FINAL REPORT

TEST AND EVALUATION OF THE AMERICAN POLLUTION CONTROLLED, INC. EXHAUST EMISSION CONTROL DEVICE

PREPARED UNDER CONTRACT ARB 1902
WITH
STATE OF CALIFORNIA
AIR RESOURCES BOARD

By:

Northrop Corporation Electro-Mechanical Division NORTHROP

IN ASSOCIATION WITH OLSON LABORATORIES, INC

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SECTION 1
INTRODUCTION

The subject of this report is an examination of the extent to which motor vehicle air pollution can be reduced by the installation of an exhaust emission control device on pre-1966 vehicles.

A potentially suitable "used-car" emission control device is produced by American Pollution Controlled, Inc. (APC). This report documents the installation of 50 APC devices on 50 uncontrolled cars. It covers the ability of Class A garages to accomplish satisfactory installations, the cost of installation, emission reductions achieved, and drivability impressions with and without the device installed. The convertibility of device manufacture from low- to high-volume production is also evaluated.

The work performed in the accomplishment of this study was under contract to the State of California Air Resources Board, Standard Agreement ARB 1902. The report was compiled by Northrop Corporation, Environmental Systems, in conjunction with Olson Laboratories, Inc., at Anaheim, California.

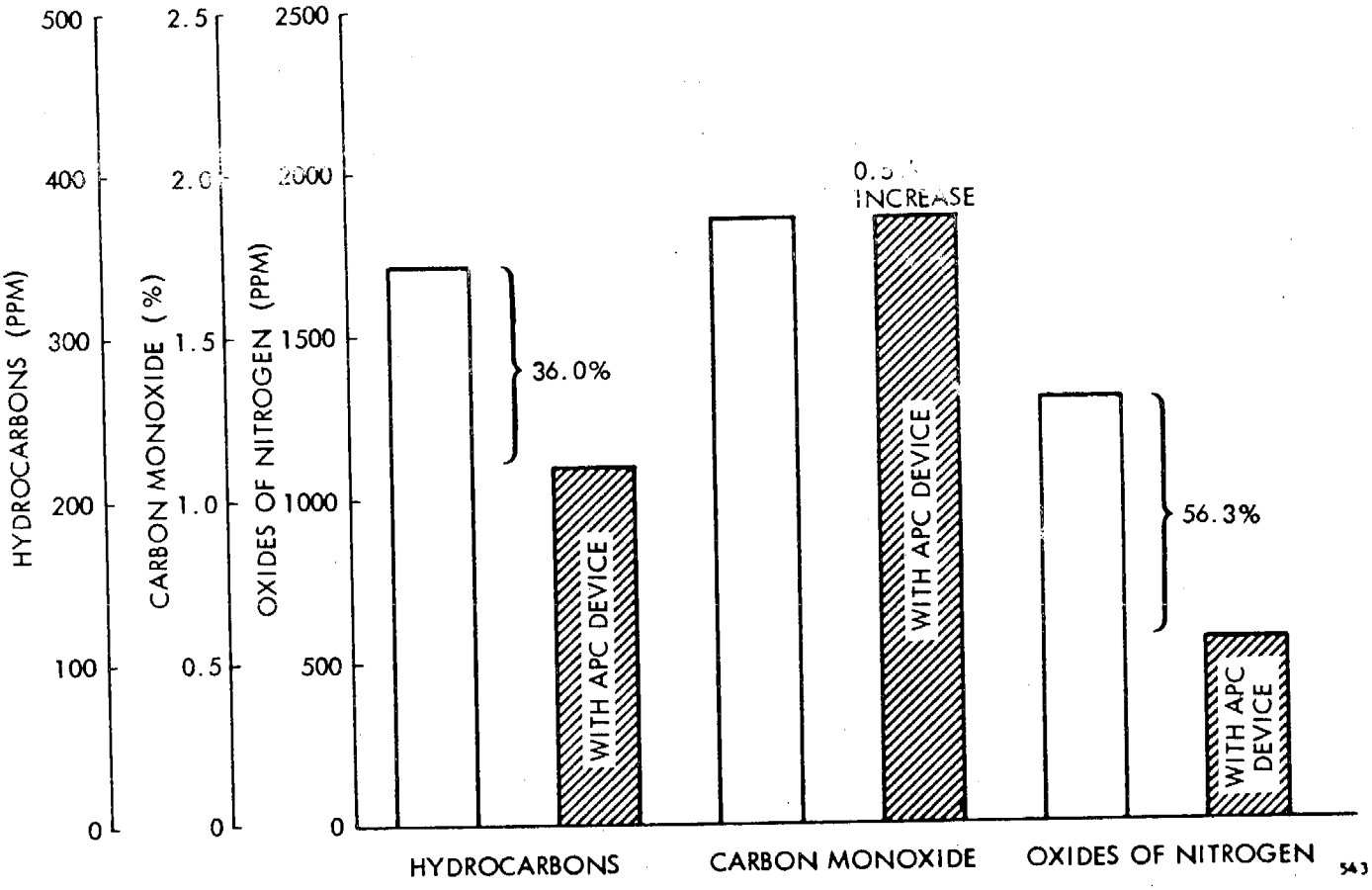


Figure 2-1. PROFILE OF FLEET EXHAUST EMISSIONS

These emission improvements represent a 48 percent reduction in the number of reactive tons of exhaust pollutants emitted from these uncontrolled vehicles, and should lead to a large reduction in photochemical smog.

The majority of vehicle owners interviewed believed their car's performance degraded after the device was installed. An assessment of the drivability of each test vehicle performed by trained test drivers as a part of the testing program did not reveal the same degree of degradation indicated by the vehicle owners. This discrepancy is the result of the qualitative nature of the drivability test and of overly critical vehicle owners. Several of the high percentage complaints recorded by the owners are similar to those being voiced by owners of 1971 cars that are equipped with NO_x control devices and that meet the current HC, CO, and NO_x

standards. These problems were difficult cold starting, rough idle, surge, hesitation, loss of power, and lower gas mileage.

The average cost of device installations performed by the participating Class A garages was $20.66 for labor and $0.66 for parts, for a $21.32 total average installation cost. The ability to perform the device installations was not a major problem, and the mechanics neither received nor requested support after the first installation. The effectiveness of the installation with respect to owner complaints does, however, require improvement.

A manufacturing engineering evaluation of the device revealed that it could be mass produced. It also suggested design changes that would improve its ease of manufacture, and would improve its reliability.

2.2 PROGRAM NARRATIVE

Fifty uncontrolled cars representing a cross section of California's uncontrolled vehicle population were selected as test vehicles. Each vehicle selected was adjusted or repaired to manufacturer's specifications, followed by a baseline 7-mode hot-start test and a baseline warm vehicle drivability test. After these initial reference tests had been performed, each test vehicle was sent to one of five device installation facilities. Each facility is a licensed Class A garage which is either a dealer, an independent garage, or a service station. Personnel at each installation facility were given minimal instruction in installation of the device and were to rely solely upon the instructions provided with the device.

Immediately after installation of the device, each test vehicle was returned to the Northrop test site for a second 7-mode hot-start test and a subsequent drivability test. The vehicle was then returned to the owner for approximately 30 days of normal driving to determine the effects of acclimatization. At the end of this period, the vehicle was subjected to a third 7-mode hot-start test, the device was removed, and the car returned to its owner.

SECTION 3
TECHNICAL REPORT

This report presents an objective evaluation of the American Pollution Controlled, Inc. (APC) exhaust emission control device. The effectiveness of the APC device in reducing exhaust emission pollution from uncontrolled automobiles is presented.

APC devices were installed on 50 pre-1966 vehicles by Class A garages. All emission testing was performed at Northrop Corporation, Electro-Mechanical Division, Anaheim, California, by Olson Laboratories, Inc. The testing facility has been certified by the California Air Resources Board.

The steps performed with respect to the cars involved in accomplishment of this study were:

- Select vehicles.
- Determine general condition and applicability of installation kits available.
- Repair as required to obtain reasonably good operating condition.
- Perform baseline 7-mode hot-start test.
- Perform baseline drivability test.
- Install APC device.
- Perform post-installation 7-mode hot-start test.
- Perform post-installation drivability test.
- Return vehicle to owner for mileage accumulation.
- Return vehicle for final emission test after mileage accumulation.
- Remove APC device.
- Determine that vehicle is operating satisfactorily.

- Interview vehicle owner as to performance appraisal with APC device installed.
- Return vehicle to owner.

To evaluate the effect of the device on various engine sizes, the vehicles were grouped by engine class as follows:

Class	Displacement (Cubic Inches)
B	140 - 200
C	200 - 250
D	250 - 300
E	300 - 375
F	375

3.1 VEHICLE SELECTION

Fifty vehicles were selected from the group of Northrop-employee vehicles tested previously in the ARB/Northrop vehicle emission inspection and maintenance study program. A limitation was placed on the sample mix by the availability of APC installation kits that were provided for this study at no cost. Some previously untested vehicles were also used when initially selected vehicles were unobtainable. The average mileage for the vehicles used is 78,305 miles, while the average age is approximately 7.5 years.

The vehicles used were generally in good mechanical condition, although some possessed initially high emission levels. Repairs and adjustments were performed before the baseline 7-mode test to bring the HC and CO emissions within good uncontrolled levels.

The mix of engine sizes, makes, and models spans the domestic motor vehicle population of uncontrolled cars in the State. Table 3-1 presents a tabulation of the vehicle mix used.

Table 3-1. VEHICLE SAMPLE DISTRIBUTION

Class	No.	Manufacturer	No.
B	6	G. M.	21
C	8	Ford	11
D	10	Chrysler	16
E	19	Other	2
F	7		
Total	50		50

3.2 GARAGE SELECTION

An attempt was made to distribute the installations among three dealer garages representing the three major manufacturers, one independent garage, and one service station. The garages are identified as follows:

Installer No.	Installer
1	Dodge Dealer
2	Ford Dealer
3	Chevrolet Dealer
4	Independent Garage
5	Service Station

Each of these installers was briefed on the installation procedure by a representative from APC, was given an instruction and parts manual specifically written for this study, and was given a master kit (box of extra parts) for use as needed.

3.3 BASELINE VEHICLE TESTING

Each vehicle used in the program was initially inspected for applicability of the available installation kits and for its general operating condition. Unsafe and badly worn vehicles were rejected, as were vehicles that could not be fitted with the available kits.

Those vehicles accepted into the program were given minimum service to bring their HC and CO exhaust emissions within reasonably good uncontrolled levels.

A 7-mode hot-start emission test was then run on each vehicle, followed by a warm-vehicle drivability test.

3.3.1 Preparation for the Test

Each vehicle accepted into the program was analyzed utilizing an oscilloscope to determine the condition of the electrical system. Dwell and timing adjustments were made as required. The exhaust was sampled for CO, and adjustments to the idle mixture were made where necessary.

Twenty-nine of the vehicles accepted were participants in an earlier test program for the ARB and were expected to be in reasonably good shape. One car received a complete ignition tune-up, one received an accelerator pump diaphragm, one received one spark plug, and three needed carburetor linkage parts.

The remaining 21 vehicles were previously untested and probably represent cars as they would come in off the street for device installation. They required more work to get them into shape. This group is discussed further in paragraph 3.7.

3.3.2 Emissions Test

A standard 7-mode hot-start test was performed on each of the 50 vehicles before installation of the APC device. The results are tabulated in Table 3-2. To allow comparison of the results of device installation, the following generally accepted used-car emission cold-start standards were used:

HC	350 ppm
CO	2.0 percent
NO	800 ppm

Table 3-2. BASELINE EXHAUST EMISSION SUMMARY

Car No.	Yr/Make/CID/TR/Carb	As Received			
		Odom	HC (PPM)	CO (%)	NO (PPM)
Engine Class B					
1201	64 Che 194 A 1V	47,018	387*	1.29	1,466*
1226	62 Dod 170 A 1V	74,983	392*	3.73*	971*
1237	62 Mer 170 A 1V	49,878	500*	1.20	1,953*
1250	63 Dod 170 A 1V	61,440	244	0.77	1,836*
1253	63 Ch2 191 A 1V	66,565	322*	2.12*	871*
1327	63 Fal 170 A 1V	79,565	292	.80	867*
Average		63,242	356*	1.82*	1,327*
Engine Class C					
1207	64 Ply 225 A 1V	54,262	444*	3.31*	922*
1229	65 Tmp 215 A 1V	151,250	184	2.34*	803
1301	65 Dod Drt 225 A 1V	53,984	175	1.43	1,561*
1305	62 Old 215 A 4V	49,819	593*	0.82	1,101*
1316	63 Ply Val 225 A 1V	86,957	302	0.76	1,389*
1326	63 Ply Val 225 A 1V	110,992	336*	1.28	1,086*
1329	63 Che 230 A 1V	84,827	557*	4.18*	1,114*
1330	63 Dod Drt 225 A 1V	102,060	186	0.70	1,754*
Average		86,769	347*	1.85*	1,216*
Engine Class D					
1213	64 Ram 287 A 2V	58,132	307	0.76	1,254*
1255	64 Mus 289 A 2V	74,042	271	2.55*	452
1257	65 For 289 A 4V	63,997	358*	4.06*	781
1265	65 Che 283 A 2V	55,845	434*	2.02*	1,121*
1273	64 Bui Sklk 300 A 2V	76,523	280	1.79	1,476*
1292	63 Che 283 A 2V	78,882	546*	2.37*	821
1306	64 Fal 260 A 2V	73,584	351*	1.16	1,505*
1323	64 Dod Drt 273 A 2V	83,757	250	0.39	1,379*

Table 3-2. BASELINE EXHAUST EMISSION SUMMARY (Continued)

Car No.	Yr/Make/CID/TR/Carb	As Received Odom	HC (PPM)	CO (%)	NO (PPM)
Engine Class D (Continued)					
1325	65 Che 283 A 2V	59,443	247	1.96*	644
1337	65 Mus 289 A 4V	72,743	466*	2.46*	1,704*
Average		69,695	351*	1.95*	1,114*
Engine Class E					
1240	58 Ply 318 A 2V	86,547	216	0.59	3,055*
1245	64 Old 330 A 2V	129,904	320*	1.63	1,497*
1248	60 Bui 364 A 2V	83,674	337*	0.90	912*
1267	58 Dod 361 A 2V	105,600	239	1.21	870*
1274	65 Che 327 A 4V	64,646	421*	1.07	2,065*
1285	65 Bui 310 A 2V	104,434	376*	2.22*	1,183*
1302	63 Chr 361 A 2V	71,209	432*	3.87*	856*
1310	64 For 352 A 2V	94,678	349*	0.61	2,601*
1320	63 For 352 A 2V	83,476	335*	1.28	1,831*
1321	65 Che 327 A 4V	68,330	488*	1.83*	1,654*
1324	65 Ply 318 A 2V	88,352	410*	2.78*	1,070*
1328	64 Chr 361 A 2V	85,324	328*	2.22*	920*
1332	65 Ply 361 A 2V	69,909	307	1.95*	1,794*
1333	63 Ram 327 A 4V	80,115	376*	3.08*	641
1335	63 Dod 361 A 4V	76,616	268	0.68	1,779*
1338	64 Dod 318 A 2V	77,242	339*	1.71	2,124*
1339	61 Mer 352 A 2V	93,832	304	1.19	1,320*
1342	64 Che 327 A 4V	77,704	556*	2.46*	960*
1343	64 Tmp 326 A 2V	66,196	410*	2.83*	682
Average		84,620	358*	1.79	1,463*

Table 3-2. BASELINE EXHAUST EMISSION SUMMARY (Continued)

Car No.	Yr/Make/CID/TR/Carb	As Received Odom	HC (PPM)	CO (%)	NO (PPM)
Engine Class F					
1230	63 Old 394 A 2V	82,441	213	2.26*	715
1270	64 Mer 390 A 2V	81,662	255	2.18*	1,092*
1300	65 For 390 A 4V	80,100	364*	1.92*	1,405*
1322	62 Bui 401 A 4V	86,914	234	2.34*	534
1331	63 Cad 390 A 4V	42,703	228	1.86*	1,015*
1334	64 Pon 389 A 4V	86,954	382*	1.36	1,572*
1340	65 Cad 429 A 4V	76,152	207	1.09	1,788*
Average		76,704	269	1.72	1,160
Grand Average		78,305	342*	1.83*	1,295*

*Did not meet standard:

HC 318 ppm
CO 1.82%
NO 842 ppm

Standard conversion to hot-start standards according to ARB laboratory data yielded the following hot-start standards:

HC	318 ppm
CO	1.82 percent
NO	842 ppm

Table 3-3 includes a tally of the number of vehicles meeting 0 to 3 of these standards before installation of the APC device. It shows that two-thirds of the vehicles were unable to meet even two of the three used-car standards.

Table 3-3. NUMBER OF VEHICLES MEETING VARIOUS COMBINATIONS OF THE THREE EMISSION STANDARDS - BEFORE APC DEVICE INSTALLATION

Engine Class	No. of Standards Met				Total
	0	1	2	3	
B	2	2	2	0	6
C	2	2	4	0	8
D	2	3	5	0	10
E	6	9	4	0	19
F	1	3	3	0	7
All Vehicles	13	19	18	0	50

3.3.3 Drivability Test

A warm-vehicle drivability test was performed on each vehicle according to the procedures described in Appendix A. The drivability test course used was a training course set up in the Los Angeles Riverbed, approximately 25 freeway-minutes from the test facility. This distance ensured complete engine warmup before the drivability tests commenced. The results of the drivability test are presented in paragraph 3.5.2 along with a comparative analysis of the before- and after-installation performance.

3.4 APC DEVICE INSTALLATION

After the baseline emission and drivability tests were completed, the vehicles were dispatched, with the appropriate installation kit, to one of the participating garages for device installation.

3.4.1 Garage Utilization

It was intended to utilize all of the garages equally. When a car was ready to go out for device installation, the appropriate dealer was notified, but in some cases declined due to other business already scheduled. It was not possible to give the garages advance notice due to uncertainties of the completion of the emission and drivability testing.

Because of this declination, the utilization of the garages turned out to be very lopsided, especially in the case of the Dodge dealer. The high incidence of General Motors cars led to a high utilization of the Chevrolet dealer. This dealer also did the installation on other than GM cars when the other garages were not available. The number of installations performed by each garage was:

Installer	No. of Installations
1	1
2	7
3	18
4	16
5	8
	50

3.4.2 Cost of Installation

The cost of installation for the APC devices is, in general, based on 2.5 hours of labor. Several of the cars required new radiator hoses to ensure a sound installation, and a few needed carburetor base studs of a length not included in the kit or with the spare parts provided. Three cars required throttle-linkage bushings. The cost of the installations are tabulated in Table 3-4. The average cost of installation was $20.66 for labor and $0.66 for parts, for an average total installation cost of $21.32.

3.4.3 Problems Encountered

Though the actual active installation time was approximately 2.5 hours, the cars were at the installers for something like 4 to 6 hours. This could prove to be a convenience problem if mass installation of this or any similar device were required.

A number of customer-satisfaction problems were encountered after installation. The bulk of the problems was traced to misadjustment of the idle speed and automatic transmission shift linkage. The base plate with the recirculating valve raised the linkage attachment point and changed the angle of the linkage, requiring a readjustment which was rarely, if ever, done at the time of installation. Exceptional complaints are listed in Table 3-5. The cars not listed had no complaints traceable to the installation procedure.

Table 3-4. APC DEVICE INSTALLATION COSTS

Car No.	Engine Class	Installer					Installation Cost($)	
		1	2	3	4	5	Labor	Parts
1201	B			X			22.50	
1207	C				X		12.75	
1213	D		X				25.00	1.38
1226	B				X		12.75	3.30
1229	C			X			22.50	
1230	F			X			27.00	
1237	B		X				23.00	5.42
1240	E					X	19.00	1.00
1245	E			X			27.00	
1248	E			X			27.00	
1250	B				X		12.75	
1253	B			X			18.00	
1255	D					X	23.75	
1257	D		X				25.00	2.81
1265	D			X			22.50	
1267	E				X		21.25	
1270	F		X				16.00	
1273	D			X			22.50	
1274	E			X			22.50	
1285	E			X			18.00	
1292	D			X			18.00	
1300	F		X				20.00	2.50
1301	C				X		12.75	
1302	E				X		21.25	
1305	C				X		21.25	
1306	D					X	19.00	
1310	E		X				20.00	0.60
1316	C				X		12.75	
1320	E		X				19.00	3.79

Table 3-4. APC DEVICE INSTALLATION COSTS (Continued)

Car No.	Engine Class	Installer					Installation Cost($)	
		1	2	3	4	5	Labor	Parts
1321	E			X			22.50	
1322	F					X	23.75	1.00
1323	D				X		21.25	
1324	E				X		21.25	
1325	D			X			22.50	
1326	C			X			22.50	
1327	B					X	19.00	
1328	E				X		21.25	3.45
1329	C			X			18.00	
1330	C				X		14.75	
1331	F					X	19.00	
1332	E					X	19.00	2.70
1333	E				X		21.25	
1334	F			X			22.50	
1335	E			X			27.00	
1337	D			X			31.50	4.15
1338	E	X					13.50	
1339	E				X		21.25	
1340	F					X	19.00	
1342	E				X		21.25	
1343	E				X		21.25	
Total							1,033.00	32.10
Average							20.66	0.66

Table 3-5. INSTALLATION PROBLEMS

Car No.	Remarks
1201	Wide open throttle hesitation noted before installation
1213	Recycle tube not attached properly; ferrule not gripping tube - corrected; chain too tight - corrected
1226	Installer put in wrong jet - corrected; throttle rod bushing replaced
1230	Installer missed bad radiator hose - changed
1237	Wrong jet installed - APC mistake in identifying carburetor - replaced with correct jet
1240	Wrong jet installed - APC mistake - replaced with correct jet
1248	Carburetor badly worn - installation undertaken anyway
1253	Bad stumble noted before installation
1305	Transmission troubles noted before installation
1310	Installer broke original carburetor spacer plate on removal for device installation
1323	Wrong jet identified in kit - APC mistake - replaced with correct jet
1328	Throttle rod travel not adjusted properly by installer - replaced throttle rod bushing - adjusted travel
1332	Choke and transmission linkage not hooked up by installer - returned for hookup
1335	Air cleaner rotated to miss new hose position - jammed choke closed - moved air cleaner to original position and freed choke
1342	Vacuum leak in brake booster noted - repaired by owner

The majority of these problems would have been brought to light if a road test on every vehicle had been performed. A few of the garages road-tested the first one or two vehicles after installation, but ceased at that point. The installation procedure does not call for a road test after installation.

3.5 POST-INSTALLATION TESTING

Upon completion of device installation, each vehicle was returned to the test facility for another 7-mode hot-start test and a final warm vehicle drivability test. The drivability test results for each car have been submitted to the ARB as a separate attachment to this report and are available from them upon request.

3.5.1 Emission Test

The results of the post-installation 7-mode tests are included in Table 3-6, along with the baseline test results and the emission reductions obtained. The percent reductions are:

HC	34.5 percent
CO	-3.8 percent (increase)
NO	51.3 percent

In addition to the large average reductions achieved for HC and NO at little expense to CO, the ability of 45 of the 50 vehicles to meet at least 2 out of 3 of the used-car standards is very significant (see Table 3-7). This is compared to only 18 of the 50 meeting at least 2 out of 3 standards before device installation. In addition, the ability to meet all three standards was achieved by 21 vehicles, whereas not one vehicle demonstrated this capacity before device installation.

Most of the cases of failure to meet the standard was with CO. It is felt that an idle mixture adjustment procedure designed to ensure lowest CO without appreciably increasing NO should be included in the installation instructions. No carburetor adjustment procedure is included with, or even mentioned in, the installation kit instructions. The master instruction book does request that the original manufacturer's specifications and adjustments be checked.

The failing pollutant in most cases was CO. The device installation was effective in reducing the number of NO failures, from 41 to 8, with significant reductions achieved on an additional 6 vehicles. One of the remaining two failing vehicles had an improperly installed recirculation tube, rendering the recycle effect useless. The other vehicle (number 1253) showed no significant NO decrease. The reason for this is not apparent.

Table 3-6. EXHAUST EMISSION SUMMARY - AFTER DEVICE INSTALLATION

Car No.	Yr/Make/CID/TR/Carb	As Received				Device Installed			Reduction		
		Odom	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)
Engine Class B											
1201	64 Che 194 A 1V	47,018	387*	1.29	1,466*	215	1.10	875*	172	0.19	591
1226	62 Dod 170 A 1V	74,983	392*	3.73*	971*	414*	3.23*	578	22	0.50	393
1237	62 Mer 170 A 1V	49,878	500*	1.20	1,953*	242	3.01*	430	248	(-1.81)	1,523
1250	63 Dod 170 A 1V	61,440	244	0.77	1,836*	179	1.01	504	65	(-0.24)	1,332
1253	63 Ch2 191 A 1V	66,565	322*	2.12*	871*	399*	2.18*	821	(-77)	(-0.06)	50
1327	63 Fal 170 A 1V	79,565	292	1.80	867*	214	3.41*	186	88	(-1.61)	681
Average		63,242	356*	1.82	1,327*	279	2.32*	566	86	(-0.50)	762
Engine Class C											
1207	64 Ply 225 A 1V	54,262	444*	3.31*	922*	249	2.24*	609	195	1.07	313
1229	65 Tmp 215 A 1V	151,250	184	2.34*	803	175	2.93*	681	9	(-0.59)	122
1301	65 Dod Drt 225 A 1V	53,984	175	1.43	1,561*	97	1.10	848*	78	0.33	713
1305	62 Old 215 A 4V	49,819	593*	0.82	1,101*	407*	1.15	541	186	(-0.33)	560
1316	63 Ply Val 225 A 1V	86,957	302	0.76	1,389*	243	2.34*	511	59	(-1.58)	878
1326	63 Ply Val 225 A 1V	110,992	336	1.28	1,086*	194	0.81	678	142	0.47	408
1329	63 Che 230 A 1V	84,827	557*	4.18*	1,114*	218	2.08*	622	339	2.10	492
1330	63 Dod Drt 225 A 1V	102,060	186	0.70	1,754*	154	1.01	437	32	(-0.31)	1,317
Average		86,769	347	1.85*	1,216*	217	1.71	616	130	0.14	600

Table 3-6. EXHAUST EMISSION SUMMARY - AFTER DEVICE INSTALLATION (Continued)

Car No.	Yr/Make/CID/TR/Carb	As Received				Device Installed			Reduction		
		Odom	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)
Engine Class D											
1213	64 Ram 287 A 2V	58,132	307	0.76	1,254*	148	0.76	1,258*	159	0	(-4)
1255	64 Mus 289 A 2V	74,042	271	2.55*	452	339*	2.56*	264	(-6)	(-0.01)	188
1257	65 For 289 A 4V	63,997	358*	4.06*	781	235	3.70*	397	123	0.36	384
1265	65 Che 283 A 2V	55,845	434*	2.02*	1,121*	220	1.88*	620	214	0.14	501
1273	64 Bui Sklk 300 A 2V	76,523	280	1.79	1,476*	175	1.80	480	105	(-0.01)	996
1292	63 Che 283 A 2V	78,882	546*	2.37*	821	275	1.48	775	271	0.89	46
1306	64 Fal 260 A 2V	73,584	351*	1.16	1,505*	326*	1.13	798	25	0.03	707
1323	64 Dod Drt 273 A 2V	83,757	250	0.39	1,379*	291	1.09	673	(-41)	(-0.70)	706
1325	65 Che 283 A 2V	59,443	247	1.96*	644	257	2.61*	527	(-10)	(-0.65)	117
1337	65 Mus 289 A 4V	72,743	466*	2.46*	1,704*	302	2.76*	631	164	(-0.30)	1,073
	Average	69,695	351*	1.95*	1,114*	257	1.98*	642	94	(-0.03)	471
Engine Class E											
1240	58 Ply 318 A 2V	86,547	216	0.59	3,055*	177	0.41	997*	39	0.18	2,058
1245	64 Old 330 A 2V	129,904	320*	1.63	1,497*	121	1.36	598	199	0.27	899
1248	60 Bui 364 A 2V	83,674	337*	0.90	912*	134	0.65	571	203	0.25	341
1267	58 Dod 361 A 2V	105,600	239	1.21	870*	623*	10.70*	101	(-384)	(-9.49)	769
1274	65 Che 327 A 4V	64,646	421*	1.07	2,065*	265	1.37	896*	156	(-0.30)	1,169

Table 3-6. EXHAUST EMISSION SUMMARY - AFTER DEVICE INSTALLATION (Continued)

Car No.	Yr/Make/CID/TR/Carb	As Received				Device Installed			Reduction		
		Odom	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)
Engine Class E (Continued)											
1285	65 Bui 310 A 2V	104,434	376*	2.22*	1,183*	145	1.07	733	231	1.15	450
1302	63 Chr 361 A 2V	71,209	432*	3.87*	856*	196	3.46*	393	236	0.40	463
1310	64 For 352 A 2V	94,678	349*	0.61	2,601*	221	0.61	1,059*	12	0.0	1,542
1320	63 For 352 A 2V	83,476	335*	1.28	1,831*	168	0.96	860*	167	0.32	971
1321	65 Che 327 A 4V	68,330	488*	1.83*	1,654*	266	1.48	793	222	0.35	861
1324	65 Ply 318 A 2V	88,352	410*	2.78*	1,070*	184	1.91*	585	226	0.87	475
1328	64 Chr 361 A 2V	85,324	328*	2.22*	920*	88	0.92	627	240	1.30	293
1332	65 Ply 361 A 2V	69,909	307	1.95*	1,794*	247	1.13	464	60	0.82	1,330
1333	63 Ram 327 A 4V	80,115	376*	3.08*	641	206	1.25	666	170	1.83	(-25)
1335	63 Dod 361 A 4V	76,616	268	0.68	1,779*	143	1.36	816	125	(-0.68)	963
1338	64 Dod 318 A 2V	77,242	339*	1.71	2,124*	255	2.63*	1,210*	84	(-0.92)	914
1339	61 Mer 352 A 2V	93,832	304	1.19	1,320*	170	0.80	413	134	0.39	907
1342	64 Che 327 A 4V	77,704	556*	2.46*	960*	178	0.76	746	378	1.70	214
1343	64 Tmp 326 A 2V	66,196	410*	2.83*	682	201	4.12*	193	209	(-1.29)	489
	Average	84,568	358*	1.79	1,463*	210	1.94*	669	148	(-0.15)	794
Engine Class F											
1230	63 Old 394 A 2V	82,441	213	2.26*	715	216	3.04*	565	(-3)	(-0.78)	150
1270	64 Mer 390 A 2V	81,662	255	2.18*	1,092*	96	1.36	637	159	0.82	455

Table 3-6. EXHAUST EMISSION SUMMARY - AFTER DEVICE INSTALLATION (Continued)

Car No.	Yr/Make/CID/TR/Carb	As Received				Device Installed			Reduction		
		Odom	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)
Engine Class F (Continued)											
1300	65 For 390 A 4V	80,100	364*	1.92*	1,405*	147	0.67	759	217	.25	646
1322	62 Bui 401 A 4V	86,914	234	2,34*	534	360*	1.96*	540	(-126)	0 38	(-6)
1331	63 Cad 390 A 4V	42,703	228	1.86*	1,015*	134	1.21	443	9[illegible]	0.65	572
1334	64 Pon 389 A 4V	86,954	382*	0.36	1,572*	129	0.80	614	253	(-0.44)	958
1340	65 Cad 429 A 4V	76,152	207	1.09	1,788*	114	1.28	512	93	(-0.19)	1,275
Average		76,704	269	1.72	1,160*	171	1.47	582	98	0.24	579
Grand Average		78,305	342*	1.83*	1,295*	223	1.89*	631	119	(-0.06)	664
% Reduction									34.8	(-3.3)	51.3

NOTES: *Failed to meet standard:

HC 318 ppm

CO 1.82%

NO 842 ppm

Negative values indicate increases

Table 3-7. NUMBER OF VEHICLES MEETING VARIOUS COMBINATIONS OF THE THREE EMISSION STANDARDS - AFTER APC DEVICE INSTALLATION

Engine	No. of Standards Met				Total
	0	1	2	3	
B	0	2	3	1	6
C	0	0	6	2	8
D	0	1	6	3	10
E	0	2	7	10	19
F	0	0	2	5	7
All Vehicles	0	5	24*	21	50

*The failing pollutant increased from its original value on eight of these vehicles (7 CO, 1 HC).

3.5.2 Drivability Test

A warm vehicle drivability test was performed after device installation. Noticeable power loss was the most often noted effect. Hesitation and stumble on accelerations were the other most commonly noted drivability observations. Table 3-8 lists the before and after standing-start accelerations and notes any significant comments made by the drivers. If no entry appears in the remarks column, there was no appreciable change from before to after device installation. The results listed are the average of three tests by three different drivers in both the before and after installation tests.

From the drivability result comparisons, it can be seen that 37 of the cars lost acceleration, 3 were unchanged, and 10 were improved. In general, cars that were in good shape suffered from the device installation, while cars in bad shape were improved.

3.6 MILEAGE ACCUMULATION

Following completion of the post-installation testing, the vehicles were returned to their owners who were instructed to drive as they normally would until they were

Table 3-8. DRIVABILITY TEST COMPARATIVE RESULTS

Car No.	Before 0-70	After 0-70	Remarks
1201		20.7	Power loss in PT* Crowd; Rumble and hesitation on acceleration
1207	21.5	23.2	Increased stretchiness noted in PT Tip-in
1213	18.1	18.2	
1226	19.9	19.7	Less detonation on PT acceleration, Crowd, and Tip-in with device
1229	29.0	35.0	
1230	15.8	15.6	Could attain 15" Hg with device could not without it
1237	21.8	22.6	
1240	13.5	14.5	Could attain 15" Hg with device, could not without it
1245	15.3	15.5	
1248	19.1	25.7	Significant increase in stretchiness on WOT and PT
1250	25.0	28.3	Would not accelerate at 15" Hg without device, would with it
1253	34.4	36.9	
1255	18.0	20.2	Marked elimination of hesitation and stretchiness with device
1257	15.2	15.2	
1265	18.5	16.7	
1267	16.9	26.8	Transmission would not down-shift with device
1270	17.3	18.2	Elimination of hesitation and stretchiness with device
1273	15.9	16.3	
1274	14.8	14.8	Elimination of hesitation and stretchiness with device
1285	15.1	16.0	Increased stretchiness and hesitation with device
1292	19.5	19.4	Decrease in stretchiness with device
1300	13.6	15.3	Decrease in stretchiness and hesitation with device
1301	21.3	23.2	Increased hesitation and stretchiness with device
1302	18.5	18.7	Increased hesitation and stretchiness with device
1305	18.2	16.7	
1306	17.9	18.3	

Table 3-8. DRIVABILITY TEST COMPARATIVE RESULTS

Car No.	Before 0-70	After 0-70	Remarks
1310	[illegible]	14.7	Decrease in stretchiness and hesitation with device
1316	23.7	27.1	Increased hesitation and stretchiness with device
1320	19.3	18.5	Decreased detonation with device
1321	13.9	15.5	
1322	15.5	15.5	Hesitation increased with device
1323	19.8	17.0	Hesitation increased with device
1324	17.1	15.9	Decreased hesitation with device
1325	21.7	20.9	Decreased detonation with device
1326	16.9	18.1	
1327	34.1	37.0	Increased hesitation and stretchiness with device
1328	16.5	18.4	Increased stretchiness and hesitation with device
1329	25.9	30.4	Increased stretchiness and hesitation with device; no acceleration at 15" Hg with device
1330	25.7	23.6	Increased hesitation and stretchiness with device
1331	13.3	15.3	Decreased detonation with device
1332	16.5	17.7	Increased stretchiness and hesitation with device
1333	16.1	16.8	
1334	13.4	14.5	No acceleration at 15" Hg with device; increased detonation, stumble, and stretchiness during acceleration; decreased detonation during cruise
1335	11.0	12.5	Increased hesitation during PT acceleration with device
1337	14.6	15.9	
1338	15.0	17.9	
1339	19.3	20.5	Decreased hesitation during acceleration with device
1340	14.4	19.1	Increased hesitation and stumble during WOT with device
1342	12.8	13.3	No change except cannot attain 15" Hg with device
1343	15.5	16.5	No change except cannot attain 15" Hg with device
Average	18.5	19.8	

*PT means partial throttle
WOT means wide open throttle
See Appendix A for definition of terms

called in for device removal. This period of mileage accumulation was originally intended to be 30 days. A few cars exceeded the 30 days and, due to scheduling problems, quite a few did not attain the 30-day period. The average time the devices were on the cars was approximately 24 days.

3.6.1 Problems Encountered During Accumulation

Quite a few problems were brought to light during the period of mileage accumulation. These are listed by car number in Table 3-9. Other problems were brought to light when the vehicle owner questionnaires were returned, but the ones noted here were felt by the owner to be significant enough to bring the car back before the end of the mileage accumulation phase. In all, 10 cars experienced part failures of the APC components. Six of these failures were due to the recycle valve, two fittings failed, one set of metering rods was replaced, and one carburetor base plate was bad.

3.6.2 Preparation for Removal

Thirty days from the date of the first device installations, the first vehicles were called in for device removal. The vehicles were then checked to see that the APC device was still operating. If it was, the vehicle was moved to the test area and a final 7-mode hot-start test was run. If the device was inoperative or not installed properly, appropriate notations were made and the installation corrected before the final 7-mode hot-start test. In no case was the basic engine adjustments disturbed at this point. Table 3-10 lists the cars that needed repairs prior to final test.

3.6.3 Final 7-Mode Hot-Start Test

A final 7-mode hot-start test was run on each vehicle and recorded for evaluation. Test results are compared with pre-installation results in Table 3-11.

The final tests showed an average percent reduction of:

HC	36.0 percent
CO	-0.5 percent (increase)
NO	56.3 percent

Table 3-9. PROBLEMS DURING MILEAGE ACCUMULATION

Car No.	Remarks
1207	Fitting failed - APC part - replaced
1213	Leaking carburetor - pump diaphragm replaced; recycle valve frozen open - APC part - replaced; fouled No. 2 spark plug - replaced; sealed recycle valve stuck open - shaft bent - APC part - replaced; engine missed above 50 mph - plugs loose - tightened; dist. cap corroded - cleaned; coil wire contacts corroded - cleaned and reseated
1237	Frequent stalling and transmission shift problem - idle speed and linkage adjusted
1248	Overheating and no transmission kick-down - removed bug screen and reestablished kick-down
1250	Rough idled - throttle rod bushing replaced - no help
1265	Stalled, died, and rough idled - recycle valve replaced - APC part
1274	Rough idled and stalled - recycle valve stuck open - APC part - replaced
1285	Died, stalled, and bucked on acceleration - diagnosed as lean surge condition with light throttle - no correction
1302	Rough idled and stalled - recycle valve stuck open - APC part - replaced; hard cold start - malfunctioning choke - unable to repair
1305	Stalled on upshift and acceleration - second throttle operation not working properly - second throttle operating lever disconnected
1310	Rough idled - recycle valve stuck open - owner repaired with penetrating oil - APC part
1316	Heat riser valve stuck open more than usual - owner freed valve on weekly basis; carburetor bowl cover vent valve fell off
1325	Rough idled - No. 1 plug and coil wire replaced
1327	Owner disturbed settings and replaced carburetor - reran post-installation test
1330	Rough idled - no adjustment - suspect owner readjusted mixture, says he only adjusted idle speed

Table 3-9. PROBLEMS DURING MILEAGE ACCUMULATION (Continued)

Car No.	Remarks
1335	Poor operation - APC - replaced metering rods
1338	Whistling sound, rough idled - bad base plate casting causing air leak - APC part - not corrected
1340	Rough idle and shifting problems - car returned to installer for adjustment; exhaust leak on left side - manifold fitting broken at solder joint - APC part - replaced; exhaust leak on right side - blown exhaust manifold gasket - replaced

Table 3-10. OPERATIONAL INSPECTION PRIOR TO FINAL TEST

Car No.	Remarks
1237	Adjusted chain - too tight
1285	Replaced recycle valve - shaft bent - APC part
1292	Adjusted chain - lever attaching screw loose
1316	Replaced carburetor bowl vent valve
1327	Idle mixture adjusted by mistake by test personnel - idle mixture set to CO value very close to post-installation value

The significant additional NO improvement over the post-installation tests was due primarily to correction of the installation of the recycle tube on car number 1213. Forty-six of the 50 cars passed the NO standard of 842 ppm. The four failing vehicles showed highly significant reductions (an average of 45 percent). For purposes of comparison, initial testing revealed only 9 vehicles passed the NO standard.

The number of vehicles failing the HC standard before installation of the device was 29. The post-installation test results showed only 7 failures. All 7 improved with mileage accumulation; 3 to the point where they passed the standard. Two cars that originally passed (cars 1237 and 1255) degraded to a level worse than the

Table 3-11. EXHAUST EMISSION SUMMARY - AFTER MILEAGE ACCUMULATION

Car No.	Yr/Make/CID/TR/Carb	As Received				After Mileage Accum			Reduction		
		Odom	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)
Engine Class B											
1201	64 Che 194 A 1V	47,018	387*	1.29	1,466*	257	2.05*	658	130	(-0.76)	808
1226	62 Dod 170 A 1V	74,983	392*	3.73*	971*	399*	3.00*	420	(-7	0.73	551
1237	62 Mer 170 A 1V	49,878	500*	1.20	1,953*	377*	5.45*	185	123	(-4.25)	1,768
1250	63 Dod 170 A 1V	61,440	244	0.77	1,836*	210	1.37	831	34	(-0.60)	1,005
1253	63 Ch2 191 A 1V	66,565	322*	2.12*	871*	368*	2.53*	752	(-46)	(-0.41)	119
1327	63 Fal 170 A 1V	79,565	292	1.80	867*	269	2.84*	246	23	(-1.04)	621
Average		63,242	356*	1.82	1,327*	313	2.87*	515	43	(-1.06)	812
Engine Class C											
1207	64 Ply 225 A 1V	54,262	444*	3.31*	922*	161	2.30*	381	283	1.01	541
1229	65 Tmp 215 A 1V	151,250	184	2.34*	803	254	2.72*	608	(-70)	(-0.38)	195
1301	65 Dod Drt 225 A 1V	53,984	175	1.43	1,561*	143	1.09	929*	32	0.34	632
1305	62 Old 215 A 4V	49,819	593*	0.82	1,101*	278	1.56	474	315	(-0.74)	627
1316	63 Ply Val 225 A 1V	86,957	302	0.76	1,389*	204	1.86*	689	98	(-1.10)	700
1326	63 Ply Val 225 A 1V	110,992	336*	1.28	1,086*	195	0.58	808	141	0.70	278
1329	63 Che 230 A 1V	84,827	557*	4.18*	1,114*	194	2.77*	256	363	1.41	858
1330	63 Dod Drt 225 A 1V	102,060	186	0.70	1,754*	120	0.67	673	66	0.03	1,081
Average		86,769	347*	1.85*	1,216*	194	1.69	602	154	0.16	614

Table 3-11. EXHAUST EMISSION SUMMARY - AFTER MILEAGE ACCUMULATION (Continued)

Car No.	Yr/Make/CID/TR/Carb	As Received				After Mileage Accum			Reduction		
		Odom	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	C. (	NO (PPM)
Engine Class D											
1213	64 Ram 287 A 2V	58,132	307	0.76	1,254*	192	0.99	563	115	(-0.23)	691
1255	64 Mus 289 A 2V	74,042	271	2.55*	452	446*	4.41*	218	(-175)	(-1.86)	234
1257	65 For 289 A 4V	63,997	358*	4.06*	781	214	3.99*	291	144	0.07	490
1265	65 Che 283 A 2V	55,845	434*	2.02*	1,121*	180	1.99*	396	254	0.03	725
1273	64 Bui Sklk 300 A 2V	76,523	280	1.79	1,476*	167	2.26*	429	113	(-0.47)	1,047
1292	63 Che 283 A 2V	78,882	546*	2.37*	821	245	1.79	586	301	0.58	235
1306	64 Fal 260 A 2V	73,584	351*	1.16	1,505*	243	1.11	759	108	0.05	746
1323	64 Dod Drt 273 A 2V	83,757	250	0.39	1,379*	365*	1.50	699	(-115)	(-1.11)	680
1325	65 Che 283 A 2V	59,443	247	1.96*	644	212	2.66	241	35	(-0.70)	403
1337	65 Mus 289 A 4V	72,743	466*	2.46*	1,704*	299	2.83	605	167	(-0.37)	1,099
Average		69,695	351*	1.95*	1,114*	256	2.35*	479	95	(-.40)	635
Engine Class E											
1240	58 Ply 318 A 2V	86,547	216	0.59	3,055*	226	0.36	999*	(-10)	0.23	2,056
1245	64 Old 330 A 2V	129,904	320*	1.63	1,497*	144	1.62	556	176	0.01	941
1248	60 Bui 364 A 2V	83,674	337*	0.90	912*	188	0.41	686	149	0.49	226
1267	58 Dod 361 A 2V	105,600	239	1.21	870*	309	4.92*	264	(-70)	(-3.71)	606
1274	65 Che 327 A 4V	64,646	421*	1.07	2,065*	171	0.63	824	250	0.44	1,241
1285	65 Bui 310 A 2V	104,434	376*	2.22*	1,183*	181	2.28*	576	195	(-0.06)	607

Table 3-11. EXHAUST EMISSION SUMMARY - AFTER MILEAGE ACCUMULATION (Continued)

Car No.	Yr/Make/CID/TR/Carb	As Received				After Mileage Accum			Reduction		
		Odom	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)
Engine Class E (Continued)											
1302	63 Chy 361 A 2V	71,209	432*	3.87*	856*	241	3.16*	176	191	0.70	680
1310	64 For 352 A 2V	94,678	349*	0.61	2,601*	199	1.10	888*	150	(-0.49)	1,713
1320	63 For 352 A 2V	83,476	335*	1.28	1,831*	174	0.77	671	161	0.51	1,160
1321	65 Che 327 A 4V	68,330	488*	1.83*	1,654*	156	0.35	707	332	1.48	947
1324	65 Ply 318 A 2V	88,352	410*	2.78*	1,070*	141	1.55	328	269	1.23	732
1328	64 Chy 361 A 2V	85,324	328*	2.22*	920*	110	0.65	639	218	1.57	281
1332	65 Ply 361 A 2V	69,909	307	1.95*	1,794*	215	0.96	592	92	0.99	1,202
1333	63 Ram 327 A 4V	80,115	376*	3.08*	641	246	1.61	674	130	1.47	(-33)
1335	63 Dod 361 A 4V	76,616	268	0.68	1,779*	202	0.99	628	66	(-0.31)	1,151
1338	64 Dod 318 A 2V	77,242	339*	1.71	2,124*	286	2.33*	781	53	(-0.62)	1,343
1339	61 Mer 352 A 2V	93,832	304	1.19	1,320*	155	1.06	427	149	0.13	893
1342	64 Che 327 A 4V	77,704	556*	2.46*	960*	246	0.84	850*	310	1.62	110
1343	64 Tmp 326 A 2V	66,196	410*	2.83*	682	156	1.97*	326	254	0.86	356
	Average	84,568	358*	1.79	1,463*	197	1.45	610	161	0.33	853*
Engine Class F											
1230	63 Old 394 A 2V	82,441	213	2.26*	715	221	2.90*	506	(-8)	(-0.64)	209
1270	64 Mer 390 A 2V	81,662	255	2.18*	1,092*	128	1.44	453	127	0.74	639
1300	65 For 390 A 4V	80,100	364*	1.92*	1,405*	139	1.70	588	225	0.22	817

Table 3-11. EXHAUST EMISSION SUMMARY - AFTER MILEAGE ACCUMULATION (Continued)

Car No.	Yr/Make/CID/TR/Carb	As Received				After Mileage Accum			Reduction		
		Odom	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	)	NO (PPM)
Engine Class F (Continued)											
1322	62 Bui 401 A 4V	86,914	234	2.34*	534	307	0.63	710	-73	1.71	(-176)
1331	63 Cad 390 A 4V	42,703	228	1.86*	1,015*	139	1.10	478	89	0.76	537
1334	64 Pon 389 A 4V	86,954	382*	0.36	1,572*	173	0.95	606	209	(-0.59)	966
1340	65 Cad 429 A 4V	76,152	207	1.09	1,788*	114	1.35	684	93	(-0.26)	1,104
Average		76,704	269	1.72	1,160*	174	1.44	575	95	0.28	585
Grand Average		78,305	342*	1.83*	1,295*	219	1.84*	566	123	(-0.01)	729
% Reduction									36.0	0.5	56.3

NOTES: *Failed to meet standard:

HC - 318 ppm

CO - 1.82%

NO - 842 ppm

Negative values indicate increases

standard. These degradations in HC were probably due to a large increase in CO. Both cars had very dirty carburetors that were in need of overhaul.

Nine[illegible] vehicles did not meet the CO standard of 1.82 percent after mileage accumulation. In addition, the fleet average was 0.02 percent above the 1.82 percent CO standard.

3.6.4 Mileage and Time Accumulation

Logistics problems in accomplishing emission testing, drivability, and longer-than-anticipated total device installation times precluded accumulation of at least 30 days on each test vehicle. Ten cars met or exceeded the 30-day timeframe. The average time accumulation was just over 24 days. The short time duration with the device installed on car 1342 was due to lack of an installation kit.

Mileage accumulations ranged from 2,855 down to 335, with an average accumulation of 824 per car. Car owners were asked to accumulate mileage at their normal rate.

An interesting observation is that when the average mileage accumulated for 24 days is extrapolated to a yearly basis, the annual accumulation would be 12,408 miles per year for cars averaging 7.5 years old. Even when the single high accumulated mileage car (number 1285) is removed from the sample as being unrepresentative, the annual mileage would be 11,768.

The mileage figures and dates of the tests performed as a baseline, after device installation, after mileage accumulation, and the mileage and time accumulated while the device was on each car are listed in Table 3-12.

3.7 POST-REMOVAL EVALUATION

This subsection utilizes the data recorded in the preceding paragraphs to arrive at an evaluation of the APC exhaust emission control device in terms of emission reduction, installation cost, owner drivability comments, and manufacturability.

Table 3-12. MILEAGE AND TIME ACCUMULATION

Car No.	Class	Baseline		Installation		"30" Days		Accumulation with Device	
		Odom	Date	Odom	Date	Odom	Date	Miles	Days
1201	B	47,018	5/13	47,185	5/18	47,720	6/16	535	30
1207	C	54,262	5/1[illegible]	54,480	5/17	55,402	6/16	922	31
1213	D	58,132	5/12	58,289	5/18	58,965	6/16	676	30
1226	B	74,983	5/12	75,153	5/20	75,608	6/18	455	29
1229	C	151,250	5/24	151,403	5/26	153,050	6/23	1647	28
1230	F	82,441	5/17	82,525	5/19	83,573	6/22	1048	34
1237	B	49,878	5/11	50,236	5/21	50,586	[illegible]/15	350	25
1240	E	86,005	5/17	86,309	5/24	87,562	6/[illegible]1	1253	28
1245	E	129,904	5/26	130,196	6/1	131,138	6/23	942	22
1248	E	83,674	5/14	83,927	5/19	84,583	6/21	656	33
1250	B	61,440	5/13	61,577	5/19	61,947	6/17	370	29
1253	B	66,565	5/20	66,679	5/24	67,060	6/22	381	29
1255	D	74,042	5/11	74,824	5/26	75,985	6/24	1161	29
1257	D	63,997	5/13	64,192	5/17	65,239	6/17	1047	31
1265	D	55,845	5/13	55,997	5/19	56,586	6/16	589	28
1267	E	105,600	5/24	105,733	5/27	106,187	6/24	454	28
1270	F	81,662	5/13	81,981	5/19	83,145	6/17	1164	29
1273	D	76,523	5/20	76,652	5/24	77,272	6/17	620	24
1274	E	64,646	5/14	64,804	5/18	65,894	6/17	1090	30
1285	E	104,434	5/11	104,990	5/17	107,845	6/15	2855	29
1292	D	78,882	5/11	79,106	5/17	79,965	6/15	859	29
1300	F	80,100	5/11	80,268	5/13	81,735	6/15	1467	33
1301	C	53,984	5/24	54,080	5/26	54,965	6/24	885	29
1302	E	73,503	5/14	73,644	5/19	74,493	6/17	849	29
1305	C	49,819	5/14	49,887	5/19	50,248	6/16	361	28
1306	D	73,584	5/12	74,078	5/21	75,208	6/21	1130	31
1310	E	94,678	5/11	94,977	5/17	96,014	6/15	1037	29
1316	C	86,957	5/12	87,086	5/14	88,851	6/15	1765	32
1320	E	83,476	5/17	83,587	5/19	84,113	6/17	546	29
1321	E	68,330	5/24	68,427	5/28	69,025	6/18	598	21
1322	F	86,914	5/24	87,240	5/28	88,554	6/23	1314	26

Table 3-12. MILEAGE AND TIME ACCUMULATION (Continued)

Car No.	Class	Baseline		Installation		"30" Days		Accumulation with Device	
		Odom	Date	Odom	Date	Odom	Date	Miles	Days
1323	D	83,757	5/25	84,028	6/1	84,833	6/21	805	20
1324	E	88,352	5/ ··	88,663	6/2	89,309	6/18	646	16
1325	D	59,443	5/26	59,520	5/28	60,145	6/21	625	24
1326	C	110,992	6/2	111,131	6/4	111,597	6/22	466	18
1327	B	79,565	5/28	79,516	5/27	80,41·	6/22	895	26
1328	E	85,324	6/2	85,447	6/4	86,150	6/24	703	20
1329	C	84,827	6/1	84,956	6/3	85,603	6/21	647	18
1330	C	102,060	6/1	102,289	6/7	103,024	6/22	735	15
1331	F	42,703	6/1	42,828	6/3	43,578	6/24	750	21
1332	E	69,909	6/1	69,909	6/8	69,919	6/24	†	16
1333	E	80,115	6/3	80,352	6/7	80,870	6/23	518*	16
1334	F	86,954	6/3	87,166	6/4	87,960	6/22	794	18
1335	E	76,617	6/2	76,749	6/7	77,084	6/22	335	15
1337	D	72,743	6/2	73,055	6/8	73,808	6/22	753	14
1338	E	77,242	6/7	77,355	6/9	77,71·	6/23	360	14
1339	E	82,832	6/8	82,944	6/9	83,670	6/23	726	14
1340	F	76,152	6/7	76,294	6/9	76,734	6/23	440	14
1342	E	77,704	6/8	77,997	6/16	78,·34	6/24	437	8
1343	E	66,196	6/8	66,323	6/10	67,031	6/23	708	13
						Total		40,369*	1212
						Average		824*	24.24

†Odometer inoperative

*Does not include car 1332. Car 1333 mileage questionable.

Projecting mileage to a yearly basis:

$$\frac{X}{824} = \frac{365}{24.24} \qquad X = \frac{365(824)}{24.24} = 12{,}408$$

3.7.1 Emissions Reduction

The fleet of 50 cars possessed an average baseline emission level that was extremely good for uncontrolled cars. It can be argued that these cars had received service 5 months previously in the Vehicle Emission and Maintenance Study and were therefore not representative. On the contrary, this makes the emission reductions achieved all the more impressive.

Twenty-one of the 50 APC study cars had not been previously serviced as part of any vehicle emission reduction program. They had received only normal owner maintenance. Table 3-13 lists the results obtained on this group of cars. It shows that the average emission levels achieved after minimal maintenance was almost exactly the same as the total group.

Table 3-14 lists the standards and averages achieved at each point of testing. As a point of interest, the fleet average is included for 278 uncontrolled cars after servicing in the Vehicle Emission and Maintenance Study.

Table 3-15 lists the number of vehicles in each class which met the above emission standards before installation and after mileage accumulation. This table indicates that HC emission standards are met by twice as many vehicles after the installation of the APC device. NO emission standards are met by 32 percent of the vehicles after APC device installation, rather than the 18 percent before installation. CO emission standards are also met by more vehicles after APC installation, 50 percent before compared to 62 percent after. The fleet average CO emission, however, is slightly increased.

Figure 3-1 is a pictorial presentation of the percentage reductions achieved from the baseline test to the test after mileage accumulation.

An important goal in the battle against air pollution is the reduction of photochemical smog. Considering only those measured pollutants that contribute to photochemical smog (HC and NO_x), a 48.5 percent reduction in reactive exhaust emittants was achieved by the APC device. Reactivity of 36 percent is assumed for HC. Because of the multiple sources of NO_x, it is assumed that a reduction in HC is twice as effective as an equal reduction in NO_x.

Table 3-13. EXHAUST EMISSION SUMMARY - CALIFORNIA 7-MODE HOT-START TEST DATA

Car No.	Yr/Make/CID/TR/Carb	Repairs($)	Baseline			Device Installed			30 Days			Remar
			HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	HC (PPM)	CO (%)	NO (PPM)	
1321	65 Che 327 A 4V		488*	1.83*	1,654*	266	1.48	793	156	0.35	707	
1322	62 Bui 401 A 4V	1.40	234	2.34*	534	360*	1.96*	540	307	0.63	710	Spark plug
1323	64 Dod Drt 273 A 2V	1.25	250	0.39	1,379*	291	1.09	673	365*	1.50	699	Spark plug
1324	65 Ply 318 A 2V		410*	2.78*	1,060*	184	1.91*	585	141	1.55	328	
1325	65 Che 283 A 2V		247	1.96*	644	257	2.61*	527	212	2.66*	241	
1326	63 Val 225 A 1V	3.40	336*	1.28	1,086*	194	0.81	678	195	0.58	808	Plug wires
1327	63 Fal 170 A 1V		292	1.80	867*	214	3.41	186	269	2.84*	246	
1328	64 Che 361 A 2V	16.40	328*	2.22*	920*	88	0.92	627	110	0.65	639	Spark plugs
1329	63 Che 230 A 1V		557*	4.18*	1,114*	218	2.08*	622	194	2.77*	256	
1330	63 Dod Drt 225 A 1V		186	0.70	1,754*	154	1.01	437	120	0.67	673	
1331	63 Cad 390 A 4V		228	1.86*	1,015*	134	1.21	443	139	1.10	478	
1332	65 Ply 361 A 2V		307	1.95*	1,794*	247	1.13	464	215	0.96	592	
1333	63 Ram 327 A 4V	2.89	376*	3.08*	641	206	1.25	666	246	1.61	674	PCV valve
1334	64 Pon 389 A 4V	21.00	382*	0.36	1,572*	129	0.80	614	173	0.95	606	Plugs, wires
1335	63 Dod 361 A 4V		268	0.68	1,779*	143	1.36	816	202	0.99	628	
1337	65 Mus 289 A 4V		466*	2.46*	1,704*	302	2.76*	631	299	2.83*	605	
1338	64 Dod 318 A 2V		339*	1.71	2,124*	255	2.63*	1,210*	286	2.33*	781	
1339	61 Mer 352 A 2V		304	1.19	1,320*	170	0.80	413	155	1.06	427	
1340	65 Cad 429 A 4V	21.65	207	1.09	1,788*	114	1.28	513	114	1.35	684	Exhaust mani d gasket
1342	64 Che 327 A 4V		556*	2.46*	960*	178	0.76	746	246	0.84	850*	
1343	64 Tmp 326 A 2V		410*	2.83*	682	201	4.12*	193	156	1.97*	526	
	Total Repairs	67.99										
	Scope Check and Adjustment at 8.50/Car	178.50										
	Total	246.49										
	Average	11.74	341*	1.86*	1,257*	205	1.68	589	205	1.44	569	

*Failed to meet standard: HC - 318 PPM; CO - 1.82%; NO - 842 PPM.

Table 3-14. AVERAGE EMISSION LEVELS

Pollutant	Hot-Start Used	Baseline		Pos - Installation	Mileage Accum	278 Cars After Service*
		Fleet	Previously Untested Group			
HC	318 ppm	3[illegible]	341	223	219	475
CO	1.82%	1.83	1.86	1.89	1.84	2.48
NO	842 ppm	1295	1257	631	566	1228

*From the Vehicle Emission and Maintenance Study, "Fleet Statistics - After Service - Uncontrolled Cars," Northrop Corporation.

Table 3-15. NUMBER OF VEHICLES MEETING SPECIFIC EMISSION STANDARDS - BEFORE INSTALLATION AND AFTER MILEAGE ACCUMULATION - APC DEVICE

No. of Vehicles	Class	As Received			After Mileage Accumulation		
		HC	CO	NO	HC	CO	NO
6	B	2	4	0	3	1	6
8	C	4	5	1	8	4	7
10	D	5	4	4	8	6	10
19	E	5	10	2	19	14	16
7	F	5	2	2	7	6	7
Total 50	B-F	21	25	9	45	31	46

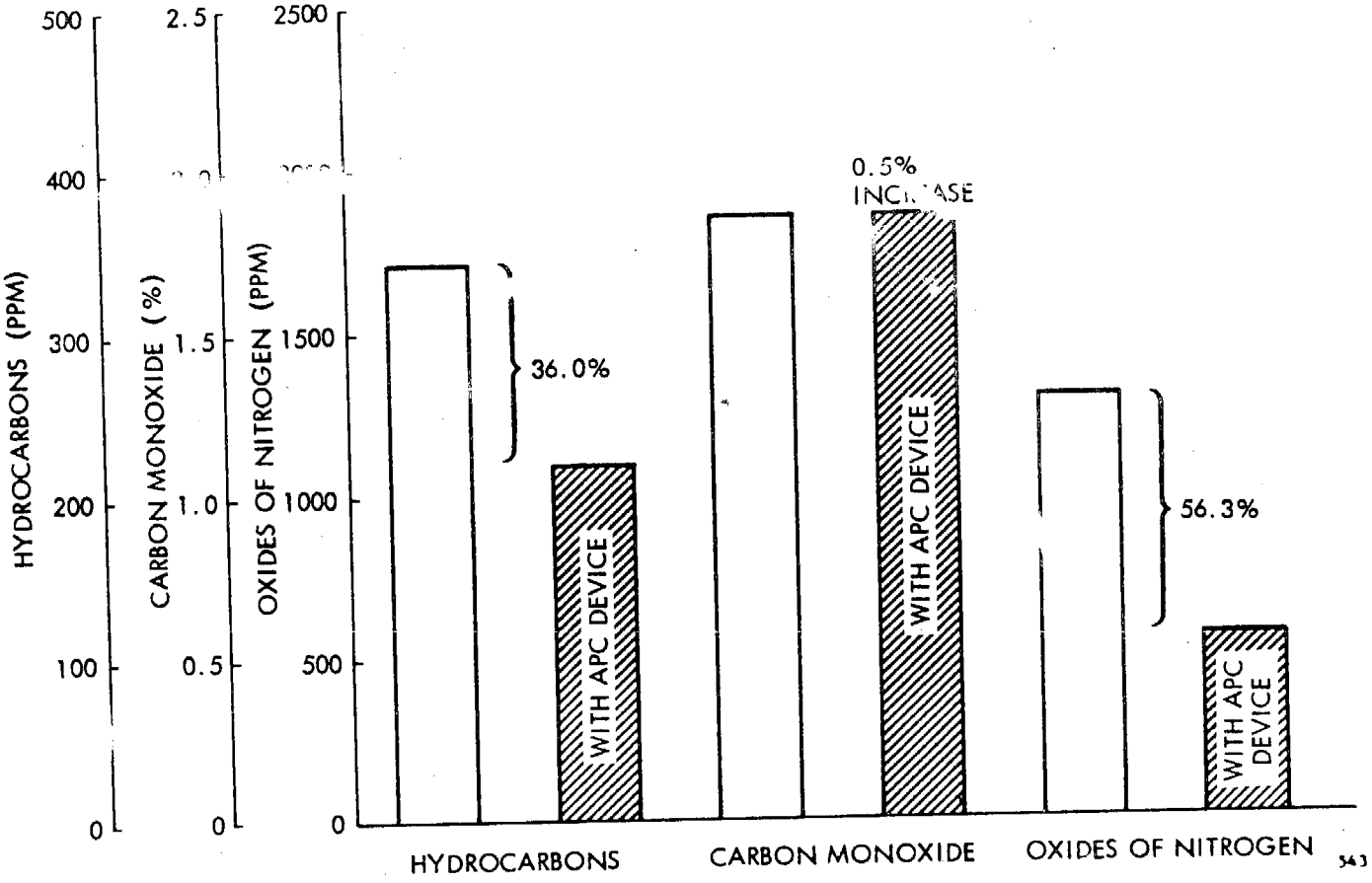


Figure 3-1. PROFILE OF FLEET EXHAUST EMISSIONS

This reduction was calculated from the following formulation.*

$$\text{\% Reduction in Reactive Emittants} = \frac{.36\ (HC_1 - HC_2) - (NO_{x_1} - NO_{x_2})/2}{.36\ HC_1 + NO_{x_1}/2}$$

$$= \frac{.36(1.50) + 2.46/2}{.36(4.07) + 4.57/2}$$

$$= \frac{.54 + 1.23}{1.47 + 2.28}$$

$$= \frac{1.77}{3.75}$$

$$= 48.5\%$$

*Gockel, J. L., Maintenance and Inspection of Used Cars, pages presented to the Fifth Technical Meeting, West Coast Section, Air Pollution Control Association, October 1970.

where: HC_1, HC_2, NO_{x_1}, and NO_{x_2} are the fleet averages before and after device installation for HC and NO_x, respectively, in grams/mile.

3.7.2 Installation Costs

The average cost of device installation was $21.32. A few parts were required that were not in the installation kits or were damaged during the installation. A small percentage of the cars required the replacement of the top radiator hose to accomplish a sound installation.

A matter of considerable interest is the cost of tuning up cars prior to device installation. All of the cars used were checked with an analyzer to determine the operating condition of the engines. Identified part failures were repaired prior to device installation. All cars were adjusted to manufacturer's specifications where necessary. Assuming a 1-hour minimum labor charge of $8.50 for this analysis and adjustment plus any parts replaced, a fleet average pre-installation tuneup cost of $10.71 was identified. For the subset of 21 cars that were new to emission reduction programs, an average repair cost of $11.74 was noted.

3.7.3 Owner Drivability

Vehicle owners were given a post card at the end of the mileage accumulation phase on which they were asked to indicate whether they felt that their car ran better, worse, or did not change as a result of the device installation. Additional comments were also solicited. Table 3-16 is a tabulation of these questionnaire responses. Of the 48 responses, 45 checked one of three choices. The breakdown is:

Choice	Percent	Responses
Improved	15.6	7
No Change	24.4	11
Worse	60.0	27
	100.0	45

Table 3-16. CAR OWNER DRIVABILITY COMMENTS

Class	Car No.	No Change	Improved	Worse	Remarks	Cold Start	Hot Start	Idle	Stall	Surge	Hesitation	Stumble	Power	Mileage	Cooling	Trans Shift
B	1201			*		X			X				X			
	1226	*			Cold start improved											
	1237			*	Felt unsafe	X		X	X	X	X			X		
	1250	*														
	1253	*														
	1327		*			X		X	X					●		
C	1207							X				X	X		X	
	1229	*				X										
	1301			*		X						X	X			
	1305		(No Check)		Eliminate exhaust smoke	X					X	X	X	●		X
	1316			*	Heat riser sticks						X	X	X	X		
	1326			*	Felt unsafe						X		X			
	1329			*						X		X				
	1330			*					X		X		X	X	X	
D	1213		(No Check)		Eliminate exhaust smoke			X					X			Y
	1255		*		Ran fine		X									
	1257		*		Smoother running										X	
	1265			*	Engine noise, choke sticks											
	1273				Questionnaire not returned											
	1292			*		X			X							
	1306			*								X			X	
	1323	*								X	X					
	1325	*														
	1337	*														
E	1240			*	Hot idle fast	X		X	X	X						
	1245	*			No comments											
	1248			*	No transmission kick-down								X		X	Y
	1267		*		Runs quite smoothly											

The comments were interpreted where possible to fit into the following problem categories:

Problem	Percent	Responses
Cold start	22.9	11
Hot start	2.0	1
Idle	22.9	11
Stall	22.9	11
Surge	12.5	6
Hesitation	16.7	8
Stumble	14.5	7
Power	33.3	16
Gas mileage	12.5 (4.1)	6 (2)
Cooling	10.4	5
Transmission	14.5	7

The gas mileage was reported to have increased on two cars, but six reported significant mileage decreases. Not all owners responded in each category.

It is interesting to note that several of the high percentage complaints recorded by the owners are not unlike those being voiced by owners of 1971 cars that are equipped with NO_x control devices and that meet the current HC, NO_x, and CO standards. These problems are: cold start, idle, surge, hesitation, lower power, and lower gas mileage.

3.7.4 Manufacturing Engineering Evaluation

A manufacturing engineering evaluation of the APC device was performed by Northrop Manufacturing Engineering. The purpose of the evaluation was to determine the producibility of this device in production quantities and to determine what changes would be required both from design and production requirements. The following paragraph documents the results of these findings.

3.7.4.1 Results - As noted previously, problems were encountered in the gas recirculation valve. Carbon deposits accumulated internal to the valve and resulted

in a "stuck" valve (open position). While this condition does not present a safety hazard, it does present an unacceptably rough idle condition.

An analysis of the problem indicated that the teflon coating was not uniformly deposited on all the internal moving parts of the valve assembly and resulted in formation of carbon deposits causing the valve to malfunction. Areas of improvement of the design are discussed below. These suggested changes would result in better performance and less expensive manufacturing.

a. Redesign valve assembly and restrictor. Make from Type 303, 347, or 416 CRES Hex Rod with male and female threads to eliminate modified standard fittings that are presently silver soldered to the body (see Figure 3-2).

b. Use Type 321 or 347 stainless steel mechanical tubing or inconel tubing in place of copper. Copper tubing has a tendency to corrode and flake when exposed to exhaust gases at elevated temperatures. These flakes could cause obstructions in the restrictor.

c. Use all stainless steel standard fittings.

d. Buy metering rods from carburetor manufacturers to close tolerance specifications, or buy standard jets with a smaller orifice and ream to required size.

e. Make standardized gaskets for carburetor adaptors. This would reduce the required inventory from approximately 50 presently being used to 9.

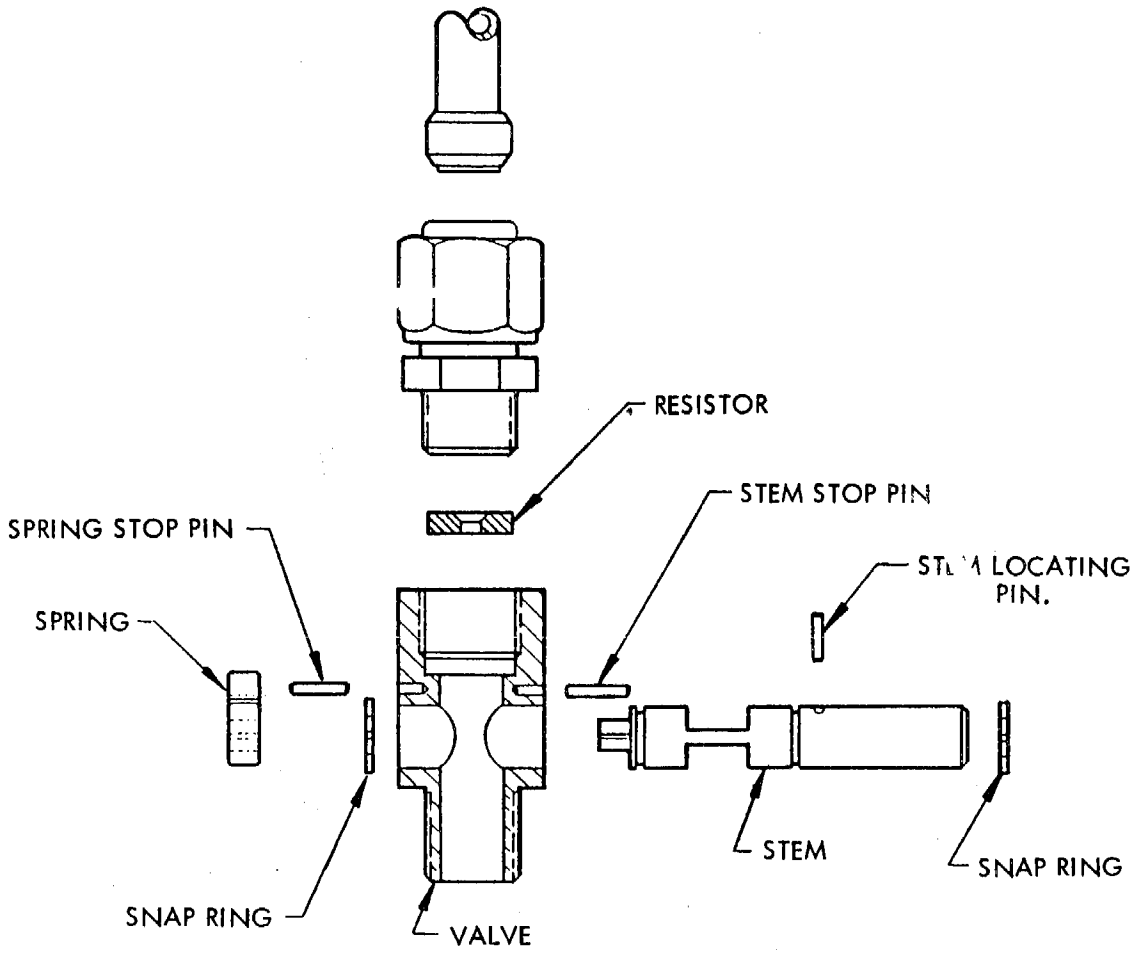
f. Evaluate vacuum switch installation. Alternate methods are:

   (1) Design switch assembly that would pierce radiator hose and be held in place with a clamp assembly. A liquid or paste sealant would be required to ensure leakproof installation.

   (2) Vulcanize or pot switch into an adaptor to eliminate welding special metal tube and fitting.

   (3) Design a special vacuum and heat indicator switch to replace original heat indicator.

g. Evaluate linkage assembly. Replace rod and chain assembly with boden wire (similar to a choke or throttle cable).



NOTES:

1. APPLY TEFLON COATING TO I.D. BORES OF VALVE, RESTRICTOR & STEM
2. VALVE MAT'L IS TYPE 303, 347 OR 416 CRES. HEX. BAR.

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Figure 3-2. APC VALVE ASSEMBLY

h. Use Type 303, 347, or 416 CRES Rod for restrictor and stem (see Figure 3-2).

i. Use permanent mold castings in place of sand castings for the adaptor plates. This change would eliminate most of the machining presently required on sand cast parts. The surface condition and the aesthetic value of the part would be greatly improved at no additional cost.

Because of the large variety of carburetors, detail parts and assemblies should be originally distributed to installation stations in a specially designed cabinet. The cabinet should contain the following items:

a. Compartments or drawers for each detail part or assembly.

b. Complete installation/repair manual with pictorial illustrations of installations for each type or group of cars.

c. An inventory card file for each part. A card could be removed each time a part is used. The cards for used parts can be evaluated and returned to the distributor to order replacement parts.

d. Counter work area (bench or shelf).

e. Tools not commonly used in service/repair station:

   (1) Tube bender
   (2) Drill and tap set (to drill and tap exhaust manifold)
   (3) Snapring pliers
   (4) Special tools, if any, developed by APC.

f. Maintenance leaflets, for the customer, defining cleaning requirements and emergency repairs.

3.8 CONCLUSIONS

The conclusions drawn from this study are:

- The APC exhaust emission control device is highly effective in reducing NO.
- The device is also very effective in reducing HC.
- The contribution of pre-1966 vehicles to photochemical smog can be greatly reduced with the installation of the APC device.
- A reduction in CO could also be achieved with the inclusion of an idle mixture adjustment procedure in the installation instructions. Use of a CO measuring device before and during installation would help to ensure a reduction in CO.
- Many of the owner complaints could be reduced with an improved installation procedure and the inclusion of a road test following installation.

- Requirement of a road test, with a checklist, as part of the installation. This may add 30 minutes to the cost of installation, but would eliminate many of the problems encountered.

3.8.2 Drivability

The drivability problems noted above and in paragraph 3.7.3 can be reduced by improvement of the installation procedure as indicated in preceding paragraphs.

The problems can be reduced further with an education process stressing the benefits to be gained in reduction of air pollution and preparing the owner for the potential drivability problems that might occur. Driving habits have to be changed somewhat, especially in areas requiring use of power on sudden accelerations. These include passing on two-way roads or getting out of the way of on-coming traffic. Most of these problems affect owners of lower powered cars, but can also occur in larger engine cars.

3.8.3 Production and Packaging

The use of stainless steel valve assembly tubing and standard fittings in place of brass and copper will increase the life expectancy of troublefree operation, with no appreciable increase in the cost of material and fabrication. A more comprehensive and extensive Engineering/Manufacturing evaluation would increase the efficiency and lower the cost of fabrication and installation. These suggested changes should not result in any change with respect to emission improvements experienced in the prototype hardware configuration.

APPENDIX A

DRIVABILITY TEST PROCEDURE FOR APC TESTING

The following is the drivability test procedure to be used for testing of the APC device. The Warm Vehicle Drivability Test Procedure is to be used. Three tests are to be performed by three different drivers as delineated in the test procedure.

INITIAL SCREENING PROCEDURE FOR VEHICLE DRIVABILITY

I. Vehicle Preparation

a. Install tachometer and vacuum gauge - warm up vehicle (minimum 5 miles, driving).

II. Warm Vehicle Drivability Procedure - (See data sheet)

a. Warmup - Warm up vehicle for approximately 10 miles at freeway speeds.

b. Curb Idle Evaluation - Operate vehicle in neutral (N) for manual transmissions and drive (D) gear for automatic transmission. Record idle quality, speed, and vacuum.

c. Road Load Operations - Operate vehicle at cruise conditions from 20 through 70 mph. Record drive quality, speed, and vacuum at 10-mph intervals.

d. Wide Open Throttle (WOT) Accelerations - With automatic transmission vehicle, make the slow, moderate, and sudden WOT accelerations from 0 through 30 mph. With manual transmission vehicle, accelerate in high gear from 20 through 30 mph at WOT for indicated throttle openings. Record drive mode quality.

e. Partial Throttle (PT) Accelerations - With automatic transmission vehicle, make the indicated accelerations from 0 through 30 mph at various constant throttle positions from very light to nearly WOT. With manual transmission vehicle, these PT accelerations are to be made from 20 through 30 mph. Record drive mode quality.

f. Partial Throttle Crowd - "Crowds" are evaluated in high gear from 20 through 70 mph by accelerating at a continually increasing throttle opening. Several runs should be made varying the rate of throttle opening (i.e., 15", 10", and 5" Hg). Record drive mode quality.

g. Partial Throttle Tip-In - Evaluate the "tip-in" characteristics by making several PT accelerations from 20 and 30 mph Do not accelerate at a load which will cause the automatic transmission to down-shift. Record drive mode quality.

h. Acceleration Time - Run WOT acceleration from 0 through 70 mph and record time of acceleration.

i. Deceleration Time - Engine coast conditions are evaluated from 70 to 30 mph at closed throttle (record time). If necessary, run in opposite directions to cancel effect of wind.

j. Repeat tests (a) through (i), above, two additional times using different drivers. Record results on separate data sheets. (Average results.)

k. Soak - After the above tests have been completed, perform three consecutive WOT accelerations from 0 through 70 mph - idle for 30 seconds. Shut off engine and soak for 15 minutes. Restart at 1/2 throttle (record time) and hold at 1500 rpm for 3 seconds return to idle, maintain idle for 10 seconds in Neutral and, for AT, 10 seconds in Drive.

DEFINITIONS OF TERMS APPLICABLE TO ATTACHED DRIVABILITY PROCEDURE

a. Road Load - A fixed throttle position which maintains a constant vehicle speed on a level road.

b. Coast - Deceleration at closed (curb idle) throttle.

c. Wide Open Throttle (WOT) Acceleration - An acceleration made entirely at wide open throttle (from any speed).

d. Part Throttle (PT) Acceleration - An acceleration made at any fixed throttle position less than WOT.

e. Tip-In - Vehicle response (up to 2 seconds in duration) to the initial opening of the throttle.

f. Crowd - An acceleration made at a continually increasing throttle opening.

g. Idle Quality - An evaluation of vehicle smoothness, with the engine at the curb idle in drive as judged from the driver's seat.

h. Backfire - An explosion in the induction or exhaust system.

i. Hesitation - A temporary lack of initial response in acceleration rate.

j. Stumble - A short, sharp reduction in acceleration rate.

k. Lean Operation - This condition, depending on its severity, can manifest itself as outlined in the following categories:

(1) Stretchiness - A lack of anticipated response to throttle movement. This may occur on slight throttle movement from road load or during light to moderate accelerations.

(2) Surging - A condition of leanness, resulting in short, sharp, fluctuations. These may be cyclic or random and can occur at any speed and/or load.

Warm Vehicle Driveability Test

Vehicle _____ _____

Date _____ Time: Start _____ am/pm Finish _____ am/pm

Odometer Reading: Start _____ Finish _____

Temperature: Start _____ Finish _____

Test Driver: _____ Observer _____

MODE		RPM	Hg	Idle: Satisfactory	Idle: Rough	Idle: Stall	Drive Mode: Satisfactory	Drive Mode: Detonation	Drive Mode: Hesitation	Drive Mode: Stumble	Drive Mode: Stretchiness	Drive Mode: Backfire
Idle	N											
	D											
Road Load	20 mph											
	30 mph											
	40 mph											
	50 mph											
	60 mph											
	70 mph											
WOT Acc	20-30 Manual Trans											
	0-30 Auto Trans											
	Sudden Throttle Opening											
PT Acc	20-30 Manual Trans											
	0-30 Auto Trans											
	¼ Throttle											
	½ Throttle											
	3/4 Throttle											
PT Crowd	20-70											
	15" Hg											
	10" Hg											
	5" Hg											
PT Tip In From 20 mph	1											
	2											
From 30 mph	1											
	2											

ACC Time 0-70 mph (Sec) _____ Soak (Min): _____

Dec Time 70-30 mph (Sec) _____ Start Time (Sec): ____ Attempts: _____

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4. Title and Subtitle TEST AND EVALUATION OF THE AMERICAN POLLUTION CONTROLLED, INC. EXHAUST EMISSION CONTROL DEVICE			5. Report Date July 2, 1971 6.
7. Author(s) R. L. Gibney			8. Performing Organization Rept. No. NOR71-Y-139
9. Performing Organization Name and Address Northrop Corporation Electro-Mechanical Division 500 East Orangethorpe Ave. Anaheim, CA 92801			10. Project/Task/Work Unit No. ARB-2-131-1 11. Contract/Grant No. ARB-1902
12. Sponsoring Organization Name and Address Air Resources Board Resources Agency 1709 11th Street Sacramento, CA 95814			13. Type of Report & Period Covered Final Apr-Jul 1971 14.
15. Supplementary Notes			

16. Abstracts
This project evaluated 50 exhaust emission control devices supplied by American Pollution Controlled, Inc. (APC). It is concluded that significant reductions in exhaust emissions of HC and NO can be achieved through installation and continued use of the APC device on the uncontrolled segment of California's vehicle population. The results obtained after installation and operation of the device are: (1) average HC reduction of 36%; (2) average NO reduction of 56.3%; (3) average CO increase of 0.5%. These emission improvements represent a 48% reduction in the number of reactive tons of exhaust pollutants emitted from these uncontrolled vehicles and should lead to a large reduction in photochemical smog. The majority of vehicle owners interviewed believed their car's performance degraded after the device was installed. The major problems were difficult cold starting, rough idle, surge, hesitation, loss of power, and lower gas mileage. An assessment of the driveability of each test vehicle performed by trained test drivers as a part of the testing program did not reveal the same degree of degradation indicated by vehicle owners. The average cost of device installations performed by the participating Class A garages was $20.66 for labor and $0.66 for parts, a $21.32 average total installation cost.

17. Key Words and Document Analysis. 17a. Descriptors

1. Hydrocarbon
2. Nitric oxide
3. Carbon monoxide
4. Exhaust emissions

17b. Identifiers/Open-Ended Terms

1. Uncontrolled vehicle population
2. APC device

17c. COSATI Field/Group

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