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Effectiveness of the General Motors' Retrofit Device on a Fleet of Twenty-five 1962-1964 Passenger Vehicles

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Purpose of Test Program

With increasing local and national concern about emissions from pre-1968, uncontrolled, passenger vehicles, the Air Pollution Control Office under took a project to evaluate the emission reduction effectiveness of a commercially available retrofit control device. It was desired to compare the emissions of vehicles as they exist on the road to the emissions resulting with a retrofit device installed, with a normal tuneup, and with both the tuneup and retrofit device. With data compiled in this manner it was hoped that a statistical evaluation would lead to a prediction of the impact on mass emissions of legislation in a given community, locale, or state once its vehicle population was determined.

The test program was initiated in February 1971 at the Federal Laboratory in Los Angeles, California. Lab personnel were supplied under contract by the California Air Resources Board. This report will evaluate the test data compiled for the first 25 vehicles. It is planned to collect data on 85 additional automobiles in the remaining phase of testing. While this report will indicate trends in the testing to date it will not be able to answer the statistical question mentioned previously. It will, however, indicate some reasonable expectations of the emission reduction effectiveness of tuneups and installation of retrofit devices.

Device Evaluated

The General Motors' retrofit device was employed in the testing of all the cars. "The control consists of increased idle speed, leaner idle mixture, and retarded ignition timing. A thermostatic vacuum switch provides engine cooling protection with the retarded ignition."[1]

The control system requires increasing idle speed to 600 rpm in drive for cars with automatic transmissions and 700 rpm for cars with manual transmissions. Idle mixture is set at a lean level of 14:1 air/fuel ratio. This is equivalent to about 1.5 percent idle carbon monoxide and can be set either with an exhaust gas analyzer or by a speed drop method allowing a 40 rpm drop for two and four barrel carburetion, and 20 rpm drop for one barrel carburetion. The specific manufacturer's ignition timing is set and the vacuum advance is made inoperative during normal operation. Full vacuum

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[1] SAE paper, "Exhaust Emission Control for Used Cars", G. W. Niepoth, G. P. Ransom, J. H. Currie, presented at International Automotive Engineering Congress, January 11-15, 1971.

is restored when engine coolant temperatures exceed 205°F through the use of a thermostatic vacuum switch.

There are five kits available; all are the same in function but differ in hose sizes or lack the thermostatic vacuum switch in the case of air cooled engine applications. The kit seems to fit all domestic passenger vehicles manufactured from 1955 to 1967 with the exception of the relatively limited population of those engines which utilize a distributor without centrifugal advance.

The kit is sold at a retail price of about $10.00; the air cooled engine model is somewhat less expensive. Installation time for one mechanic is less than an hour. In commercial use it would appear that the installed cost to the customer would be less than $20.00. It is anticipated that no maintenance of the installation would be necessary, although periodic checking of idle speed and mixture might be recommended.

A comprehensive tuneup was performed on each vehicle. This tuneup includes the replacement of spark plugs, points, condenser, rotor, distributor cap, ignition wires and air filter. Miscellaneous minor replacements are also allowed if necessary. The car is set to manufacturer's specifications. Idle mixture on the first 25 vehicles was set at the lean level mentioned previously. Subsequent setting will be to best manifold vacuum at idle. The parts' cost for this tune-up is about $25.00 while a mechanics labor charge is in the vicinity of $15.00. Thus the tuneup cost to the customer is about twice the cost of the retrofit system.

Vehicles Tested

Passenger vehicles were supplied to the Federal Laboratory by Olson Laboratories, Inc. The first 25 cars were all 1962 to 1964 models with automatic transmissions. A list of vehicles and their mechanical characteristics appears in Table I of this report. These cars are all normally operated passenger vehicles. They were not acquired from fleets or used car lots. Cars were rejected that appeared to suffer from gross mechanical defects which would jeopardize their probability of completing the testing sequence. It was further required that leak-free exhaust systems be present or installed to insure the validity of emission test results.

The 25 cars tested consisted of fifteen 1964 models, eight 1963 models and two 1962 models. Thirteen were General Motors' cars, six Fords, four Chryslers, and two American Motors. Twenty of the vehicles had eight cylinder engines

while five were six cylinder models. Cubic inch displacement ranged from 194 CID to 425 CID. Carburetion included one, two, and four barrel carburetors. The average mileage of the first 25 vehicles as they arrived at the laboratory for testing was about 68,000 miles according to the vehicles' odometers. Mileage ranged from a low of 39,000 miles to a high of 122,600 miles. Vehicle inertia weight ranged from 3000 to 5000 pounds.

Test Procedure

When a test vehicle was received in the laboratory the exhaust system was inspected for tightness and vehicle characteristics noted. No adjustments to the engine were allowed at this time. The vehicle was then tested according to the 1972 Federal emission test procedure as described in the November 10, 1970, Federal Register. After the "as received" testing was completed, a visual inspection was conducted. This included checking belts, hoses, wires, exhaust systems, and air intake systems for good condition. A pre-tuneup inspection was then conducted to determine the mechanical condition of the engine. This inspection included checking of ignition system, air/fuel ratios and manifold vacuum at various engine speeds and conditions. The GM retrofit kit was then installed. A second 1972 FTP was then performed. After the "as received with retrofit" testing was completed the retrofit kit was de-activated and the vehicle tuned to manufacturer's specifications as previously described. After a "tuned" 1972 FTP the retrofit kit was re-activated with necessary idle and mixture settings being made and a "tuned with retrofit" 1972 FTP was performed. Thus each car was tested in four different configurations.

a) Emission tests

The constant volume sampling technique was employed to obtain bag samples during the emission driving cycle, LA 4-S4. These samples were analyzed by non-dispersive infrared equipment for carbon monoxide, carbon dioxide, and nitric oxide. Hydrocarbons were measured by a flame ionization detector. Saltzman analysis of oxides of nitrogen were made on cars number 16 through 25. It is felt that the data obtained on oxides of nitrogen is questionable as NDIR analysis can measure nitric oxide concentrations only thus missing any conversion of nitric oxide to nitrogen dioxide which occurs prior to bag analysis. The modification of the Saltzman technique employed for these tests was questionable and the data should not be relied on. This analysis has been improved in further testing.

b) Fuel consumption

The quantity of fuel used during the driving cycle was measured in each test configuration. Indolene 30, the specified test fuel, was contained in portable tanks. The tanks were weighed immediately prior to and after the 1972 FTP was completed. The difference was recorded as a measure of the fuel consumption.

c) Vacuum advance monitoring

Since retarding ignition timing could cause engine overheating thus re-establishing vacuum advance, vacuum was monitored during the 1972 FTP. It was noted whether or not the thermostatic switch controlling vacuum advance was activated during "as received with retrofit" and "tuned with retrofit" testing.

d) Performance evaluation

After completion of each 1972 FTP the test driver took the car on a short drive in the vicinity of the laboratory. He made a subjective evaluation of the performance of the vehicle in each test configuration. Because of the necessity of stringent scheduling requirements and the lack of quantitative data in this testing, performance evaluations will not be conducted in the phase II testing of 85 vehicles.

Emission Test Results

Complete emission data for each vehicle in each configuration appears in appendices 1, 2, 3, and 4. Table II summarizes this emission data. Hydrocarbon emissions are reduced by 28 percent with "retrofit", 23 percent with "tuneup", and 31 percent with "tuneup with retrofit". Carbon monoxide emissions are similarly reduced 21 percent, 24 percent and 21 percent respectively. NDIR-NO data indicated 4 percent, 2 percent and 16 percent reductions. Saltzman analysis resulted in 19 percent, 5 percent, and 21 percent reductions in oxides of nitrogen. Also in appendices 5, 6, and 7 the percent reductions over baseline or "as received" for each individual vehicle is tabulated. It should be noted that the oxides of nitrogen data is presented to indicate possible trends only. None of the data, Saltzman or NDIR-NO, should be reviewed as absolute--the techniques employed in each is questionable. Figures 1 to 3 show the relative mass emissions

of each car in each configuration. Figures 4 and 5 show the approximate hydrocarbon and carbon monoxide emission distributions as well as the arithmetic means for each configuration. As is expected the "as received" configuration shows the broadest distribution band for each pollutant. The other three configurations are quite similar and more test points would be needed to accurately differentiate their distributions. No distribution of oxides of nitrogen is presented as conversion of NO to NO_2 in the sample bag causes a varying and potentially misleading distribution.

Figures 6, 7, 8 and 9 show the average mass emissions and the average percent reduction over "as received" of each configuration for hydrocarbon, carbon monoxide, carbon dioxide, and oxides of nitrogen. Also the increased effectiveness of the retrofit kit with a tuneup is depicted. Again these figures indicate the small difference obtained in the last three configurations when compared to the "as received" vehicle.

It is of interest to note that 14 of the "as received" vehicles met the 1972 hydrocarbon standard of 3.4 grams per mile, 22 of "as received with retrofit", 20 of the "tuned" vehicles and 22 of the "tuned with retrofit" also met the hydrocarbon standard.

The 1972 carbon monoxide standard of 39 grams per mile was met by none of the "as received" cars, one of the "as received with retrofit", four of the "tuned", and three of the "tuned with retrofit". One car in the "as received with retrofit" configuration met both the 1972 hydrocarbon and carbon monoxide standard. This was car number 23, a 1962 Rambler American with a six cylinder engine. The emissions from this car were 1.9 grams per mile (gpm) hydrocarbon and 28.2 gpm carbon monoxide. In the "tuned" configuration cars number 3, 11, 21 and 23 surpassed the standard. These cars were respectively a 1964 Oldsmobile, a 1963 Dodge Dart, a 1963 Oldsmobile, and again the 1962 Rambler mentioned previously. Cars number 3, 14, and 23 met the standards in the "tuned with retrofit" configuration, car number 14 being a 1964 Ford Fairlane. For the actual emission values of all of the cars reference is made to Appendix 1 to 4.

It is of interest to note the ranges of hydrocarbon and carbon monoxide emissions and percent reductions obtained. Again NO_x data is ignored as results are not significant enough to warrant evaluation. "As received" hydrocarbon emissions varied from a low of 1.15 gpm to a high of 6.06 gpm. Carbon monoxide similarly varied from 52.68 gpm to 231.89 gpm. "As received with retrofit" hydrocarbons varied from 0.94 gpm to 4.39 gpm. Carbon monoxide varied from

28.17 gpm to 213.16 gpm. "Tuned" hydrocarbon emissions varied from 0.97 to 4.30 gpm; carbon monoxide from 34.28 to 219.13 gpm. Finally the "tuned with retrofit" configuration resulted in hydrocarbon emissions varying from 0.93 gpm to 4.49 gpm and carbon monoxide emissions from 34.42 gpm to 215.72 gpm.

Percent effectiveness of "as received with retrofit" as compared to "as received" showed from a 5 percent increase to 63 percent decrease in hydrocarbons and from a 13 percent increase to a 60 percent decrease in carbon monoxide. Hydrocarbon and carbon monoxide reductions for the "tuned" configuration were from 34 percent increase to 50 percent decrease and 6 percent increase to 64 percent decrease respectively. For the "tuned with retrofit" configuration as compared to "as received" hydrocarbon reductions varied from 6 percent increase to 61 percent decrease and for carbon monoxide from a 23 percent increase to a 56 percent decrease. This definitively shows that there is a certain small yet significant proportion which responds unfavorably with respect to emissions from the installation of the retrofit kit.

It was desired to get an idea of the test repeatibility for statistical purposes. Two vehicles, car numbers 17 and 20, were arbitrarily selected for this purpose. Since there is great difficulty in predicting the repeatibility of a given vehicle without extensive effort this type of variation is ignored. However, a preliminary idea of variability inherent in the test procedure can be made from back-to-back testing of a well-repeating vehicle. For this reason it was decided to conduct repeatibility in the "tuned" configuration, thus minimizing the vehicular variability. Table III compares the actual mass emission value for the two vehicles used for the back-to-back testing. It was not expected that NO_x emissions in this phase of the testing would repeat closely because of the inadequacies of the testing procedure previously noted in the report. Carbon dioxide and hydrocarbon emissions repeat well within the $\pm$ 10 percent expected in this type of analysis. While one carbon monoxide data set repeated quite well, the 20 percent variation of the other set is disturbing. More repeatibility testing in the phase II, 85 vehicle, portion of the program will be necessary to dispel the necessary reservation created by this unseemingly large variation.

Fuel Consumption Results

Fuel consumption in each configuration was measured by weighing the quantity of fuel used during the 1972 FTP. Complete data for each configuration of each vehicle is presented in Appendix 8. Table IV shows that the average fuel consumption for the "as received" vehicles for the 7.5 mile driving cycle was 1.783 kilogram. In the "as received with retrofit" test 1.807 kg. was consumed. The best economy was displayed in the "tuned" configuration in which an average of 1.770 kg. of Indolene 30 was consumed. The last phase, "tuned with retrofit", had the highest average fuel consumption rate of 1.868 kg. per test. Thus a 1 percent penalty for just installation of retrofit kit, and a 5 percent penalty over baseline, "as received", for the "tuneup with retrofit" configuration. "Tuneup" alone resulted in an average fuel saving of 1 percent over the "as received" vehicle.

Again it is useful to consider the test variability or repeatibility involved in this analysis. Back-to-back testing was conducted as described under "Emission Results". The percent differences indicated were 1 percent and 8 percent on car numbers 17 and 20 respectively.

Vacuum Advance Monitoring

It was desired to determine what proportion of the vehicles tested had a tendency to overheat (coolant temperatures exceeding 205°F), thus restoring full vacuum advance. Two vehicles demonstrated short duration vacuum advance operation in the "as received with retrofit" configuration. Two vehicles had long duration vacuum advance operation in the "tuned with retrofit" configuration while two others had vacuum advance restored for a short period.

Performance Evaluation

One of the anticipated penalties of the installation of a GM type of retrofit device is the possible introduction of adverse driveability effects. In the subjective evaluation of the 25 vehicles tested it was reported that three vehicles performed worse in the "as received" configuration. One car was reported to suffer from the tuneup. Three cars were worse in the "tuned with retrofit" configuration than in the "as received" configuration. One car's driveability improved with installation of the retrofit kit and remained in this improved condition for the remaining evaluations. One other car demonstrated an improvement in the "tuned with retrofit" configuration.

Statistical Evaluation of Emission Results

The emission results for the first 25 vehicles were statistically analyzed to predict any outstanding trends and to determine the statistical significance of the average emission values presented in Table II. Comparing the "as received" hydrocarbon, carbon monoxide, and carbon dioxide with those of the other three configurations as a group confidence in excess of 99.9 percent exists that there is a real reduction of hydrocarbon and carbon monoxide emissions as well as an increase in carbon dioxide emissions. The confidence level of a difference in oxides of nitrogen emissions is well below the 90 percent level. This is not unexpected due to the inadequate analysis procedure used.

Table V indicates the statistical range of the average emission levels. It should be noted that for this purpose NO_x emissions were not corrected for temperature and humidity. No analysis of Saltzman NO_x data was performed as too few points to be of significance were available. The interval calculated was found at the 90 percent confidence level in each case. As can be seen from the table the "as received" hydrocarbon emission range is higher than the ranges for the other three configurations. This is also true for the carbon monoxide emission ranges. "As received" carbon dioxide overlaps with the "tuned" range, but is lower than either of the other two configurations. All four NO_x ranges overlap so no significance in these averages can be ascertained.

Of most importance is the comparison of the last three configurations to each other. In every case, with the exception of "tuned" and "tuned with retrofit" carbon dioxide emissions, the ranges of all three configurations overlap. Statistically this means that no real difference between the last three test configurations can be predicted at this time for any measured constituent of the vehicles' exhausts. It is as important also to bear in mind that all of the first 25 vehicles were 1962-1964 models and newer vehicles were not tested until the second phase. Thus even if the emission levels of the last three configurations had varied with statistical significance, no idea of the emission reduction effect on a typical population could be made after this preliminary phase of testing.

Conclusions

1. Emission Results:

   Installing a retrofit kit on the "as received" vehicle resulted in an average of 28 percent

reduction in hydrocarbons, 21 percent reduction in carbon monoxide, and 7 percent increase in carbon dioxide. Tuning the "as received" vehicle to manufacturer's specifications while maintaining the lean idle mixture prescribed with the GM kit resulted in averages of 23 percent reduction in hydrocarbons, 24 percent in carbon monoxide, and a 4 percent increase in carbon dioxide. Installing the retrofit kit on the tuned vehicle resulted in average reductions of 31 percent in hydrocarbons, 21 percent in carbon monoxide and a 16 percent increase in carbon dioxide. As a result of the statistical evaluation made, however, these varying averages have little significance when compared to each other, but one can predict that on the average a magnitude of 20 percent reductions in hydrocarbon and carbon monoxide can be expected with proper installation of a retrofit kit or lean tuneup. These, of course, are overall average reductions and do not predict the effect on a given vehicle. As was seen in this preliminary phase of testing some vehicles are made worse polluters while others were drastically improved by the procedures described.

2. Fuel Consumption Results:

No statistical analysis of fuel consumption was made. Certain trends are indicated and at least theoretically expected. The two retrofitted configurations resulted in slight (1 percent and 5 percent) increases in fuel consumption. The tuneup resulted in a 1 percent fuel savings. These differences could well be explained by the change of idle speed with the resulting change of idle fuel flow.

3. Vacuum Advance Monitoring:

Four different vehicles demonstrated a tendency to overheat (coolant temperatures in excess of 205°F) resulting in thermostatic cutoff of the vacuum advance disconnect.

4. Performance Evaluation Results:

Three vehicles suffered adverse driveability effects after installation of the GM retrofit kit. One car in each of the retrofitted configurations improved in driveability. One car suffered from the tuneup. These results on the average indicate a nominal tendency of the retrofit kit to decrease the driveability of some of these vehicles.

Table I

Retrofit Study

Test Vehicle Population

Car Number	Model Year	Make and Model	Engine Disp. CID	Number of Cylinders	Carb. Type Number-Barrels	Trans. Type	Mileage	Inertia Weight	Vehicle ID Number
1	64	Buick Special	300	8	1-2	Auto	53180	3500	1K3019162
2	63	Pontiac Catalina	389	8	1-2	Auto	70211	4000	363560823
3	64	Olds. Jetstar 88	330	8	1-2	Auto	64113	4000	834C015418
4	64	Cadillac Sedan	429	8	1-4	Auto	48745	5000	64B136696
5	64	Mercury Comet	260	8	1-2	Auto	51015	3000	4322F516768
6	64	Ford Galaxie	352	8	1-4	Auto	58109	4000	4J66X122628
7	64	Olds. Cutlass	330	8	1-2	Auto	83277	3500	824F021660
8	63	Plymouth Valiant	225	6	1-1	Auto	84779	3000	1332656497
9	63	Chevrolet Nova	194	6	1-1	Auto	71788	3000	304370109944
10	63	Chevrolet Chevy II	194	6	1-1	Auto	78228	3500	302350160874
11	63	Dodge Dart	225	6	1-1	Auto	89548	3000	7435154248
12	64	Chevrolet Impala	283	8	1-2	Auto	*122634	4000	418470139467
13	63	Chevrolet Impala	283	8	1-2	Auto	77700	4000	318475250145
14	64	Ford Fairlane	260	8	1-2	Auto	60883	3500	4R38F121217
15	63	Ford Falcon	260	8	1-2	Auto	66264	3500	3R17F154734
16	64	Rambler Classic	287	8	1-2	Auto	76981	3500	070680
17	64	Ford Thunderbird	390	8	1-4	Auto	79010	5000	4Y83Z183406
18	62	Chrysler Newport	361	8	1-2	Auto	49600	4000	8123173499
19	64	Buick Electra	401	8	1-4	Auto	55930	4500	8K1028440
20	64	Mercury Parklane	390	8	1-4	Auto	75737	4500	4Z642550646
21	63	Oldsmobile 98	394	8	1-4	Auto	40003	4500	638C04827
22	64	Plymouth Fury	318	8	1-2	Auto	60981	3500	3345106757
23	62	Rambler American	195	6	1-1	Auto	39590	3000	C200A22
24	64	Pontiac Tempest	326	8	1-2	Auto	63840	3500	8I4FI8608
25	64	Buick Riviera	425	8	1-4	Auto	72775	4500	7K1121318

* probably over 100,000 miles

Table II

Mass Emission Result Summary
(average of 25 vehicles
except where noted)

Configuration	HC	CO	CO_2	NO_2[1,3]	NO_x[2,3]
"As Rec'd."	3.44 gpm	131.50 gpm	576.59 gpm	5.85 gpm	5.56 gpm
"As Rec'd. w/ Retrofit"	2.46 gpm	104.17 gpm	617.55 gpm	5.62 gpm	4.53 gpm
% Reduction over Baseline	28%	21%	7% inc.	4%	19%
"Tuned"	2.64 gpm	100.56 gpm	598.64 gpm	5.74 gpm	5.27 gpm
% Reduction over Baseline	23%	24%	4% inc.	2%	5%
"Tuned w/ Retrofit"	2.39 gpm	104.18 gpm	647.17 gpm	4.91 gpm	4.42 gpm
% Reduction over Baseline	31%	21%	12% inc.	16%	21%

1 NDIR NO data reported as NO_2 corrected for temperature & humidity.
2 Saltzman data reported as NO_2 corrected for temperature & humidity.
Saltzman analysis on no more than 11 vehicles
3 NOX data should not be considered accurate as discusses in report.

Table III

Comparison of Repeatibility Tests Conducted

Car Number	HC	CO	CO_2	NO_2 gpm[1]	NO_x gpm[2]
FB-17	1.87	70.66	750.26	5.80	6.71
	1.88	56.41	786.49	3.34	5.82
% difference	-1%	+20%	-5%	+42%	+13%
FB-20	2.09	92.47	797.25	4.96	4.81
	1.97	93.22	755.67	7.09	4.96
% difference	+6%	-1%	+5%	-43%	-3%

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1 NDIR NO data reported as NO_2 corrected for temperature & humidity.
2 Saltzman data reported as NO_2 corrected for temperature & humidity.

Table IV

Fuel Consumption Summary

Configuration	Kilograms of fuel
"As Rec'd." Average	1.783 kg.
"Rec'd. w/Retro"	1.807 kg.
% Increase over "As Rec'd."	1% increase
"Tuned"	1.770 kg.
% Increase over "As Rec'd."	1% decrease
"Tuned w/ Retrofit"	1.868 kg.
% Increase over "As Rec'd."	5% increase

Table V

Statistical Range of Average Emission Values (calculated at the 90% confidence level)

	HC gpm	CO gpm	CO_2 gpm	NO_2 gpm[1]
As Rec'd.	3.25-3.62	125.30-137.70	558.98-594.21	5.71-6.91
As Rec'd. with Retro.	2.28-2.64	97.97-110.38	599.90-635.12	5.49-6.69
Tuned	2.46-2.82	94.36-106.76	581.03-616.25	5.59-6.79
Tuned with Retro.	2.21-2.57	97.98-110.39	629.60-664.82	4.83-6.03

1 NDIR NO data as NO_2, not corrected for temperature & humidity.

APPENDIX

Table 1

Baseline Emissions

Car Number	HC gpm	CO gpm	CO_2 gpm	NO_2 gpm[1]	NO_x gpm[2]
FB-1	3.19	116.00	529.04	7.31	----
2	3.07	169.60	571.24	2.00	----
3	2.46	59.65	568.62	5.47	----
4	2.35	149.49	737.29	5.66	----
5	4.38	104.20	479.13	5.12	----
6	3.91	167.28	574.79	6.98	----
7	3.08	153.51	574.98	3.74	----
8	1.73	70.17	469.77	6.43	----
9	2.38	105.18	458.91	7.63	----
10	3.22	117.44	460.26	2.25	----
11	1.15	48.98	461.00	7.03	----
12	4.95	172.76	506.25	6.40	----
13	4.38	112.31	528.67	8.17	----
14	2.28	52.68	580.35	8.99	----
15	2.99	117.76	541.79	8.72	----
16	4.66	204.76	450.25	4.34	----
17	3.77	197.31	668.80	2.93	----
18	3.54	180.39	692.58	4.83	3.40
19	5.80	175.10	558.91	4.95	5.86
20	2.26	110.09	736.40	6.11	5.23
21	1.90	85.03	727.32	7.21	5.56
22	4.49	125.84	459.04	7.42	5.96
23	2.85	69.59	443.44	5.70	7.83
24	5.05	190.44	933.39	3.64	4.66
25	6.06	231.89	702.62	7.13	6.01
Average	3.44 gpm	131.50 gpm	576.59 gpm	5.85 gpm	5.56 gpm

1 NDIR NO data reported as NO_2 corrected for temperature & humidity.
2 Saltzman data reported as NO_2 corrected for temperature & humidity.

Table 2

Retrofit Alone

Car Number	HC gpm	CO gpm	CO_2 gpm	NO_2 gpm[1]	NO_x gpm[2]
FB-1	1.94	96.59	634.17	4.77	----
2	1.81	89.66	648.81	2.97	----
3	1.96	42.18	707.30	4.31	----
4	1.80	110.32	729.46	5.04	----
5	4.39	51.44	575.46	5.78	----
6	4.11	188.55	649.37	6.01	----
7	2.51	139.28	574.47	4.58	----
8	1.48	72.14	584.18	7.77	----
9	2.35	80.00	537.84	7.26	----
10	2.28	119.56	523.51	6.43	----
11	0.94	41.31	639.43	5.72	----
12	2.85	131.39	559.39	6.72	----
13	2.31	107.63	605.95	6.40	----
14	2.13	42.86	654.61	7.14	----
15	2.81	101.16	576.66	6.55	----
16	3.73	213.16	486.32	4.37	----
17	2.69	155.88	655.10	4.69	1.33
18	2.86	139.34	612.66	4.79	3.74
19	3.16	122.49	627.25	2.81	5.79
20	2.15	98.45	742.13	6.20	5.04
21	1.57	75.20	844.94	7.07	3.84
22	2.53	78.84	507.42	5.75	5.73
23	1.89	28.17	460.60	5.83	6.12
24	1.88	87.01	627.45	5.94	4.87
25	3.37	191.76	674.26	5.59	4.31
Average	2.46 gpm	104.17 gpm	617.55 gpm	5.62 gpm	4.53 gpm

1 NDIR NO data reported as NO_2 corrected for temperature & humidity.
2 Saltxman data reported as NO_2 corrected for temperature & humidity.

Table 3

Tune-up Alone

Car Number	HC gpm	CO gpm	CO_2 gpm	NO_2 gpm[1]	NO_x gpm[2]
FB-1	2.08	100.13	641.62	4.59	----
2	2.52	128.42	639.41	6.18	----
3	1.76	34.28	724.03	4.67	----
4	2.36	114.77	735.60	6.40	----
5	4.13	84.34	518.61	2.88	----
6	4.10	165.63	597.33	8.23	----
7	3.73	163.18	579.36	1.20	----
8	1.37	56.05	493.15	6.88	----
9	2.18	81.49	495.01	8.54	----
10	2.61	112.33	504.87	6.88	----
11	0.97	38.04	498.22	6.39	----
12	3.15	126.15	487.55	4.64	----
13	2.44	101.39	605.97	7.10	----
14	2.33	50.18	616.26	6.89	----
15	2.99	100.16	498.12	5.68	5.00
16	3.37	194.49	423.88	2.73	1.02
17	1.87	70.66	750.26	5.80	6.71
18	2.25	122.85	663.39	2.07	3.06
19	4.30	119.50	632.74	2.78	----
20	2.09	92.47	797.25	4.96	4.81
21	2.55	38.44	724.82	8.43	6.42
22	2.26	70.06	532.40	7.80	8.85
23	1.87	34.29	479.61	6.49	7.17
24	2.53	95.57	630.86	7.25	5.07
25	4.18	219.13	695.75	8.04	4.56
Average	2.64 gpm	100.56 gpm	598.64 gpm	5.74 gpm	5.27 gpm

1 NDIR NO data reported as NO_2 corrected for temperature & humidity.
2 Saltzman data reported as NO_2 corrected for temperature & humidity.

Table 4

Tune-up & Retrofit

Car Number	HC gpm	CO gpm	CO_2 gpm	NO_2 gpm[1]	NO_x gpm[2]
FB-1	1.71	103.31	614.79	3.52	----
2	2.29	148.59	741.02	6.58	----
3	1.31	34.85	792.91	6.18	----
4	1.83	120.77	793.12	1.72	----
5	4.34	88.91	526.28	5.53	----
6	3.38	149.85	630.62	6.47	----
7	3.28	188.70	756.56	7.52	----
8	1.23	60.68	631.62	1.80	----
9	2.25	76.87	525.47	2.19	----
10	2.42	129.28	549.61	4.74	----
11	0.93	50.45	602.70	2.15	----
12	4.49	137.42	551.84	4.93	----
13	1.88	97.99	641.03	6.88	----
14	1.89	34.42	666.65	4.73	----
15	2.81	83.70	526.24	5.50	7.67
16	3.30	204.24	499.66	3.39	2.65
17	1.99	126.88	716.02	5.74	4.71
18	2.47	135.79	753.68	5.11	3.35
19	3.19	114.96	645.00	5.59	3.14
20	1.89	87.88	728.32	3.56	3.25
21	1.81	42.18	750.05	6.60	4.11
22	1.83	56.31	560.00	4.26	4.18
23	1.59	30.89	516.54	6.28	7.41
24	1.95	83.95	729.43	6.59	4.13
25	3.73	215.72	730.17	5.13	4.06
Average	2.39 gpm	104.18 gpm	647.17 gpm	4.91 gpm	4.42 gpm

1 NDIR NO data reported as NO_2 corrected for temperature & humidity.
2 Saltzman data reported as NO_2 corrected for temperature & humidity.

Table 5

Retrofit-% Reduction over Baseline

Car Number	HC	CO	CO_2	NO_2[1]	NO_x[2]
FB-1	39%	17%	*20%	35%	----
2	41	47	*14	* 49	----
3	20	29	*24	21	----
4	23	26	1	11	----
5	0	51	*20	* 13	----
6	* 5	*13	*13	14	----
7	19	9	0	* 22	----
8	14	* 3	*25	* 21	----
9	1	24	*17	5	----
10	29	* 2	*14	*186	----
11	18	16	*39	19	----
12	42	24	*10	* 5	----
13	47	4	*15	22	----
14	7	19	*13	* 21	----
15	6	14	* 6	25	----
16	20	* 4	* 8	* 1	----
17	29	21	2	* 60	----
18	19	23	12	0	*10%
19	46	30	*12	43	1
20	5	11	* 1	* 1	4
21	17	12	*16	2	31
22	44	37	*11	23	4
23	34	60	* 4	* 2	22
24	63	54	33	* 63	* 5
25	44	17	4	22	28
Average	25%	21%	* 9%	* 8%	9%

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1 NDIR NO data - corrected

2 Saltzman data

* indicates increase

Table 6

Tuneup-% Reduction over Baseline

Car Number	HC	CO	CO_2	NO_2[1]	NO_x[2]
FB-1	35%	14%	*21%	37%	----
2	18	24	*12	*209	----
3	28	43	*27	15	----
4	0	23	0	* 13	----
5	6	19	* 8	44	----
6	* 5	1	* 4	* 18	----
7	*21	* 6	* 1	68	----
8	21	20	* 5	* 7	----
9	8	23	* 8	* 12	----
10	19	4	*10	*206	----
11	16	22	* 8	9	----
12	36	27	4	28	----
13	44	10	*14	13	----
14	* 2	5	* 6	23	----
15	0	15	8	35	----
16	28	5	6	37	----
17	50	64	*12	* 98	----
18	36	32	4	57	10%
19	26	32	*13	* 44	----
20	8	16	* 8	19	8
21	*34	55	0	* 17	*15
22	50	44	*16	* 5	*48
23	34	51	* 8	* 14	8
24	50	50	32	* 99	* 9
25	31	6	1	* 13	24
Average	19%	24%	* 5%	* 15%	* 3%

1 NDIR NO data - corrected

2 Saltzman data - corrected

* indicates increase

Table 7

Tuneup & Retrofit-% Reduction over Baseline

Car Number	HC	CO	CO_2	NO_2[1]	NO_x[2]
FB-1	40%	11%	*16%	52%	----
2	25	12	*29	*229	----
3	47	42	*39	* 13	----
4	22	19	* 7	70	----
5	1	15	*10	* 8	----
6	14	10	*10	7	----
7	* 6	*23	*32	*101	----
8	29	14	*34	72	----
9	5	27	*15	71	----
10	25	*10	*19	*111	----
11	19	* 3	*31	69	----
12	9	20	* 9	23	----
13	57	13	*21	16	----
14	17	35	*15	47	----
15	6	29	3	37	----
16	29	0	*11	22	----
17	47	36	* 7	* 95	----
18	30	25	* 9	* 6	1%
19	45	34	*15	* 13	46
20	16	20	1	42	38
21	5	50	* 3	8	26
22	60	55	*22	43	30
23	44	56	*16	* 10	5
24	61	56	22	* 81	11
25	38	7	* 4	28	32
Average	28%	22%	*14%	* 2%	24%

1 NDIR NO data - corrected

2 Saltzman data - corrected

* indicates increase

Table 8

Fuel Consumption

(measured during 1972 FTP)

Car Number	"As Rec'd"	"Rec'd w/ Retrofit"	"Tuned"	"Tuned w/ Retrofit"
FB-1	1.571 kg	1.708 kg	1.713 kg	1.702 kg
2	1.725	1.915	2.046	2.278
3	1.535	1.901	1.648	1.748
4	2.211	---	2.311	2.436
5	1.567	1.585	1.376	1.792
6	1.968	2.053	1.897	1.967
7	1.973	1.881	1.936	2.094
8	1.301	1.490	1.354	1.523
9	1.563	1.575	1.503	1.632
10	1.605	1.622	1.518	1.623
11	1.246	1.434	1.336	1.528
12	1.865	1.752	1.726	1.929
13	1.707	1.707	1.726	1.799
14	1.665	1.620	1.623	1.683
15	1.864	1.572	1.525	1.617
16	1.649	1.825	1.670	1.834
17	2.198	2.098	2.002	2.068
18	2.045	2.011	2.046	2.018
19	2.086	2.103	1.855	1.907
20	2.070	2.144	2.073	2.093
21	1.852	2.236	2.070	2.310
22	1.725	1.578	1.569	1.563
23	1.326	1.324	1.261	1.277
24	1.811	1.775	1.884	1.862
25	2.445	2.458	2.583	2.409
Average	1.783 kg.	1.807 kg.	1.770 kg.	1.868 kg.