. The figure indicates that the 3-way system is effective in controlling CO and NOx emissions at least when these vehicles are relatively new. However, the average HC emissions are 68% greater than the standard following maintenance. Only the correction of the "obvious" maladjustments and disablements have any effect in reducing the as-received HC levels. The HC level was reduced 14% following that maintenance step.

The percent of vehicles that passed the standards is given in Table 4 for the 3-way catalyst vehicles that were in the restorative maintenance phase of the Los Angeles study. The passing rate was increased from 0% to 29% following the maintenance. Most of the failures were related to the HC standard.

Thus, the relatively low mileage 3-way catalyst vehicles operated in Los Angeles appear to control CO and NOx to their standards even when tested in their as-received condition. Most of the vehicles that fail the standards fail the HC standard.

Based upon the data presented above, the oxidation catalyst is capable of reducing HC and CO emissions even when the vehicle has advanced well beyond the defined "useful life." In several studies, the average HC and CO emission levels of oxidation catalyst vehicles were well below the standards following restorative maintenance. However, the effectiveness of the oxidation catalyst appears to deteriorate with age and mileage accumulation.

Figure 1

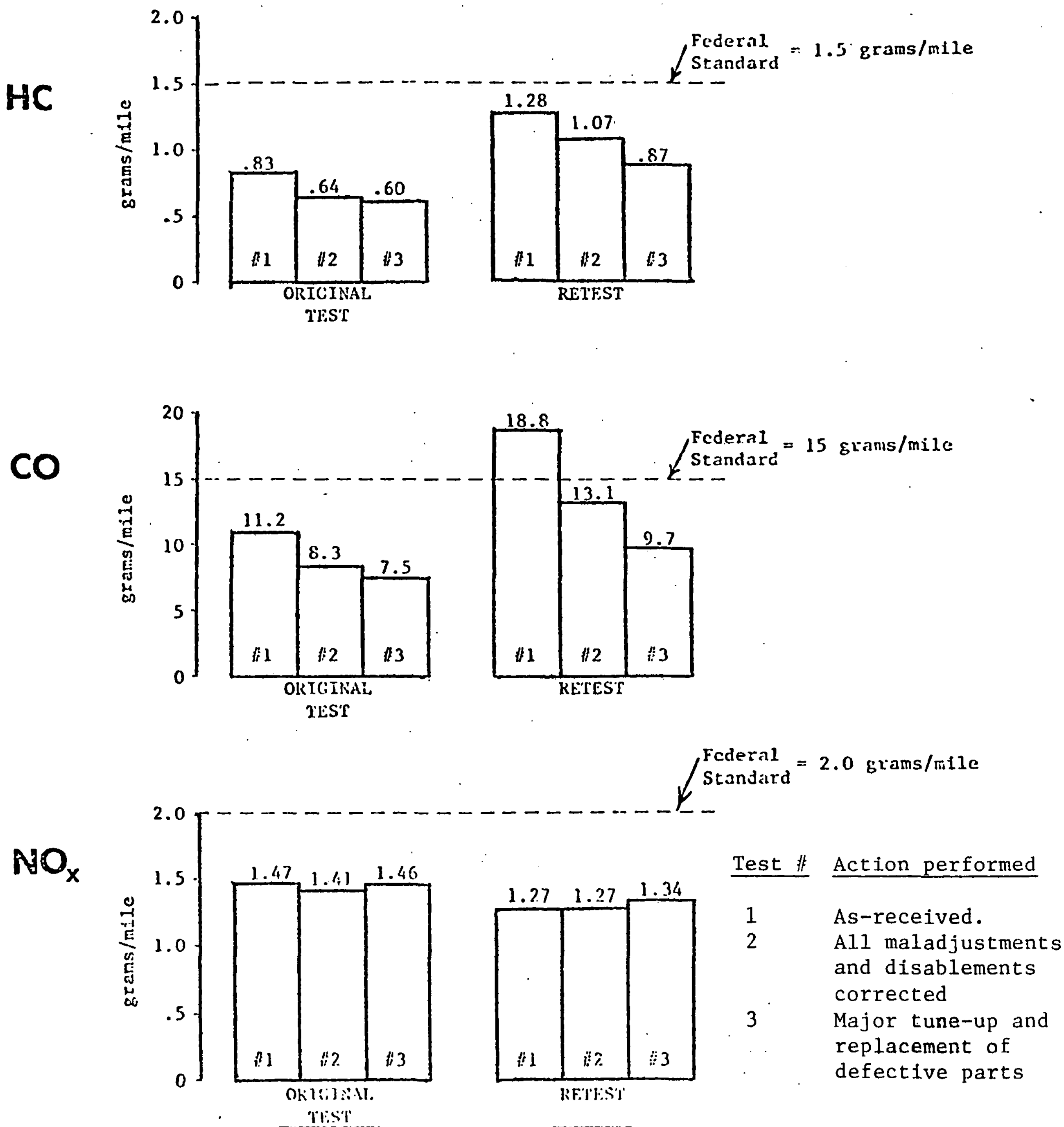


Test #	Action performed prior to test
1	None, as-received.
2	All maladjustments other than ICO, IRPM or disablements corrected.
3	ICO, IRPM adjusted.
4	Major tune-up and replacement of defective components.

Figure 2

Restorative Maintenance Retesting

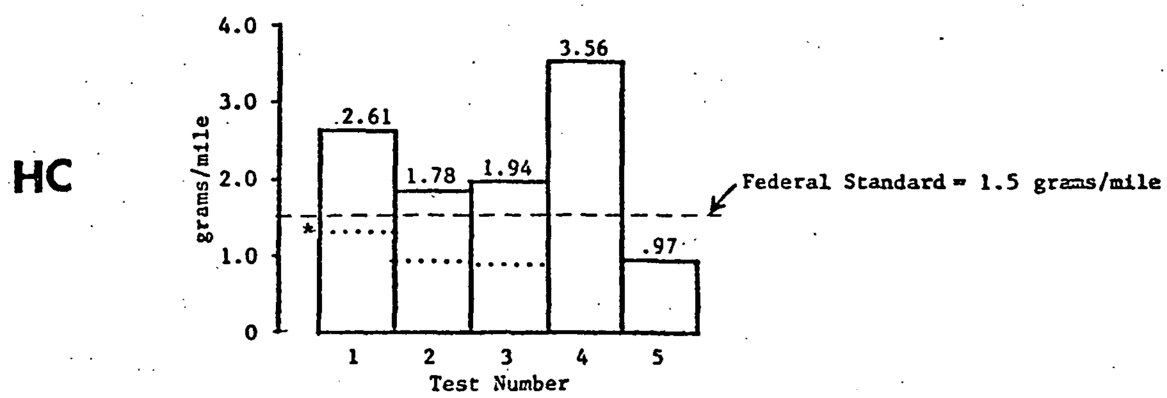
Fleet Average Emission Levels of 6 1977 Model Year Vehicles in Detroit

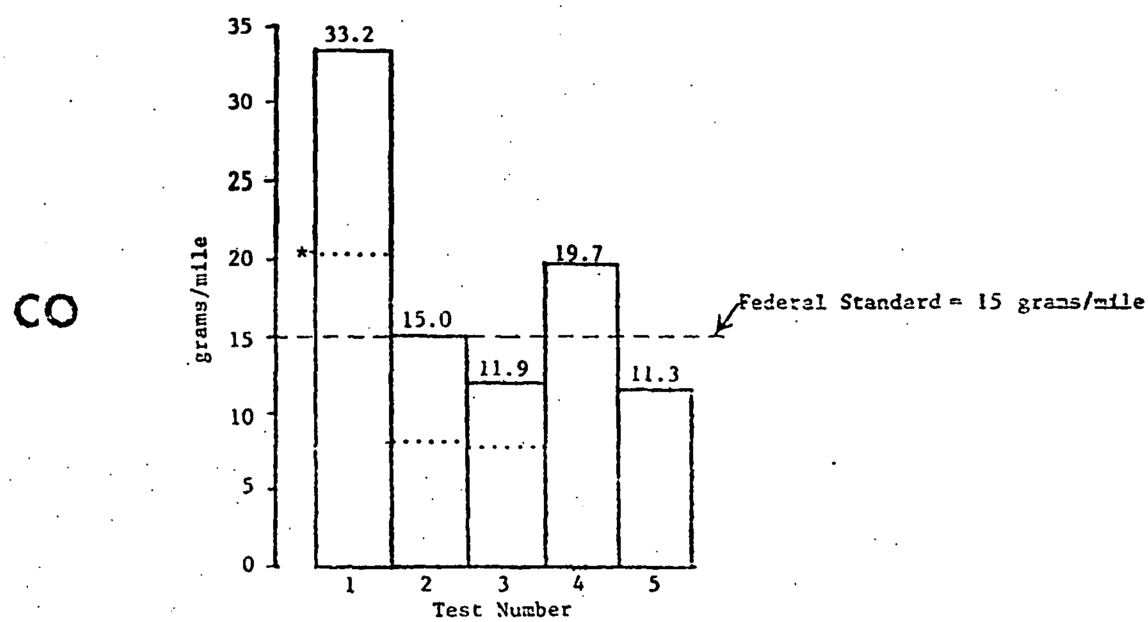


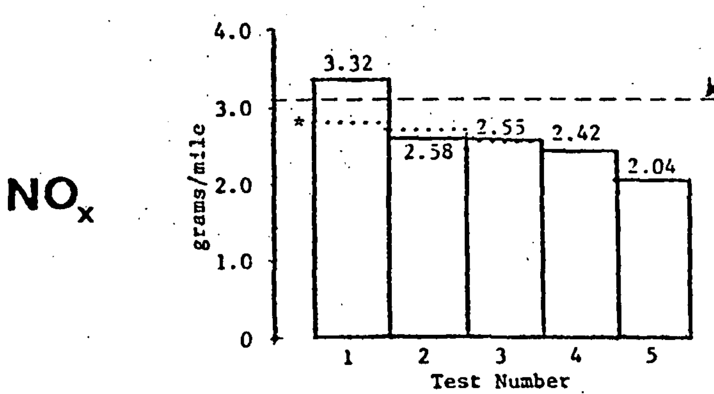
	ORIGINAL TEST	RETEST
Average Odometer (miles) :	2,573	19,826
Dates of Testing :	5/77-8/77	7/78-10/78

Figure 3

Evaluation of Restorative Maintenance and Catalyst Replacement
On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis
Average Mileage:104,479





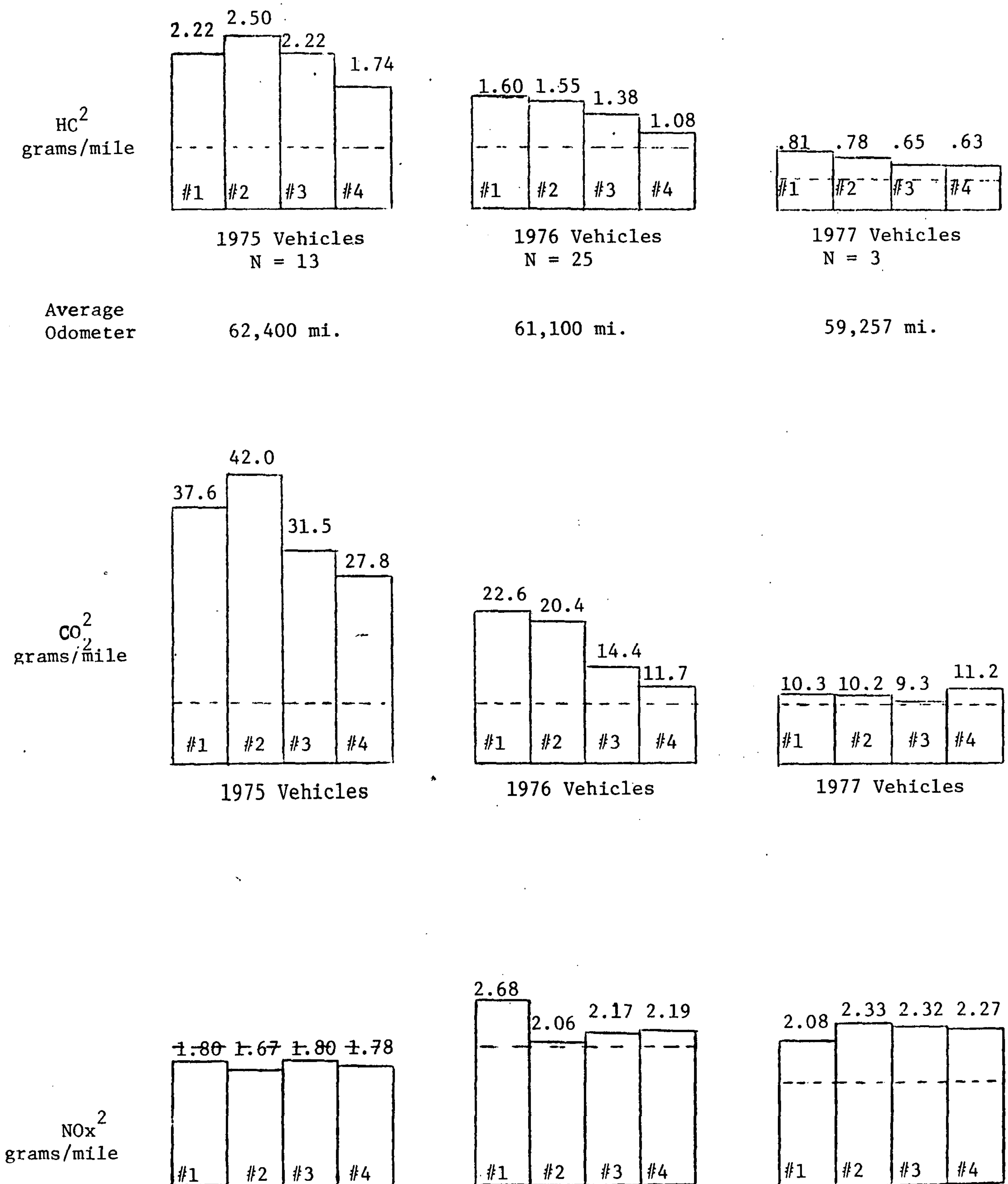


Test #	Action performed prior to test
1	None, tested "as received".
2	All maladjustments and disablements corrected.
3	Major tune-up and the replacement of defective components.
4	Replace catalyst with non-catalytic back pressure duplicator.
5	Install new catalyst.

*Note: Dotted lines represent fleet average emissions of 300 1975 and 1976 Restorative Maintenance Vehicles

Figure 4

Los Angeles - Contract 68-02-2590
41 Oxidation Catalyst Vehicles
Restorative Maintenance[1]



[1] Test sequence #1-#4 are defined as on Figure 1.

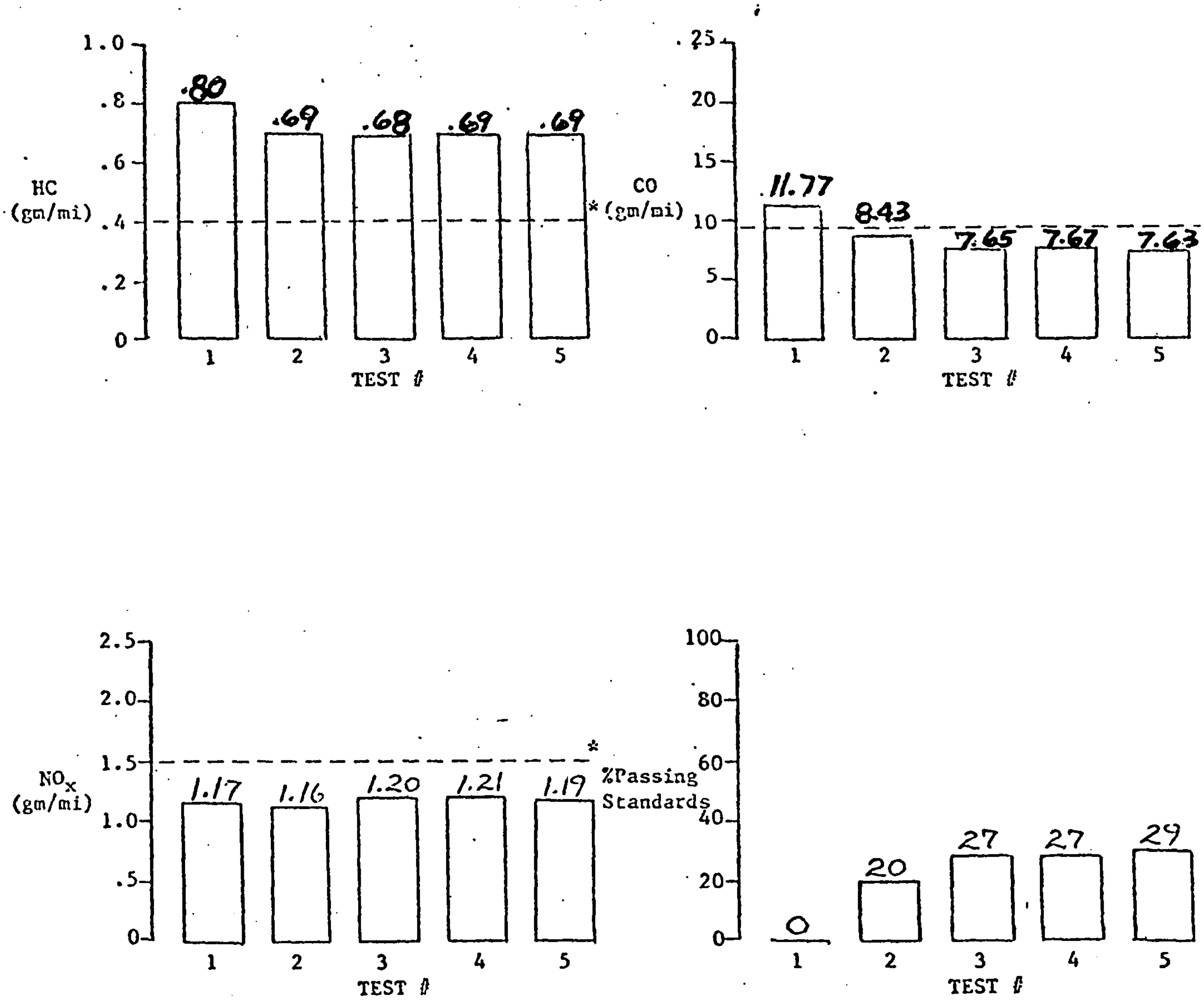
[2] Dotted lines represent California standards .9/9.0/2.0 for 1975-76 and .41/9.0/1.5 for 1977.

Figure 5

Los Angeles Contract 68-03-2774

Restorative Maintenance Evaluation of Passenger Cars

51 1978/79 Model Year Vehicles



Test#	Maintenance performed prior to test
1	As received.
2	Correct any obvious maladjustments or disablements.
3	Correct or replace O_2 sensor.
4	Correct remaining maladjustments and disablements with readjustments as required.
5	Major tune-up and replacement of defective components.

	HC	CO	NOx
* California Standards:	.41	9.0	1.5

Table 1

Restorative Maintenance Retesting of Cars in Detroit
Percent Passing Standards

Model Year	N	Original Test Test Sequence* 1	2	3	4	First Retest Test Sequence* 1	2	3	4	Second Retest Test Sequence* 1	2	3	4
1976	13	54	54	85	92	38	38	62	77	54	62	69	77
1977	6	50	100	100	-	50	67	83	-	-	-	-	-

* See Figures 1, 2 for descriptions of test sequences

Table 2

Restorative Maintenance and Catalyst Replacement
on Eight Very High Mileage 1975 Cars in St. Louis
Percent Passing Standards

Test Sequence*	Percent Passing
1	13
2	38
3	50
4	0
5	63

* See Figure 3 for descriptions of test sequences.

Table 3

Los Angeles Contract 68-03-2590
1975-1979 Oxidation Catalyst Vehicles
Restorative Maintenance

Percent Passing

Model Year	N	Test Sequence[1] 1	2	3	4
1975	13	0	0	0	0
1976	25	0	4	20	28
1977	3	0	0	0	0
1979[2]	1	0	0	100	100

[1] See Figure 1 for a description of test sequences.

[2] This vehicle was not displayed in Figure 1 due to the impracticality of presenting the results of one vehicle.

Table 4

Los Angeles Contract 68-03-2774
51 1978-1979 3-Way Catalyst Vehicles
Restorative Maintenance

Test Sequence*	Percent Passing
1	0
2	20
3	27
4	27
5	29

* See Figure 5 for a description of test sequences.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980- 651-112/0226