

Evaluation of Restorative Maintenance and Catalyst  
Replacement on Exhaust Emissions from Eight Very  
High Mileage Passenger Cars in St. Louis

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by

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## Abstract

This report describes the results of an exhaust emission testing program on eight catalyst-equipped passenger cars in the St. Louis area. Vehicles from each of the three major domestic manufacturers were procured from the general public. The vehicles were sought to obtain a general representation of popular models and engines with the final selection based on odometer reading. The vehicles chosen were from the 1975 model year and averaged 104,479 miles with a range from 71,026 to 138,831. The test sequence included the exhaust emission portion of the 1975 Federal Test Procedure, the Highway Fuel Economy Test and three short cycle tests. This sequence was employed five times over two phases. The first phase consisted of test sequences in (1) as-received condition, (2) after correction of maladjustments and disablements of emission control systems, and (3) after a complete tune-up with replacement of defective parts. The second phase provided for two test sequences; one after the existing catalyst was replaced with a plain section of pipe (with restrictions to duplicate back pressure) and the other after installation of a new OEM catalyst.

The results from the first phase indicate that high mileage vehicles generally exhibit higher HC and CO emission levels than their counterparts with lower mileage which were tested in earlier Restorative Maintenance programs. The results from the second phase appear to indicate a loss in catalyst activity with age and mileage when compared to the activity of a brand new unit.

## Introduction

For the purpose of Federal Regulations which pertain to motor vehicle emissions, "the useful life" of a vehicle has been defined as 5 years or 50,000 miles, whichever occurs first. Prior EPA surveillance studies of passenger cars have demonstrated that even low-mileage, relatively new vehicles exhibit poor average emission performance when compared to applicable standards (Reference 1). These studies went on to determine that maladjustments and disablements within the emission control system (primarily idle mixture) were the primary cause of the problem. Significant reductions in average levels were possible once these actions were corrected.

Recently, there has been an increased interest in the possibilities of Inspection/Maintenance (I/M) Programs on in-use motor vehicles as a major tool in controlling air pollution. When this interest is combined with the fact that many of the first catalyst-equipped vehicles have now exceeded the 50,000 miles of this "useful life", it is clear some assessment of these vehicles must be undertaken to project their impact on air quality.

### Program Design

The purpose of this effort is to gather information on catalyst-equipped passenger cars which have exceeded their defined "useful life". The following areas were to be addressed:

1. Emission performance in as-received condition.
2. Extent of malperformance in the emission control system.
3. Capability of restorative maintenance in reduction of emission levels.
4. Effectiveness of both old and new catalysts on emission levels.

A total of eight catalyst-equipped passenger cars were procured from private owners in the St. Louis area. Vehicles of each of the three major domestic manufacturers were chosen to constitute the test fleet. The actual vehicles were sought to obtain a general representation of popular models and engines with the final selection based on odometer reading.

Each vehicle was subjected to a prescribed series of tests, inspections and maintenance actions. The flow diagram for this effort is attached as Figure 1. The basic test sequence conducted at each point included the current Federal Test Procedure (exhaust emissions only), the Highway Fuel Economy Test and three short cycles (Federal Short Cycle, Two-Speed Idle and Federal Three-Mode). The initial test was performed in as-received condition. This was followed by an underhood inspection and a correction of all maladjustments and disablements. A second test was performed with the vehicle in this condition. The third test was preceded by a major tune-up and replacement of any defective parts. This phase of the program would serve to address the first three aspects of the listed purposes. The last aspect would be addressed by the elements in the second phase.

The fourth test on each vehicle was performed to obtain "engine-out" emissions. The original catalyst was replaced with a section of plain pipe after measurements of exhaust back pressure had been recorded under a range of steady state conditions. The back pressure was duplicated as nearly as possible by introduction of a device which was tailored to restrict exhaust flow at the tailpipe. For the fifth and final test, a new OEM catalyst was installed. The original catalysts were retained and are being thoroughly examined and analyzed under a separate effort.

### Inspection Results

After the first "as-received" test sequence, each vehicle received a thorough inspection for maladjustments, disablements and defective

emission control components. As in earlier Restorative Maintenance programs, the most common disablement was broken or missing limiter caps. Only one vehicle had its limiter caps present and unbroken. This vehicle was also the only vehicle to pass Federal Standards "as-received". The second most common disablement was plugged or disconnected EGR vacuum lines. This disablement was found on three vehicles. Rich idle mixture on half of the test vehicles accounted for the most common maladjustment which may be slightly lower than expected considering that all but one vehicle had missing or broken limiter caps. Two of the test vehicles had defective vacuum breaks (leaky diaphragms). There were many other defective parts found and replaced, but no single part was prevalent in frequency of failure. The majority of these parts would not have had an adverse affect on driveability and consequently would not have likely been repaired by the vehicle owner.

#### Phase I Test Results

The results of the first phase of testing show the improvement in emission performance that has been witnessed in past Restorative Maintenance programs. Through correction of maladjustments and disablements, all three regulated emissions were reduced. Average HC emissions were reduced 32%, average CO emissions were reduced 55% and the average NOx emissions were reduced 22%. As has been the case in past programs, idle mixture adjustments were found to have the greatest impact in reducing emissions. This can also be seen in the improvement of idle CO which decreased from an average of 2.02% to .06%. Although the major tune-up performed prior to Test #3 reduced the average CO 21% from Test #2 on the FTP, the average HC increased slightly (9%). NOx remained essentially the same. Through Test 1, 2 and 3, the percent of vehicles meeting Federal Standards was 13%, 38% and 50%, respectively. These percentages are displayed graphically in Figures 2 and 3.

#### Phase II Test Results

Preparation for Test #4 consisted of removing the catalyst and replacing it with a plain section of pipe. Before removing the catalyst, the backpressure created in the exhaust systems of the test vehicles by the catalyst was measured by a water manometer at a point just before the inlet of the catalytic converter. These measurements were taken at idle through 60 miles per hour in 10 mile per hour increments. After recording these measurements, the catalytic converter was removed and the plain section of pipe was installed in its place. An adjustable orifice was then introduced into the exhaust system at a point near the end of the tailpipe. The backpressure was then measured at the same point in the system as it was earlier. The aperture of the back-pressure duplicator was varied until the pressure matched the earlier measurement (plus or minus 2 inches of water). As expected, the average HC and CO emissions increased from the averages shown in Test #3. HC showed the most dramatic increase (87%) over Test #3, and was considerably greater (36%)

than the "as received" emission values. The average CO emissions were only 59% of the "as received" values but were 66% greater than the Test #3 average values. NOx displayed a decrease of 5% from Test #3. Under the Test #4 conditions, none of the vehicles were able to meet Federal Standards. Test #5 consisted of removing the backpressure duplicator and the plain pipe section and replacing it with a new catalyst. Test #5's average emission results were lower than any of the previous tests for all three regulated pollutants. The average HC emissions in Test #5 were 27% of those recorded in Test #4 and 37% of the "as received" values. Average CO was 57% of the Test #4 value and 34% of the "as received" average CO emissions. The average NOx emissions were 84% of Test #4 values and 61% of the "as received" values. The new catalyst obviously had a significant impact on reducing emission levels. This completed the vehicle testing sequence. No subsequent tests were performed on these vehicles once the new catalysts had accrued some mileage.

#### Conclusions

The results show that these high-mileage vehicles had significantly higher average emissions "as-received" than similar vehicles with lower mileage tested in an earlier Restorative Maintenance program. In this condition, only one of the eight vehicles was able to meet Federal Standards. However after the correction of maladjustments and disablements along with a major tune-up and replacement of defective components, HC and CO levels were reduced and half of the test vehicles were able to meet Federal Standards. The test after removal of the original catalyst showed evidence of its activity because of the emission increases witnessed. The installation of a new catalyst showed that although the old catalyst was still working, it was not up to the efficiency of the new one. But even with new catalysts installed, only 63% of the vehicles meet Federal Standards. This indicates that even though an individual high-mileage vehicle is tuned-up and a new catalyst is installed, it may not meet the standards under which it was certified. On the other hand, the average results for the fleet display some durability of emission control systems and the ability of such vehicles to respond favorably to proper maintenance.

References

1. J. T. White, "An Evaluation of Restorative Maintenance on Exhaust Emissions from In-Use Automobiles", SAE Paper 780082, March 1978.

Figure 1

Evaluation of Restorative Maintenance and Catalyst Replacement  
On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
Flow Diagram

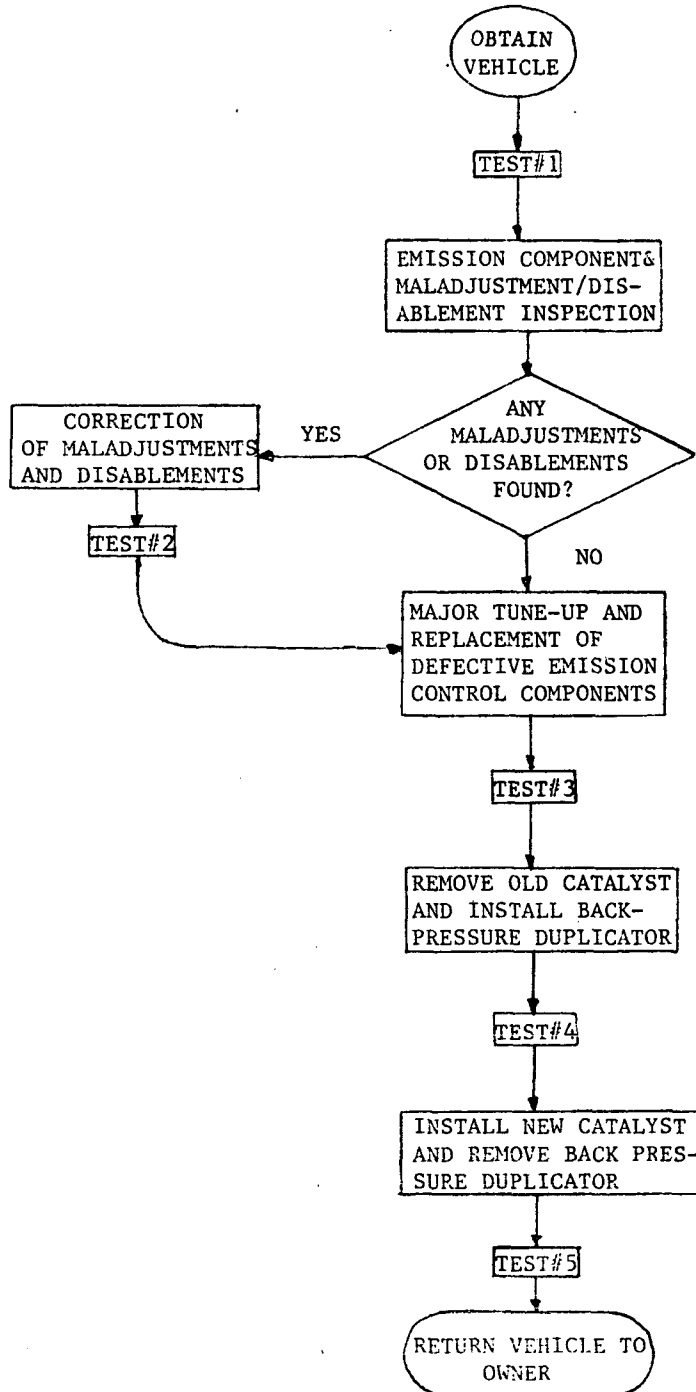
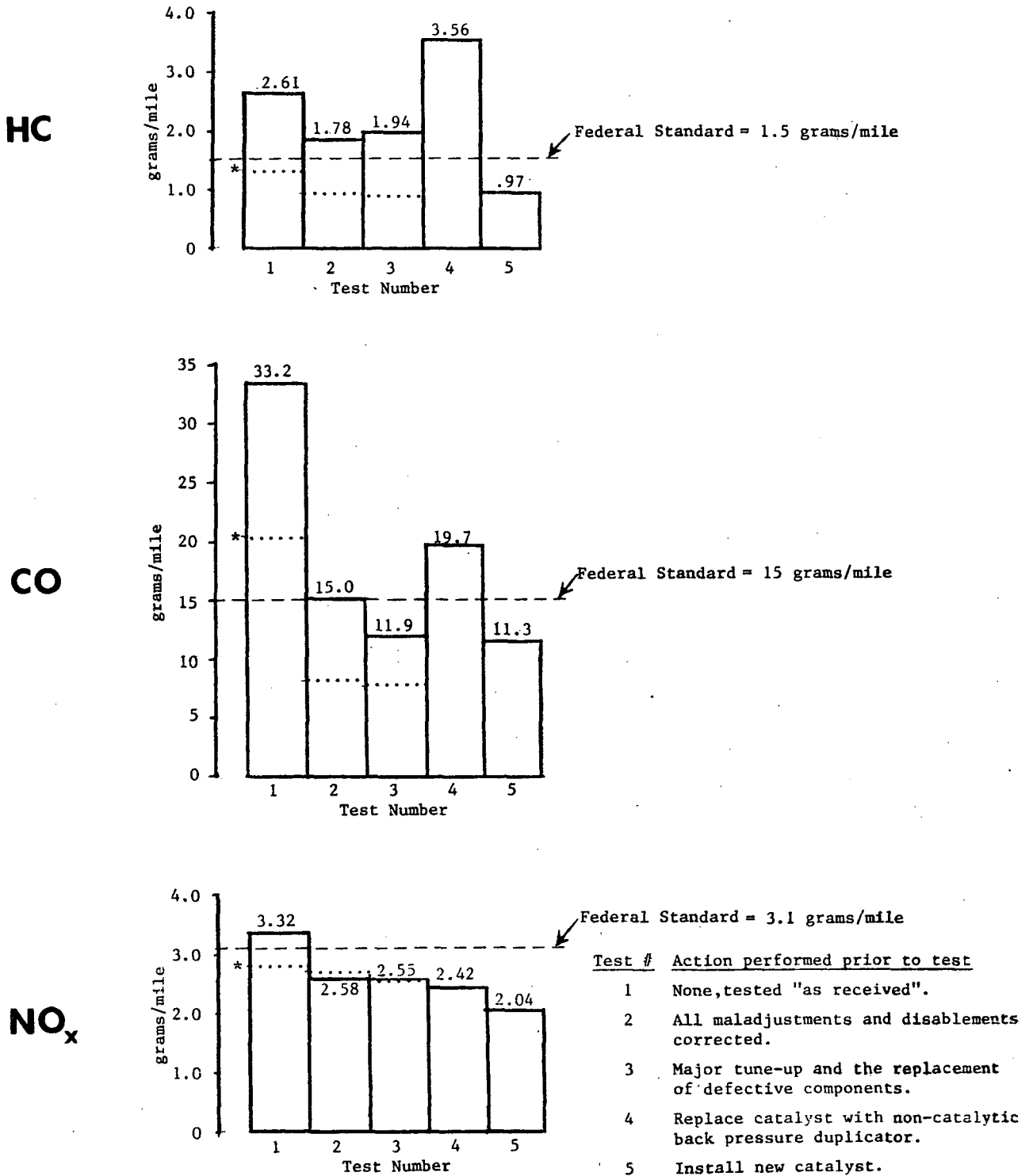


Figure 2

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

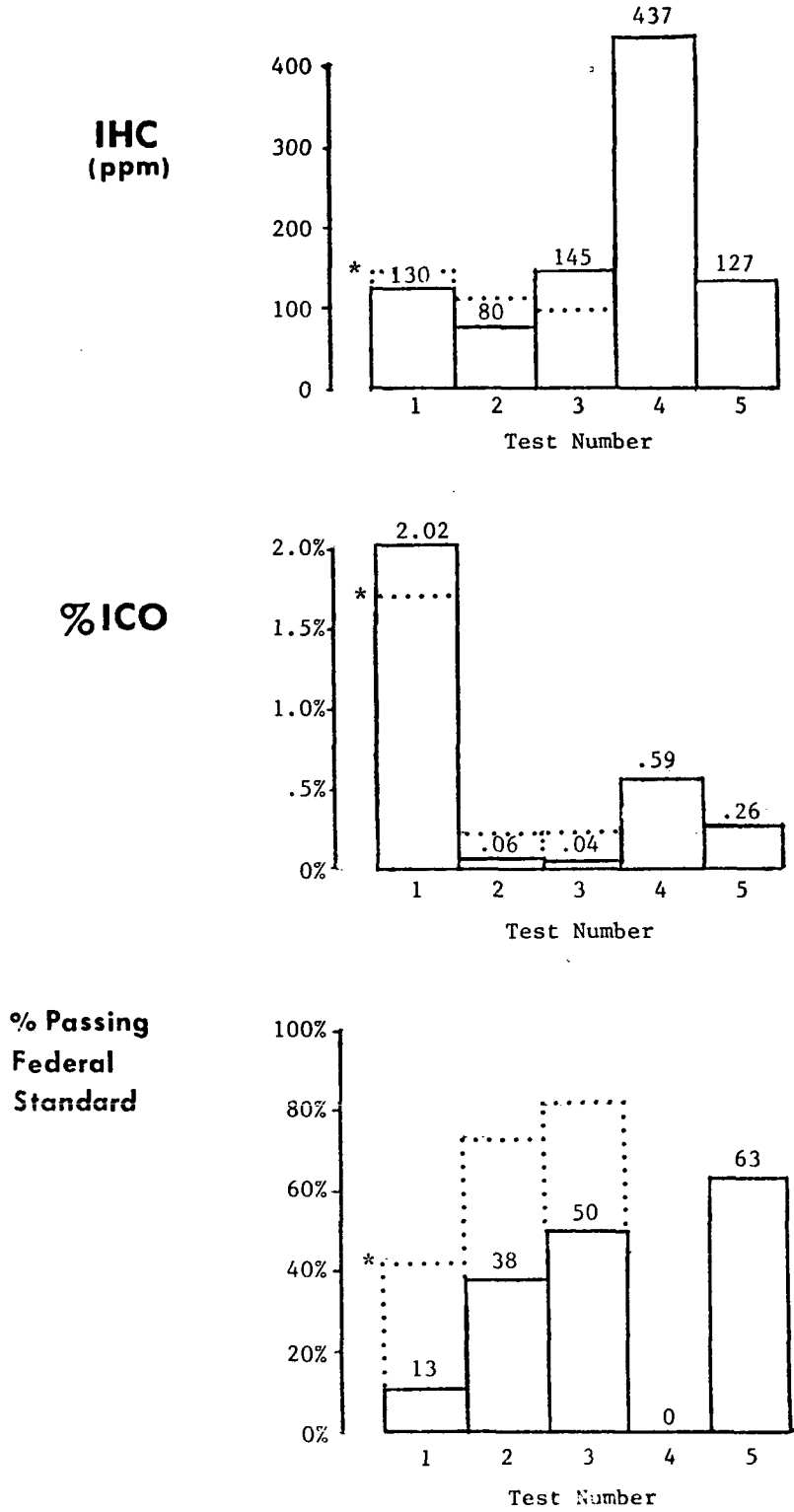


\*Note: Dotted lines represent fleet average emissions of 300 1975 and 1976 Restorative Maintenance Vehicles tested in a earlier program (Reference 1).



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



\*Note: Dotted lines represent fleet average emissions of 300 1975 and 1976 Restorative Maintenance Vehicles tested in a earlier program (Reference 1).

Evaluation of Restorative Maintenance and Catalyst Replacement  
On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
-Vehicle Test Results-

Veh. # 511 Odometer 138,831 Make Plym. Model Duster CID 225 Carb 1V Trans A RLHp 11.2 Inertia 3500

Test#	Date	FTP (gm/mi)			MPG		IHC (ppm)	ICO (%)	Comments
		HC	CO	NO <sub>x</sub>	FTP	HFET			
1	10-10-78	3.22	45.3	2.77	17.82	26.99	110	4.43	CAPS MISSING IDLE STOP SOLENOID DEFECTIVE
2	10-12	1.74	11.8	3.17	18.34	26.16	29	.01	ADJUST IDLE MIXTURE
3	10-15	3.00	22.9	2.54	17.11	24.99	557	.21	MAJOR TUNE UP IDLE STOP SOLENOID REPLACED
4	10-18	3.15	29.8	2.10	18.24	26.66	640	1.67	CATALYST REPLACED WITH BY-PASS.
5	10-20	1.65	20.1	1.34	17.49	25.94	661	.98	NEW CATALYST INSTALLED

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 by-pass.
- 5 Install new catalyst.

1975/76 Federal Standards:  $\frac{\text{HC}}{1.5}$   $\frac{\text{CO}}{15}$   $\frac{\text{NO}_x}{3.1}$   
(grams/mile)

Evaluation of Restorative Maintenance and Catalyst Replacement  
 On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
 -Vehicle Test Results-

Veh.# 512 Odometer 75064 Make Dodge Model Charger CID 360 Carb 2v Trans A RLHp 12.7 Inertia 4500

Test#	Date	FTP (gm/mi)			MPG		IHC (ppm)	ICO (%)	Comments
		HC	CO	NO <sub>x</sub>	FTP	HFET			
1	10-9-78	4.36	77.7	3.29	13.47	21.16	270	3.83	CAPS MISSING, EGR VACUUM LINE DISC, TIMING -3, AIR CLEANER TOP FLIPPED
2	10-12	2.94	19.0	4.11	13.33	20.63	85	.06	IDLE MIXTURE ADJUSTED, EGR VACUUM LINE CONNECTED, TIMING ADJUSTED, AIR CLEANER TOP CORRECTED.
3	10-13	3.75	16.6	2.08	11.05	18.08	126	.02	MAJOR TUNE UP
4	10-18	8.97	16.8	1.79	12.01	19.46	934	.20	CATALYST REPLACED WITH BY-PASS.
5	10-20	.93	21.8	.67	11.17	17.69	47	.98	NEW CATALYST INSTALLED

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 by-pass.
- 5 Install new catalyst.

1975/76 Federal Standards:  $\frac{HC}{1.5}$   $\frac{CO}{15}$   $\frac{NO_x}{3.1}$   
 (grams/mile)

Evaluation of Restorative Maintenance and Catalyst Replacement  
On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
-Vehicle Test Results-

Veh. # 513 Odometer 71026 Make Plym Model Sta. Wag. CID 318 Carb 2v Trans A RLHp 14.7 Inertia 5000

Test #	Date	FTP (gm/mi)			MPG		IHC (ppm)	ICO (%)	Comments
		HC	CO	NO <sub>x</sub>	FTP	HFET			
1	10-12-78	.65	5.3	7.36	13.16	19.00	67	.04	CAPS MISSING, OSAC VALVE BYPASSED, "BB" IN EGR VALUUM LINE, TIC DEFECTIVE
2	10-14	1.12	26.5	1.75	11.08	15.50	35	.02	OSAC CONNECTED, "BB" REMOVED FROM EGR VALUUM LINE
3	10-17	.74	4.6	2.12	11.46	15.21	31	.02	MAJOR TUNE UP, REPLACED TIC.
4	10-19	1.68	28.5	1.78	11.67	16.10	126	1.55	CATALYST REPLACED WITH BY PASSED
5	10-20	.62	14.4	1.34	11.69	15.99	22	.02	NEW CATALYST INSTALLED

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 by-pass.
- 5 Install new catalyst.

1975/76 Federal Standards:  $\frac{HC}{1.5}$   $\frac{CO}{15}$   $\frac{NO_x}{3.1}$   
(grams/mile)

Evaluation of Restorative Maintenance and Catalyst Replacement  
 On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
 -Vehicle Test Results-

Veh.# 524 Odometer 103,977 Make Merc Model Monarch CID 250 Carb 1v Trans M-3 RLHp 12.0 Inertia 4000

Test#	Date	FTP (gm/mi)			MPG		IHC (ppm)	ICO (%)	Comments
		HC	CO	NO <sub>x</sub>	FTP	HFET			
1	9-28-78	1.90	6.8	2.55	18.13	24.76	39	.01	CAPS PRESENT CHOKE 4NL
2	9-29	1.15	8.5	2.55	16.95	24.16	42	.02	CHOKE ADJUSTED
3	10-2	1.52	8.0	2.68	17.79	23.77	32	.01	MAJOR TUNE UP
4	10-5	2.09	20.7	2.41	18.17	24.82	48	.47	CATALYST REPLACED WITH BY-PASS
5	10-11	.60	4.8	2.81	17.73	24.46	24	.01	NEW CATALYST INSTALLED

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 by-pass.
- 5 Install new catalyst.

1975/76 Federal Standards:  $\frac{\text{HC}}{1.5}$   $\frac{\text{CO}}{15}$   $\frac{\text{NO}_x}{3.1}$   
 (grams/mile)

Evaluation of Restorative Maintenance and Catalyst Replacement  
 On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
 -Vehicle Test Results-

Veh. # 526 Odometer 111,512 Make Ford Model LTD CID 351 Carb 2v Trans A RLHp 14.7 Inertia 5000

Test#	Date	FTP (gm/mi)			MPG		IHC (ppm)	ICO (%)	Comments
		HC	CO	NO <sub>x</sub>	FTP	HFET			
1	9-30-78	3.25	20.1	5.65	10.91	16.59	75	.37	CAPS MISSING, EGR PLUGGED, AIR PVS DEFECT. DELAY VL. DEFECT H.A.D. SENSOR DEFECTIVE (WILL NOT ALLOW VACUUM THROUGH)
2	10-2	3.27	23.4	3.71	11.03	15.24	64	.36	PLUG REMOVED FROM EGR VACUUM LINE.
3	10-7	2.04	11.0	6.38	11.63	16.86	136	.05	MAJOR TUNE UP, REPLACED: HAD SENSOR, DELAY VALVE, AND AIR PVS.
4	10-10	2.84	10.3	6.76	11.73	16.51	211	.08	CATALYST REPLACED WITH BY-PASS
5	10-11	2.05	8.0	6.21	11.64	17.18	209	.03	NEW CATALYST INSTALLED

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 by-pass.
- 5 Install new catalyst.

1975/76 Federal Standards:  $\frac{HC}{1.5}$   $\frac{CO}{15}$   $\frac{NO_x}{3.1}$   
 (grams/mile)

Evaluation of Restorative Maintenance and Catalyst Replacement  
On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
-Vehicle Test Results-

Veh. # 537 Odometer 89,691 Make Chev. Model Nova CID 250 Carb 1v Trans A RLHp 11.2 Inertia 3500

Test#	Date	FTP (gm/mi)			MPG		IHC (ppm)	ICO (%)	Comments
		HC	CO	NO <sub>x</sub>	FTP	HFET			
1	10-23-78	2.01	30.8	1.42	16.51	23.31	176	2.52	CAPS MISSING, EGR VACUUM LINE SPLIT, PRIMARY VACUUM BREAK LEAKY
2	10-24	.83	8.1	1.26	18.04	22.94	77	.01	IDLE MIXTURE ADJUSTED
3	10-26	1.14	7.5	1.17	17.67	21.74	84	.01	MAJOR TUNE UP, REPLACED EGR VACUUM LINE REPLACED PRIMARY VACUUM BREAK
4	10-28	3.35	9.1	1.25	18.56	22.04	849	.18	CATALYST REPLACED WITH BY PASS
5	10-30	.64	5.6	1.08	18.41	22.23	19	.01	NEW CATALYST INSTALLED

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 by-pass.
- 5 Install new catalyst.

1975/76 Federal Standards:  $\frac{HC}{1.5}$   $\frac{CO}{15}$   $\frac{NO_x}{3.1}$   
(grams/mile)

Evaluation of Restorative Maintenance and Catalyst Replacement  
On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
-Vehicle Test Results-

Veh. # 538 Odometer 107979 Make Chev Model Malibu CID 350 Carb 2v Trans A RLHp 14.0 Inertia 4500

Test#	Date	FTP (gm/mi)			MPG		IHC (ppm)	ICO (%)	Comments
		HC	CO	NO <sub>x</sub>	FTP	HFET			
1	10-24-78	4.28	70.6	1.83	13.00	19.83	239	5.03	CAPS MISSING, PCV HOSE COLLAPSED, EGR DIAPHRAGM LEAKY, VACUUM BREAK DIAPHRAGM LEAKY
2	10-25	1.99	13.7	2.33	14.09	20.41	243	.02	IDLE MIXTURE ADJUSTED
3	10-30	1.90	12.9	1.52	13.05	18.89	152	.01	MAJOR TUNE UP REPLACED: EGR VALVE, VACUUM BREAK, PCV HOSE,
4	11-1	4.07	21.0	1.42	12.66	18.15	485	.18	CATALYST REPLACED WITH BYPASS
5	11-3	.69	7.4	1.37	12.36	16.39	16	.04	NEW CATALYST INSTALLED

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 by-pass.
- 5 Install new catalyst.

1975/76 Federal Standards:  $\frac{HC}{1.5}$   $\frac{CO}{15}$   $\frac{NO_x}{3.1}$   
(grams/mile)



Evaluation of Restorative Maintenance and Catalyst Replacement  
On Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis  
-Vehicle Test Results-

Veh. # 539 Odometer 137,751 Make BUICK Model Star Wag CID 350 Carb 4V Trans A RLHp 14.0 Inertia 4500

Test #	Date	FTP (gm/mi)			MPG		IHC (ppm)	ICO (%)	Comments
		HC	CO	NO <sub>x</sub>	FTP	HFET			
1	10-24-78	1.20	9.1	1.72	11.01	15.87	67	0.0	CAPS PRESENT, VACUUM BREAK DIAPHRAGM LEAKY, EFE VACUUM LINE CRACKED, INDUCTION AIR TUBE TORN
									NO MALADJUSTMENTS OR DISABLEMENTS
3	10-26	1.41	11.9	1.87	12.53	18.37	45	.01	MAJOR TUNE UP REPLACED: VACUUM BREAK, EFE VACUUM LINE, INDUCTION AIR TUBE
4	10-27	2.31	21.6	1.86	11.89	17.39	200	.43	CATALYST REPLACED WITH BY-PASS
5	10-29	.59	8.4	1.49	11.88	16.69	19	.01	NEW CATALYST INSTALLED

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 by-pass.
- 5 Install new catalyst.

1975/76 Federal Standards:  $\frac{HC}{1.5}$   $\frac{CO}{15}$   $\frac{NO_x}{3.1}$   
(grams/mile)