Automobile Emission Control - Technological Approaches Toward Improving In-Use Vehicle Emissions Performance

Emission Control Technology Division
Ann Arbor, Michigan

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Section 1

Introduction

1.1 Background

The Environmental Protection Agency has been monitoring exhaust emission levels from in-use vehicles since 1971 through the Emission Factors Program (EFP).

While the EFP has been designed to provide input of exhaust emission levels for air quality modeling, the program has indicated that a potential problem exists with in-use vehicle emissions performance when these in-use vehicles are tested in the as-received state of tune-up and maintenance condition. These levels have been in excess of the Federal Emission standards. Other EPA Surveillance Programs have shown that in-use vehicles when properly maintained and tuned to manufacturer's specifications are in substantial compliance with the Federal Emission Standards which they were designed to meet. The purpose of this study was to ascertain from currently available data sources the cause(s) for such substantial in-use differences in emission-related state-of-tune and to explore and evaluate potential technical solutions.

Data from the 1975 EPA Emission Factor Program have indicated that a substantial number of the 1975 model year low mileage vehicles were failing to meet the 1975 standards of 1.5 HC, 15 CO, 3.1 NOx for one or more pollutants.

A summary of the 1975 Emissions Factors data available when this report was prepared is shown in figures 1-1 to 1-3 for the low mileage 1975 vehicles.

The technological approaches to improving in-use performance of vehicles discussed in this report are divided into two general classes, those that involve technological changes to the vehicle, and those that involve technological changes in areas other than to the vehicle, for example maintenance practices.

EPA continues to look at the entire spectrum of approaches toward improving in-use vehicle emission performance, including inspection and maintenance (I/M) programs, short test programs, assembly line testing, in-use compliance (recall) programs, retrofit programs, and technical assistance to the various states and Air Quality regions where automobile emissions are a serious problem. However, these subjects are no treated in this report. This report deals only with technological approaches toward improving in-use vehicle emission performance, and therefore should be considered as only part of the treatment on the in-use vehicle emission performance issue. The scope of this report has been limited in order to focus in more depth on technical approaches that the automobile manufacturers could investigate in order to improve the emission performance of in-use vehicles. Because of the complexity of the problems, and the paucity of data on causes and responsibilities for vehicle malperformance, this report has relied extensively on engineering judgement and assumptions.

1.2 Purpose of this Report

This report intended to serve as a basis of discussion concerning the in-use vehicle emissions performance issue, and ways to make that performance better.

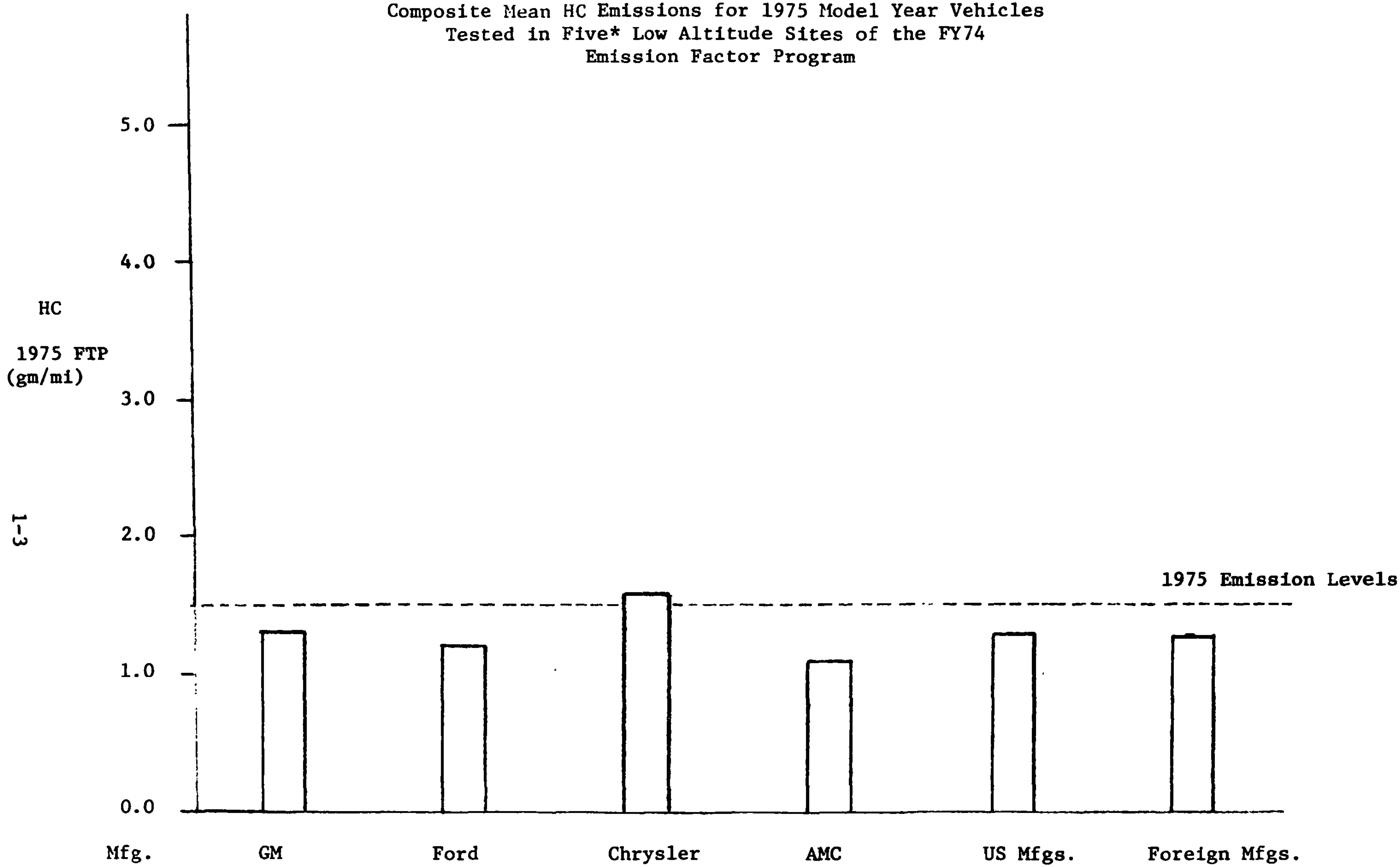
1.3 Data Sources and Nomenclature

The primary sources of data used for the preparation of this report came from reports of EPA-sponsored work that involved testing of in-use automobiles. These and other data sources are referenced as they appear in the discussion in the text.

The nomenclature used for emissions in this report is a triplet abbreviation, in which the dimensions of grams per vehicle are assumed and the emission test procedure is the 1975 Federal Test Procedure (FTP). Thus, 0.6 HC, 7.0 CO, 1.2 NOx means 0.6 grams per mile hydrocarbons (HC), 7.0 grams per mile carbon monoxide (CO) and 1.2 grams per mile oxides of nitrogen (NOx), all measured on the 1975 FTP.

Fuel Economy is described in terms of miles per gallon (MPG). The urban or "city" fuel economy is represented by MPG_U, the non-urban or "highway" fuel economy is represented by MPG_H, and the composite fuel economy, determined by a 55/45 urban, non-urban mileage weighting, is represented by MPG_C.

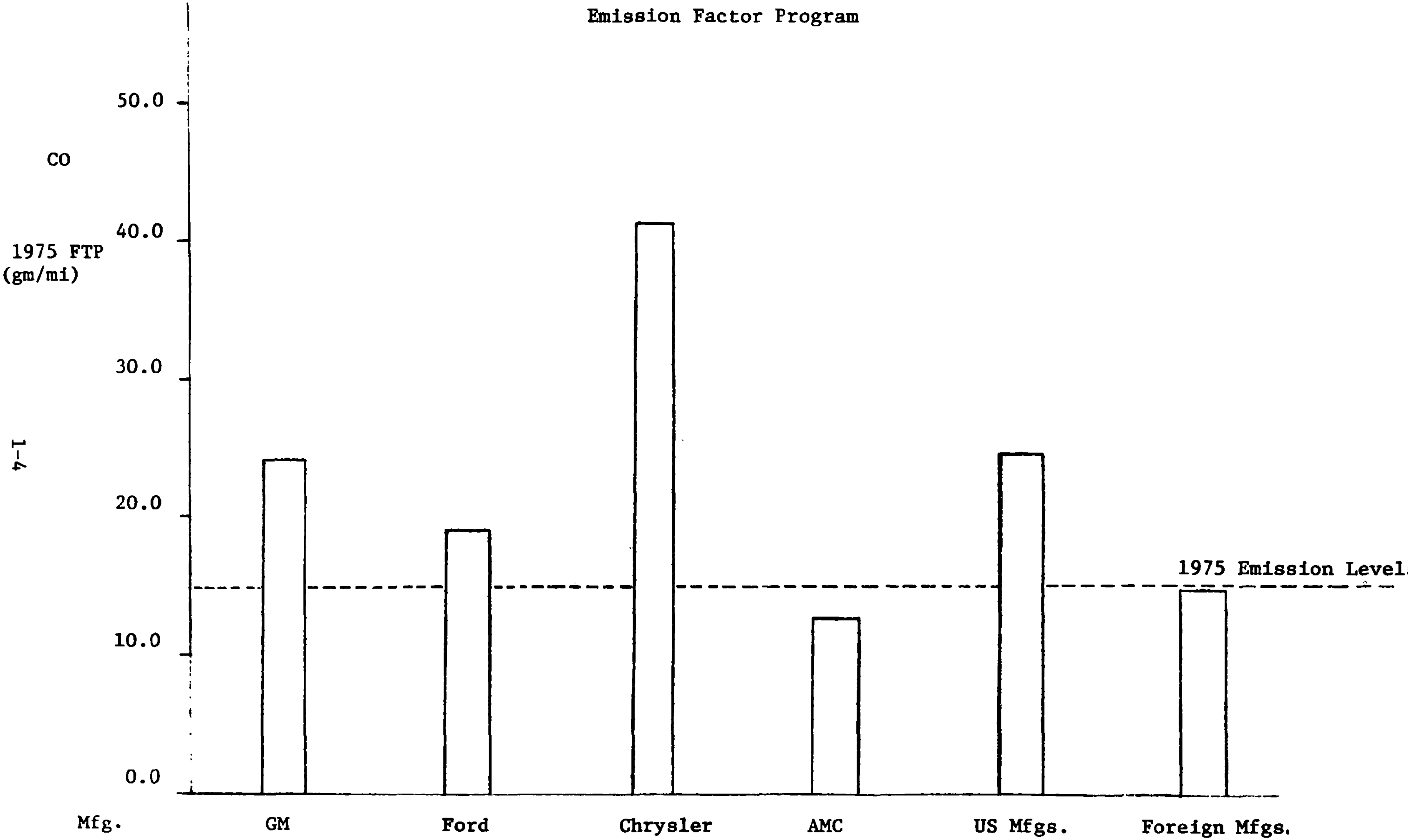
Composite Mean HC Emissions for 1975 Model Year Vehicles
Tested in Five* Low Altitude Sites of the FY74
Emission Factor Program



*The mean emissions represent data from Phoenix, Chicago, Houston, St. Louis, and Washington, D.C.

Figure 1-1

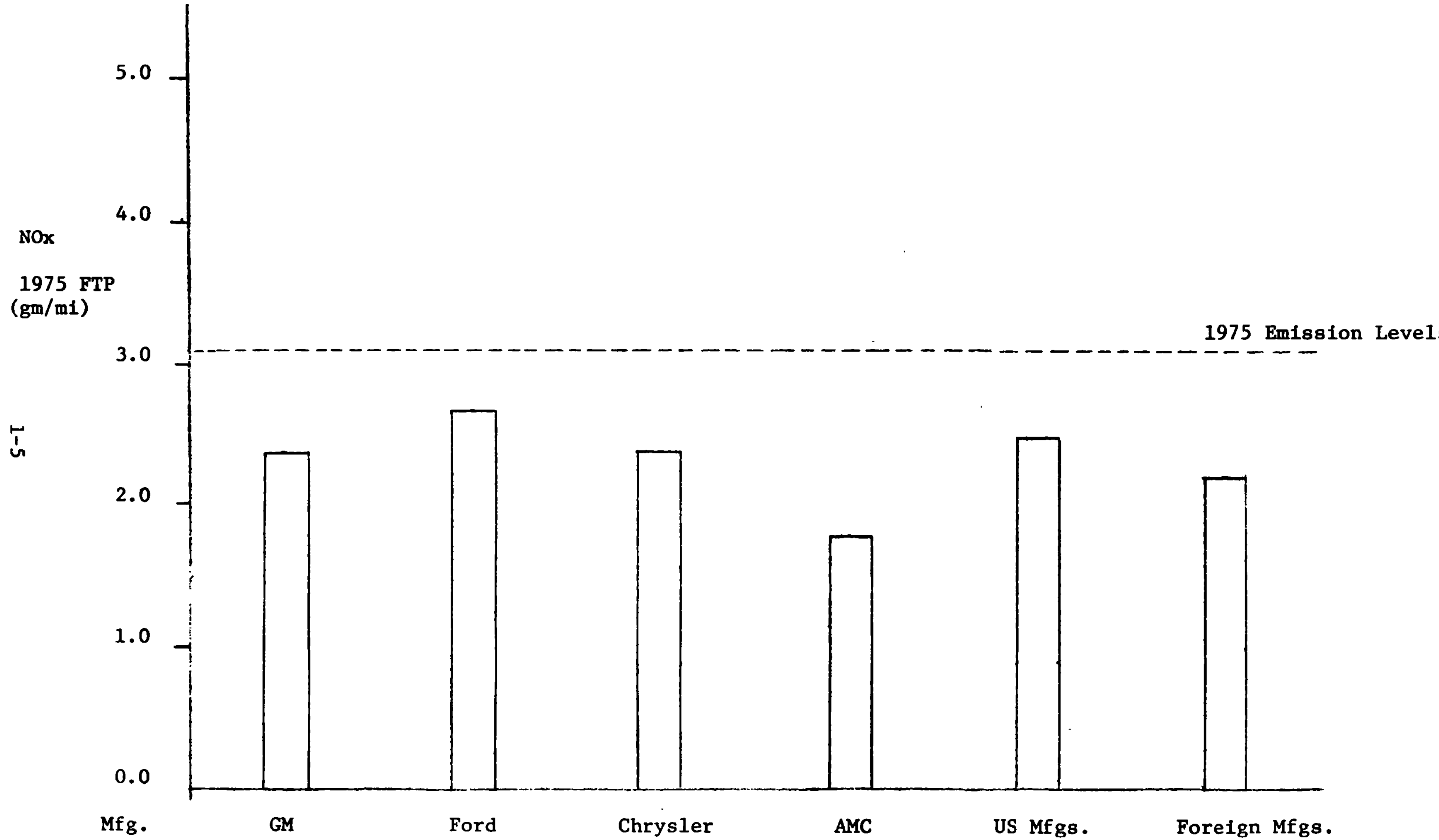
Composite Mean CO Emissions for 1975 Model Year Vehicles
Tested in Five* Low Altitude Sites of the FY74
Emission Factor Program



*The mean emissions represent data from Phoenix, Chicago, Houston, St. Louis, and Washington, D. C.

Figure 1-2

Composite Mean NOx Emissions for 1975 Model Year Vehicles
Tested in Five* Low Altitude Sites of the FY74
Emission Factor Program



*The mean emissions represent data from Phoenix, Chicago, Houston, St. Louis, and Washington, D.C.

Figure 1-3

Section 2

Discussion of The Problem

2.1 What is the Extent of the Problem?

Data from the EPA Fiscal Year 1974 Emission Factor Program (FY74 EFP) indicated that a substantial number of 1975 model year vehicles were failing to meet the 1975 standards of 1.5 HC, 15 CO, 3.1 NOx for one or more pollutants as illustrated in Figures 2-1 and 2-2. This is the definition of "The Problem" as Tables 2-1 and 2-2 indicate, 66% of all domestic vehicles tested failed one or more of the pollutant levels. Additionally, 52% of all vehicles tested failed because of high CO levels only or in combination with other high pollutant levels. Tables 2-3 and 2-4, which detail the results of the FY74 EFP for Los Angeles, shows the trend for CO to be somewhat lower in Los Angeles partly attributable to lower emission standards, different technology, and possibly the effect of more stringent enforcement of state air pollution control laws.

Other data taken both by EPA and independent sources, substantiate the fact that 1975 model year vehicles may be exhibiting emission levels higher than the standards. While these data are generated principally by tests other than the FTP, usually idle HC and CO measurement, they do again indicate that the CO levels at idle are high. Table 2-5 gives some indication of these levels identified by idle test methods. If all manufacturers had specifications for idle CO, then the idle CO measurements made on in-use vehicles could be used to compare to the manufacturer's specifications in order to determine if the vehicles are set to manufacturer's specifications. Unfortunately, most manufacturers do not have idle CO specifications, the major exception being Chrysler, with a specification of 0.3% CO in the exhaust upstream of the catalyst at idle. In order to estimate the degree of idle maladjustment, it has been assumed that a value of idle CO $<0.6\%$ would correspond to properly adjusted model year 1975 vehicles. The data in Table 2-5 would seem to indicate that average in-use vehicles have idle CO levels 2 to 3 times higher than the assumed specification.

2.2 What are Some of the Possible Causes of the Problem?

2.2.1 Idle CO Maladjustment

It has been well established that CO failure under FTP conditions is primarily a direct result of the air-fuel ratio the vehicle operates at during the test cycle. While the idle portion of the Federal Driving Cycle is less than 20% of the total cycle, the vehicle operation during the idle portion has a great influence on whether it passes the FTP or not. A rich idle air-fuel ratio enhances the possibility of the vehicle not passing the FTP. The idle mixture screws are a convenient means of enrichening the idle mixture.

Figure 2-1

Hydrocarbon Emissions of In-Use Vehicles at 50,000 miles

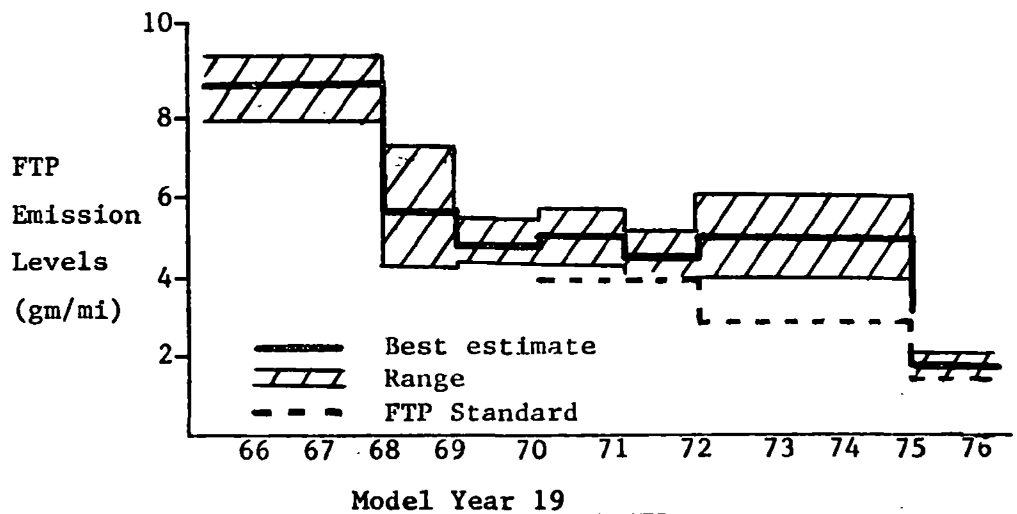


Figure 2-2

Carbon Monoxide Emissions of In-Use Vehicles at 50,000 miles

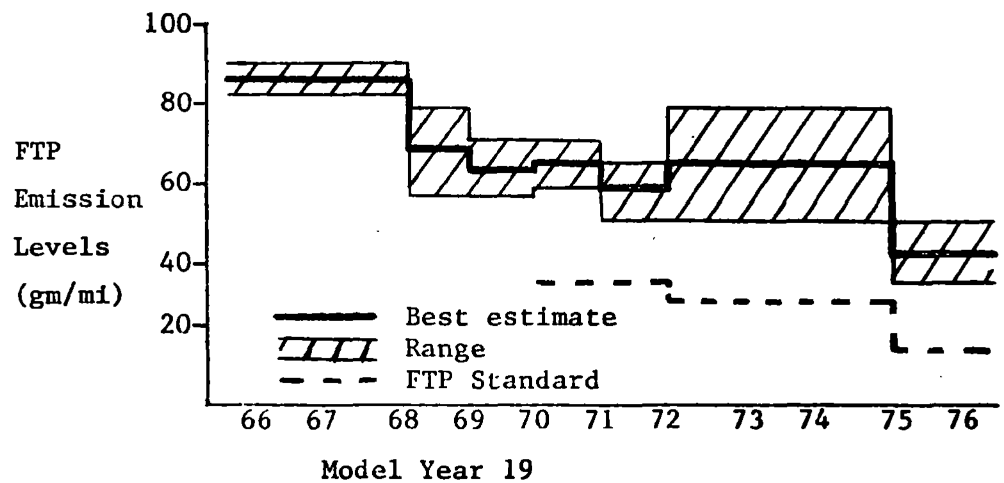


Table 2-1

Composite Mean Emissions for the 1975 Model Year Vehicles Tested in Five* Low Altitude Sites of the FY74 Emission Factor Program

Manufacturer	Number Tested	1975 FTP (gm/mi) HC Mean	CO Mean	NOx Mean
GM	229	1.3	24.3	2.4
Ford	124	1.2	19.1	2.7
Chrysler	77	1.6	41.6	2.4
AMC	23	1.1	12.9	2.8
US Mfg.	453	1.3	25.2	2.5
Foreign Mfg.	134	1.3	15.2	2.2
Overall Mfg.	587	1.3	22.9	2.4

*The mean emissions represent data from Phoenix, Chicago, Houston, St. Louis, and Washington, D.C.

Table 2-2

Number of 1975 Vehicles That Fail the Federal Standards, by Standard, for the Cities of Chicago, Houston, St. Louis, and Washington, and Phoenix

				Number of Vehicles That Fail						
Manufacturer	Total Tested	Total Number Failures	Percent Failure	Only HC	Only CO	Only NOx	Both HC, CO	Both HC, CO	Both CO, NOx	All Three Standards
GM	229	139	61%	3	41	24	53	1	8	9
Ford	124	75	60%	2	30	16	9	4	8	6
Chrysler	77	68	88%	0	24	4	31	0	4	4
AMC	23	16	70%	2	5	6	2	1	0	0
U.S. Mfg	453	298	66%	7	101	50	95	6	20	19
Foreign Mfg	134	73	54%	8	24	8	17	5	1	10
Overall Mfg	587	371	63%	15	125	58	112	11	21	29

Table 2-3

Mean 1975 FTP Emissions in Gm/mi
for the 1975 Vehicles Tested
in the Los Angeles FY74 EFP

Manufacturer	HC Mean	CO Mean	NOx Mean	Fuel Economy
GM	.6	6.4	2.5	11.8
Ford	.5	4.2	2.1	10.8
Chrysler	.4	4.3	2.5	13.4
AMC	.4	15.1	1.6	13.3
US Mfg	.5	5.8	2.4	11.9
Foreign Mfg.	.6	10.3	2.3	21.4
Overall Mfg.	.5	6.6	2.4	12.8

Table 2-4

The Percent of 1975 Vehicles that Failed the Federal Standards in Los Angeles FY74 EFP

Manufacturer	Number	Percent Failing				
		HC	CO	HC or CO	NOx	HC, CO, or NOx
GM	16	0	6	6	25	25
Ford	7	0	0	0	14	14
Chrysler	5	0	0	0	40	40
AMC	1	0	100	100	0	100
US Mfg	29	0	7	7	24	28
Foreign Mfg	6	0	17	17	0	17
Overall Mfg	35	0	9	9	20	26

Table 2-5

Idle Emission Levels
for 1975 Model Year Vehicles*

Data Source	Sample Size	Mean Idle CO Level(%)	Mean Idle HC Level(ppm)
Gulf Oil Corp.			
NJ	244	1.30	150
PA	168	1.17	133
Champion Spark Plug Co.	321	1.29	173
EPA-EFP(4 cities)	292*	2.10	-
Phoenix	117	1.29	98
LA	35	.14	34
EPA-MSED**			
Cinn.	319	.66	77
Chicago	152	.77	84
NY	181	1.00	100
Oregon	1104	.83	107

*Vehicles which failed any one or a combination of pollutants.

**MSED-Mobile Source Enforcement Division, EPA.

In 1967, the Ford Motor Company introduced idle limiter caps and by 1971 practically all vehicles were equipped with these caps with the intention of limiting the amount of adjustment of the idle mixture screws. As evidenced by Tables 2-6 and 2-7, the number of idle limiter caps removed for 1975 model year vehicles ranges from 13 to 34 percent depending on location. Therefore, idle limiter caps are probably not effective. Data from EPA's Mobile Source Enforcement Division, (MSED) also indicates that as vehicles get older the percentage of vehicles without limiter caps increase; see Table 2-8.

Unfortunately, data does not exist which identifies who removes the limiter caps; why they were removed (though it is hypothesized that it is in response to a owner driveability complaint), or if they were installed originally. Even the latter question cannot be answered with certainty, but caps are generally installed by the carburetor manufacturers after the carburetor is flow checked and before it is sent to the vehicle manufacturer. The Ford Motor Company has told CARB that limiter caps are functionally checked 100% during the vehicle manufacturing process*.

2.2.2 Other Maladjusted Parameters

The causes of high emission levels of 18 Chrysler vehicles in the EFP which had emission levels above the standards and idle CO below 0.5% were investigated in detail. CO remained the primary emission problem with these 18 vehicles. Because the Bag 1 mean emission levels remained high in relation to correctly operating vehicles, this suggested that the reason for high CO emissions could be either the malfunction of the electric choke, choke vacuum brake, retarded spark timing, or any combination of these in conjunction with some minor idle mixture maladjustment. While analysis of Bag 1 results do not prove choke maladjustment, choke malfunction or maladjustments are still considered to be the most likely as the consumer would have little incentive to greatly retard ignition timing.

Though it would be tempting to ascribe the poor emission performance of in-use vehicles solely to idle maladjustment, other emission system components cannot be overlooked. NAS in their June 1973 report**, identified 61 emission control system components which could have a deleterious effect on exhaust emissions. Informal discussions with representatives of both the Clayton Manufacturing Corporation and Champion Spark Plug Company surfaced other components which could have adverse

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*Letter from D. A. Jensen, Ford Motor Company to William H. Lewis, CARB; June 4, 1976.

**Feasibility of Meeting the 1975-1976 Exhaust Emission Standards in Actual Use, National Academy of Sciences, June 1973, pp. 59-61.

Table 2-6

Mobile Source Enforcement Division-EPA
Tampering Study Limited to Domestic Vehicles Only

Where Conducted	Cinn.	Chic.	N.J.	
When conducted	3-4/75	9-10/75	11-12/75	
Vehicle year	'75 only	'75 only	'75	'76
Number in sample	319	152	181	37
Percent limiter caps removed	15.05	13.8	26.5	12.8
Mean idle CO level w/caps (%)	.56	.60	.7	.2
Mean idle CO level w/o caps (%)	1.4	1.9	1.7	3.2
Mean idle HC level w/caps (ppm)	66	76	96	47
Mean idle HC level w/o caps (ppm)	135	140	107	322

Table 2-7

Frequency of Idle CO Maladjustment (Percent) for 1975 Vehicles

Data Source	Sampling Size	Frequency of idle Maladjustment from Spec.	Idle Limiter caps removed (percent)
Champion Spark Plug Company	298*	38.9	Not reported
Emission Factors Program	364** (Chicago, Houston, St. Louis, Washington,DC)	28.3	Not reported
	115 (LA & Phoenix)	30.4	34 (Phoenix only)
MSED	190	cannot be determined	26.5

* Specification was idle CO greater than 2.00%

** Specification was idle CO greater than 1.50%

Table 2-8

Results of Mobile Source Enforcement Division-EPA Tampering Study*
Conducted in NJ for 1974-75

Percentage of No Limiter Caps

Model Year	1974 (%)	1975 (%)
1970	76.4	76.1
1971	46.9	67.9
1972	37.0	70.2
1973	27.2	59.2
1974	5.9	45.5
1975	-	26.5
1976	-	12.8
Avg.	46.6	56.6

*The Incidence of Tampering on Cars in New Jersey During 1975, MSED, June 22, 1976.

effects on emissions. Champion stated that possibly up to 25% of the vacuum spark advance diaphragms in the field could be faulty. Clayton confirmed approximately the same levels cf vacuum advance failures, plus vacuum hose deterioration and EGR valve sticking; but ascribed no percentages to the latter two failures. Clayton (a manufacturer and distributor of vehicle diagnostic data) also indicated that much of the test equipment used for tune-up, diagnostics, and repair in the field was faulty or miscalibrated.

Data showing the frequency of failure for system components other than idle adjustments is more limited than idle setting data. Two pieces of data exists which could indicate the magnitude of the problems with other systems. These data are found in Tables 2-7 and 2-8.

Table 2-9

Frequency of Failure for Selected Components
Source Champion Spark Plug Company
All Model Years

System/Component	Sample Size	Freq. of Failure(%)
Points	3877	21.0
Cap & Rotor	4625	5.1
Ignition leads	4626	18.7
Spark Plugs	4626	31.7
PCV	4624	4.6
EGR	1247	4.0
Belts (Replaced)	4609	14.0
Hoses	4528	10.8
Air Filter	4369	34.5

The MSED in their New Jersey Tampering Study also developed a frequency of tampering rate for the above systems.

Table 2-10

New Jersey Tampering Study

System/Component	Frequency of Tampering(%) Sample size-1935,(all) model years	Sample size-230, '75-'76 model years
Limiter Caps	56.6	23
PCV	0.7	-
Vacuum Spark Retard Mechanism	2.2	1.1
AIR	0.2	-
EGR	0.4	0.5

While Tables 2-9 and 2-10 provide only circumstantial evidence of their system frequency of failure rates, these system do have a marked effect on vehicle exhaust emission when they fail.

The effects of the maladjustment of other parameters and component failures is a complicated subject. The misadjustment or failure of nearly every emission control component on a vehicle can affect its emissions.

These effects can obscure the identification of any one single parameter as the cause of high in-use vehicle emissions. The reason for not being able to identify the problem from the available data is that the status of all of the components on the vehicle is usually not determined accurately.

2.2.3 Driveability

Driveability is a highly subjective indicator of vehicle performance. The definitions associated with driveability (hard starting, hesitation, stall, stumble, sag, rough idle, etc.) usually are not uniform in perception from driver to driver. The automobile manufacturers on the other hand, have trained evaluators who drive rate the vehicles during development of the emission control systems. For some systems driveability may be traded off against exhaust emission levels and/or fuel economy.

The only extensive owner driveability data developed by other than an automotive manufacturer was done by Champion and is given below.

Table 2-11

Owner Performance Report for All Model Year Vehicles

	No. Vehicles	% of Sample		No. Vehicles	% of Sample
Hard starting	1375	29.75%	Detonation	1005	21.73%
Rough Idle	2019	43.65%	Hesitation	1935	41.84%
Misfire at Hwy speeds	680	14.70%	Run-on	1336	28.89%

Driver Satisfaction

Well Satisfied	1618	34.93%
Could be Better	2507	54.21%
Unhappy	426	9.21%
Total Reports	4551	98.40%

It can be seen that most drivers, 63% would like their vehicles to drive better. Also note particularly, 43.7% of the drivers complained of rough idle for their vehicles. Rough idle is a potential reason for maladjustment of the idle circuit.

2.2.4 Inadequacy of the Service Industry

As early as 1973, NAS wrote, "The service industry at the present time is not adequate to service the 1975-1976 cars from an emission-control standpoint." There is no reason to challenge or to believe that the situation has changed drastically since the NAS report was written.

The size of the service industry may provide some indication of the problems faced by the industry. Mr. Herb Fuhrman of the National Institute for Automotive Service Excellence (NIASE) provided the following breakdown of personnel. A recent government census estimated that there are 805,000 people who were classified as or called themselves automotive mechanics. Subtracted from this number are 265,000 people who are working for governmental bodies such as Federal, State, and local levels and other public bodies such as Public Works, Police, Fire Departments. Also subtracted are 90,000 managers, instructors, and supervisors who do not actually work on the vehicles. There are approximately 450,000 individuals who actually service vehicles or approximately one mechanic per 266 in-use vehicles.

Table 2-12 shows the problem mechanics face with servicing 266 vehicles each. This table indicates the number of times maintenance is to be performed over 50,000 miles, as instructed in the owners mannual furnished by the domestic manufacturers.

The fact that mechanics seemingly have a formidable task to perform, may be part of the explanation of poor in-use emission performance. While the role of the mechanic is indeed a critical one in assuring good vehicle emissions, driveability and performance, the subject of mechanic performance has not been addressed in this report.

Table 2-12

Operation	AMC	Chry.	Ford	GM
Replace Air Filter	1	3	a-2 b-3	1
Lubicate Choke Linkage	1	10	"	3
Replace Ignition Wires	1	3	"	2
Check Distributor Advance Mechanisms	1	-	-	3
Replace Rotor and Cap	1	3	a-2 b-3	3
Replace Points and Condensor	1	3	"	3
Adjust Ignition Timing	1	3	"	2
Check Belt Tension	1	3	"	6
Replace Fuel Filter	1	3	"	3
Check Heat Riser Valve	1	3	"	-
Adjust Idle Speed and Mixture	1	3	"	3
Repl. PCV Valve and Check Hoses	1	3	"	3
Replace Spark Plugs	1	3	"	2
Insp. Thermostatic Air Filter	1	-	-	3
Check Vapor Recovery System	1	3	a-2 b-3	-
Check EGR Valve	-	3	-	-
Check OSAC Valve	-	3	-	-
Adjust Valves	-	3*	a-2* b-2*	-
Replace Coolant	-	-	a-2 b-3	3
Check Decel Valve Operation	-	-	"	-
Change Engine Oil	10	10	10	6
Change Engine Oil Filter	10	5	5	3

a,b= Ford Motor Co. uses two maintenance schedules. Each vehicle has a permanent sticker affixed to the inside of the glove compartment door stating which schedule to follow.

Labor rate figured at $11/hr. Figures are 5 year/50,000 mile totals		AMC	CHRYS.	FORD A	FORD B	GM	VW
	Parts	$135	$210	$180	$225	$145	$135
	Labor	200	390	255	345	270	280
	Total	335	500	435	570	415	415
		$67/yr	$120/yr	$87/yr	$112/yr	$83/yr	$85/yr

* = six cylinder engines only.

Section 3

What Are Some Possible Approaches Toward Improving In-Use Vehicle Emission Performance?

Introduction

This section deals with technological approaches toward improving in-use vehicle emission performance. It was not the intention of this study to examine and propose regulatory or other actions to achieve implementation of the technological approaches. In some instances the following text suggests consideration of a regulatory approach, such as consideration of a performance specification and test, in order to follow the technological approach to one logical conclusion. It should not be interpreted by the reader to be a recommendation for a particular regulatory action. The important regulatory issues have not been examined, including applicability of the Clean Air Act, impact on current regulations, cost-effectiveness, air quality impact and consideration of alternate approaches. For example, in the case of performance specifications and tests it is questionable whether the Clean Air Act currently provides the Administrator with authority to impose such tests.

The technological approaches and means of implementation are discussed in this report with the intention of focusing the attention of industry and government on the real problem of in-use vehicle emissions performance. Hopefully, these and other yet-to-be-determined technological approaches will provide valuable means of improving the in-use vehicle performance.

3.1 Vehicle Technology Improvements

There are three types of technological approaches discussed below. The three approaches are: a) uprating current technology, b) redesign of current approaches to reduce potential for maladjustment, and c) advanced technology that would be designed and developed with improved in-use emission performance as a high priority item.

Uprating Current Technology

This category basically involves improving the performance/reliability characteristics of current components. To suggest that there may be components on current vehicles that could use some improvement may be considered by the industry to be an unwarranted attack on their current products. However, a distinction must be made here. A component could provide performance considered adequate to the customer, but be less than adequate as far as emissions are considered. For example, an ignition system that produced intermittent misfire that was either undetected by the driver or considered to be acceptable to the driver, could result in large HC penalties.

The above example incorporates a principle that must be considered when studying the in-use vehicle emission problem. The principle is that a vehicle can currently operate over a wide range of calibrations and that the emissions can vary widely over these calibrations. For most current systems the range of calibrations over which the emissions are acceptable is narrower than the range over which the vehicle can operate. This is true for the calibrating of spark timing, air/fuel ratio, EGR rate, choke vacuum break and choke heat-up rate, and for the control parameters like air injection rate and catalyst efficiency.

The fact that vehicles can operate in a manner that would be acceptabel to the public in general, while having high emissions indicates that components and systems may have to have better than just perceptibly acceptable performance in order to keep the emissions low.

It is from the above perspective that the uprating is considered. Factors that can influence emissions may be so subtle, in terms of driver perception that new levels of performance for components may be necessary, so that in addition to just "running o.k." the vehicle also produces acceptable levels of emissions.

The uprated ignition system components considered as having potential for emission performance gains are improved spark advance diaphragms, improved ignition wires, improved spark plug to ignition wire connectors, and improved spark plugs.

It may be that up to 20% of the vacuum advance diaphragms in the field are faulty. It is not known if these failures are due to faulty designs, or if they are due to tampering (i.e. changing from a ported vacuum signal to full manifold vacuum to the distributor all the time - possibly overloading the diaphragm).

If this really is a problem in the field (it would take a large program to prove it as is the case with nearly every in-use issue) then EPA or industry could consider establishing a specific performance specification and test for advance diaphragms. An accelerated vacuum cycling test coupled with aging tests may suffice. If the degree of failure of these diaphragms can be significantly reduced, then some benefits could be inferred. This is especially true if a failed diaphragm is the initiating cause for vehicle tampering in an attempt to restore performance and fuel economy. One way to tamper could be to advance the entire distributor to restore some of the ignition timing advance. This would result in potentially negative emissions consequences and possibly other problems like detonation.

The Champion survey data indicate that 63% of all the vehicles tested had malfunctioning spark plug wires. If this trend continues for the 1975 and 1976 models serious effects on HC emissions and catalyst durability may result. In order to correct this potential problem, component materials with superior high temperature tolerance could be used. If the problems are in the carbon conductor material itself a change could be made to matallic wire conductors, although this would probably require a shielded cable for RF supression.

The ignition cable/spark plug connectors are also suspect. It is entirely possible (and has happened) that when spark plugs are changed ignition performance is not improved, but degraded. This happens because mechanics yank on the wire (often the only practical means to remove), not the connector, when they detach the wires to change plugs. This can destroy the electrical integrity of the junction. A connector of the bayonet type which would provide a positive connection and would be difficult to destroy by yanking on the wire could solve this problem, which may be widespread. A performance standard for connector integrity as a consequence of pulling off the wire from the plug for example, 50 or 100 lbs pull, could help solve this problem.

Spark plugs themselves could be improved to yield longer life, and reduce the frequency of replacement. Replacing the plugs as discussed above can sometimes result in worse ignition system performance. With the types of ignition systems on today's vehicles, coupled with unleaded fuel, spark plug change intervals have extended. GM for example has spark plug change intervals of 22,500 miles on most of their vehicles. Longer spark plug life is not impossible. One manufacturer ran one engine family for 1975 certification for 50,000 miles without a plug change. EPA could possibly consider setting a performance standard for plug life to ensure that better plugs are used. This suggestion is expected to result in adverse impact on spark plug suppliers, since the replacement market represents the bulk of the sales and any reduction in replacement frequency might result in a large reduction in total sales volume.

The uprated hoses are the next category of uprated technology. Current vehicles have a large number of hoses that provide vacuum control signals and provide for gas flow. The performance of some of these hoses is suspect. It has been indicated, for example, that some vehicles sold in California had EGR hoses of such poor quality that a large percentage of new vehicles had split hoses. Besides the integrity of the hose material itself, the way in which the hoses are attached to fittings has been mentioned by some to be inadequate. Many of the hoses are just pushed on to a straight fitting with no clamp or other positive method of attachment. EPA could consider setting performance standards for hose material i.e. ozone resistance, bursting strength, fatigue resistance, etc. Additionally, a performance standard could be considered for pull-off force at connecting points to ensure that positive connections are used.

Uprated air injection systems are next. Vane-type air pumps generally tend to wear in such a way that the air delivered at a given RPM decreases with time. A performance specification on maximum decrease in delivered flow might be considered, which could be met by redesign or using an inlet air filter which some have indicated is needed.

Uprated modulating devices are the next category. On today's vehicles, there are many devices that modulate the emission control system. The performance of some of these devices is suspect.

As an example, in some instances it has been found that the thermal vacuum switch (TVS) of the type used by GM and others is performing poorly in the field. Since failure of these modulating devices more often than not results in increased emissions, EPA could consider setting specific durability tests for any modulating device component.

Improving the performance of the catalysts used on the vehicles could be considered. A 100% functional check of light-off time and stabilized conversion efficiency on the vehicle could be contemplated, with replacement of the unit if certain efficiency performance values were not met.

PCV valve designs could be uprated to be more resistant to contamination, with a goal of no replacement ever needed, possibly encouraged by specific durability performance tests.

Last but not least, the fuel metering system could be improved. This could be done in two ways. First, specific durability requirements could be set for vacuum break mechanisms, choke coils, and internal parts of the carburetor that are subject to wear. The second approach could be to improve the fuel. It appears that detergents in fuels may help improve carburetor performance. EPA could consider setting a specific performance test for in-use fuels that might result in improved detergent activity. If this would cause gasoline producers to switch from current additives, or to add additives that they do not add now, resistance might be expected. Of course, additives required by EPA (if EPA can require them be added to make emission control performance better, as EPA could require lead to be reduced for the same reason) would have to be examined carefully to ensure that combustion products of the additives are benign from a health effects point of view.

Re-Design of Current Approaches to Reduce Maladjustment Potential

This approach appears feasible but it is not known if it will be effective. If the vehicles in the field have poor performance to the extent that encourages maladjustment to provide customer satisfaction, then the public response to this approach could be the evolution of even more sophisticated and costly means of tampering or a substantial public backlash. However, it is assumed here that the vehicles perform adequately now, and that the approaches suggested here will be effective in reducing maladjustment with concommitant emissions benefits.

Limited Adjustability

If engine and emission control system parameters can be maladjusted they probably will be, to some extent. If reduced adjustability could be designed into the system maladjustments could be significantly reduced.

Basic Timing Adjustment

Many vehicles (48% according to Champion) have timing out of specifications, defined as more than $\pm$ 1 degree from the specified value.

The basic timing of an engine can be adjusted by using a simple open-end wrench by nearly anyone. In just a few minutes, basic timing can be altered drastically. Generally, timing is advanced when tampering is done. To prevent this, it is recommended that metal stops be incorporated into the the distributor mounting that would prevent the distributor from being rotated more than the minimum essential travel required to adjust for production tolerances. These tolerances could be quite tight for today's systems, since for pointless ignitions the position of the cam follower cannot change.

Idle-Air Fuel Mixture Adjustment

A significant part of the in-use emissions performance problem may be the result of incorrect carburetor adjustments. Several of which can be made in the field. These adjustments, while potentially correcting problems with driveability and performance, have an adverse effect on emissions and/or fuel economy. On most of today's carburetors, many of these can usually be made by the turn of a screwdriver or the slight bending of a linkage rod. The vehicle owner or any mechanic can easily make the adjustments to attempt to improve the performance of the vehicle. Two typical carburetor maladjustments are enriched idle mixture and modified choke operation.

The air-fuel ratio at idle is controlled by the idle mixture screws usually located on the lower portion of the carburetor body near the throttle plate. Backing the screws out richens the mixture by allowing more fuel to be drawn through the idle discharge port. There are either one or two adjustment screws depending on the number of venturis (barrels). One-barrel carburetors generally have one screw while 2- and 4-barrels generally have two screws. On a 4-barrel carburetor, the two idle mixture screws enter only into the primary venturis.

In recent years, carburetor manufacturers have been installing plastic idle limiter caps over the heads of the mixture screws to discourage maladjustment with the idle mixture. Unfortunately, these caps are easily removed or defeated, which makes idle mixture adjustment almost as simple as if there were no limiter caps at all. When limiter caps, are removed they are destroyed, thus indicating that the idle mixture may have been readjusted.

Attempts to improve the driveability usually involve richening the idle mixture from the initial calibration setting. Excessive richening will cause poor performance indicated by sluggishness and black exhaust smoke. This richening of the mixture obviously has a definite effect on exhaust emissions. Since excess gasoline is used, and all the air is utilized in the burning process, unburned gasoline will remain in the exhaust. A reasonably good indicator of the air/fuel ratio at idle is the idle carbon monoxide concentration. In general, an increase in idle carbon monoxide concentration will produce an increase in unburned hydrocarbons (HC) and carbon monoxide (CO), and a decrease in nitrogen oxides (NOx) emissions. Since all vehicles are different, the result of richening the mixture may not be exactly the same for all vehicles, but generally speaking there will be an increase in at least one of the pollutants. Fuel economy is also affected when the mixture is adjusted in that richening the mixture causes more fuel to be burned up for a given amount of air, which can tend to decrease fuel economy.

<u>Choke Adjustment</u>

The choke system can also be maladjusted in the field. There are several ways that the operation of the choke system can be altered which would affect emissions. The choke coil rod, choke unloader, automatic choke coil, vacuum break and electric-assist choke mechanisms are all components of the choke system which can be adjusted.

It is suspected that choke adjustments are usually made to overcome cold starting and cold start up and driveaway driveability problems. Most choke systems are calibrated to a certain air-fuel ratio under cold starting conditions. However, the "cold start" for which the choke calibrations are the most critical for emissions is the $68^{\circ}F$ to $86^{\circ}F$ start on the emission test. It is speculated that in the fall and winter choke calibrations designed for the emission test result in less than satisfactory starting and driveaway. The variation of driver preferences of driveability may enhance the chances that adjustments are made to the choke system. Many of the adjustments will richen the air-fuel mixture delivered to the engine during choked operation and/or increasing the time during which the choke is on.

With the electric choke mechanism, an electric heating coil is used to shorten the choke-on time. A shorter choke-on time will cause the mixture to lean out faster which helps to decrease emissions from a cold engine. As indicated above, this accelerated leaning of the mixture may result in some driveability problems under cold ambient conditions. Disconnecting the electric choke mechanism will cause the choke valve to open as a function of engine temperature only. The longer the choke system is in operation, the higher the carbon monoxide (CO) emissions because the rich warm-up mixture exists for a longer period of time. There is also a fuel economy reduction due to the extended choke-on time.

Other Carburetion Factors

There are other factors which may contribute to poor in-use emission performance of the carburetion system. These are the installation of incorrect carburetors on the engine, faulty carburetor manufacturing, and incorrect carburetor rebuilding. Each engine and vehicle combination requires a specific carburetor and calibration to meet the emission standards. If the incorrect carburetor is installed on the engine, the emissions as well as driveability may be affected, which may result in adjustment of the carburetor to cure an apparent problem. There have been instances in which incorrect carburetors have been discovered on in-use vehicles.

Faulty or improper manufacturing of carburetors includes not only the manufacturing done by the carburetor companies, but also the rebuilding or remanufacturing of carburetors done by independent companies and service stations. Missing parts and incorrect main jets are some of the problems that have been observed. These discrepancies could arise as a result of possible cost savings (e.g. to standardize and reduce number of rebuilts), insufficient stock of certain parts, or poor production practices.

As mentioned previously, the carburetor is a major target for controlling exhaust emissions. A desirable carburetor from the emission control standpoint would be one which would always deliver the correct air-fuel ratios for low emission operation and would be unable to be maladjusted. Since a major maladjusted item is the idle mixture adjustment, a partial solution to the maladjustment problem would be a carburetor with a non-adjustable idle circuit. In an attempt to develop a non-adjustable idle circuit, several factors must be considered prior to an initial design. These factors or variables are basically the reasons for an adjustable idle. Production variabilities, vehicle calibration differences and carburetor gumming are some of the major considerations involved in the design of a non-adjustable carburetor.

Production variability is said to be an important reason for an adjustable idle circuit. Present production technology does eliminate most of the part-to-part difference but a small variation still exists. A variation of a few thousandths of an inch in the diameter of a metering rod or orifice produces a significant change in the amount of fuel allowed through the orifice. An adjustable idle circuit compensates for the carburetor-to-carburetor differences by allowing identical air-fuel ratios to be obtained at idle. Eliminating these differences would reduce the need for an idle mixture adjustment. This would mean an improvement in production technology which will require a certain amount of lead time and may result in increased production costs.

Since all vehicles are not identical in terms of required carburetor calibrations, there must be a certain amount of adjustability present in the idle circuit. Of all the different vehicle/engine/transmission combinations available, each require calibration settings suitable for that combination and its intended use. The same basic carburetor may be installed on vehicles with different displacement engines, but the idle mixture setting may be different for each combination. Besides the vehicle differences, there are also individual driving patterns and preferences which may justify the need for an adjustable idle circuit.

Carburetor gumming is also said to be a reason for having an idle mixture adjustment. Gum, a product of slow oxidation, may cause operating difficulties, such as clogging of carburetor metering jets. Also possibly contributing toward the problem of clogged carburetor jets may be dirt or other solid impurities in the fuel or air that pass by the filters into the carburetor.

Freshly manufactured fuels have a relatively insignificant gum content, but with age, varying amounts of gum may be formed. The gum content increases with rise in temperature, increased concentrations of oxygen, exposure to sunlight and also on contact with metals. Current manufacturing processes have eliminated most of the gum from fuels and many of the gasolines now contain detergent additives to prevent formation of deposits and to remove existing deposits. Even though it does not seem to be a problem with freshly manufactured fuels, there may exist a problem with fuels that are stored for long periods of time. More investigation is required to determine whether or not currently available fuel additives car reduce idle circuit gumming to a level that would make non-adjustable idle circuits more feasible.

Limited Idle Adjustments

With present technology, some degree of adjustability of either an idle air bleed screw or an idle fuel metering screw appears to be required. In an attempt to approach a non-adjustable idle circuit, limiting the amount of adjustability appears to be a worthwhile course. This limited idle adjustability features allows for the trimming of the idle mixture to individual engine requirements for satisfactory idle while assuring that the exhaust emission limits will not be exceeded. Two methods for limiting the mixture adjustment are shown in Figure 3-1.*

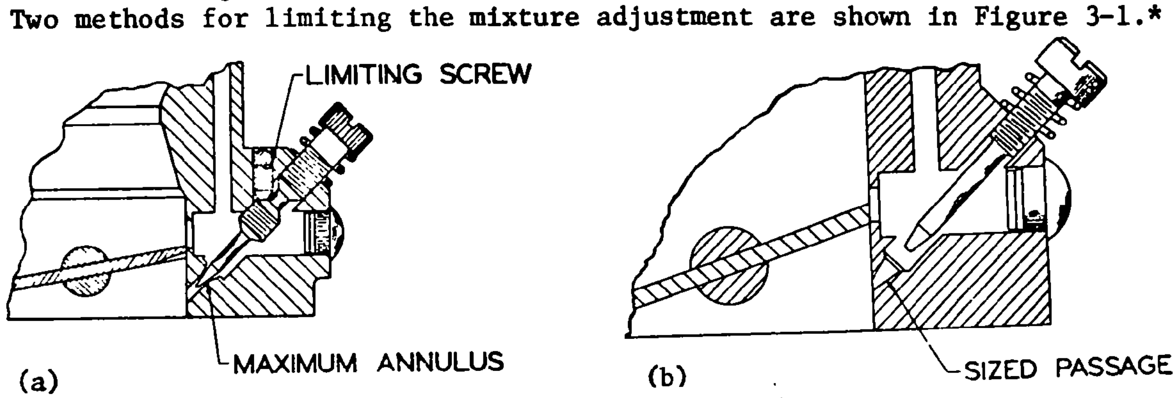

Figure 3-1 - Limited Idle Adjustments

*Cook, F. W. "Antismog Carburetor Hardware and Test Equipment." SAE paper 660110.

In Figure 3-1 by the use of a limiting screw and a modified adjustment screw, the screw can be locked after the appropriate mixture ratio has been obtained on the flow stand. The limiting screw may be covered with a lead shot to make removal more difficult. The mixture would not be able to be set beyond an allowable limit. In Figure 3-1 the passage into the throttle bore, below the idle mixture screw, is sized during the flow operation to give the desired maximum air-fuel ratio before the mixture screw is inserted. This arrangement would only allow a lean adjustment at idle. Another method to limit the mixture adjustment would be to reduce the sensitivity of the adjustment. This can be done as shown in Figure 3-2.

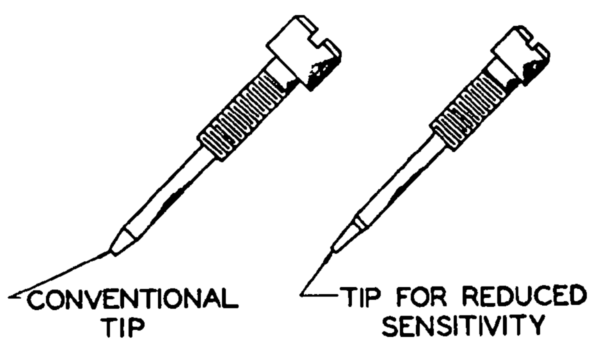

Figure 3-2 - Fine Idle Adjustment

By changing the shape of the idle adjusting needle, the sensitivity would be reduced. A smaller included angle and/or more threads per inch, would allow for finer adjustment, thus producing better control of the idle mixture within close limits.

Limiting the adjustment and/or reducing the sensitivity to a point where the mixture is essentially "non-adjustable" appears to be feasible, although extensive in-use testing of candidate designs may be required.

The Separate Idle Venturi Approach

As discussed earlier, some carburetors use multiple venturis to perform separate functions. The "4 barrel" carburetor is an example of different venturis (primary and secondary) performing different jobs.

Most carburetors have the idle circuits they have because the primary venturis are too large in diameter to provide a good signal for the low flows at idle. The multiple venturi approach leads to the postulate that a separate venturi be provided for idle and near-idle conditions only. This would be a tiny (by today's practice) venturi with its own metering circuit. The conventional idle circuit would be eliminated. It is not known if a separate small throttle would also be required, in order to handle off-idle transitions, or if acceptable transitions could be handled by other means. If the fuel passages could be sized close to the dimensions of current primary circuits gumming would probably not be a severe problem. New main body carburetor castings would probably be required, with possible lead time implications. Ethyl developed a similar approach, which was a 3-venturi carburetor, several years ago. However this carburetor had a idle adjustment screw, possibly because the idle venturi could flow enough air for above 30 mph road load conditions. In order to provide for no idle circuit, the maximum road load flow capability would probably need to be somewhat less than Ethyl's.

Electronic Fuel Metering System

The increased use of electronics in automobiles may allow for the control of the fuel flow electronically in the future. Several manufacturers are currently developing electronic fuel metering systems for use in future vehicles. As an example, the system being developed by Chrysler will be used.

The Chrysler Electronic Fuel Metering (EFM) System controls fuel flow based on an air flow signal. The electrical signal that is received from the air flow meter causes an electronic fuel control to adjust fuel flow to a predetermined air/fuel ratio schedule. To insure that the pump is responding accurately to the signal, a fuel flow sensor measures the flow of fuel going into the throttle body. The signal from the flow sensor is compared to the air flow signal by the electronics and if the proper ratio is not present, the electronics energize the pump to provide more or less fuel until the correct ratio is obtained. Programmed ratio changes and ambient corrections such as cold, load and acceleration enrichments are incorporated in the electronics and are said to be accurate.

The nucleus of Chrysler's system is the precise controller that compares the air and fuel flow and corrects it for any change in engine requirements. For each small quantity of air measured as it enters the air cleaner chamber, fuel is delivered to the throttle body until the correct air-fuel ratio is obtained. Therefore, for all engine operating conditions, fuel flow is metered depending on air flow.

This system, though still in the developmental and experimental stages, appears to show promise in terms of emission control. From the work that has been done on electronic fuel metering, it can be concluded that this system is potentially more accurate than a conventional carburetor and may have improved reliability. Because of the electronics in the system, it also may have better unit-to-unit reproducibility in production than the carburetor. This system may not be a solution to the problem of carburetor maladjustment but it may eliminate some of the adjustable mechanical controls.

Closed Loop System of Fuel Metering

A closed loop (feedback) system is one which the command (input) variable depends in some way on the value of the controlled (output) variable. This means, for example, that the air-fuel ratio delivered by the carburetor can be a function of the composition of the exhaust gas. Important properties of a closed loop system as compared to an open loop control are increased accuracy in obtaining desired values of the output variable and reduced sensitivity to internal and external disturbances. The closed loop system may allow retention of the system calibration over long periods of time. A schematic of the feedback system currently in development by Holley Carburetor is shown in Figure 3-3.*

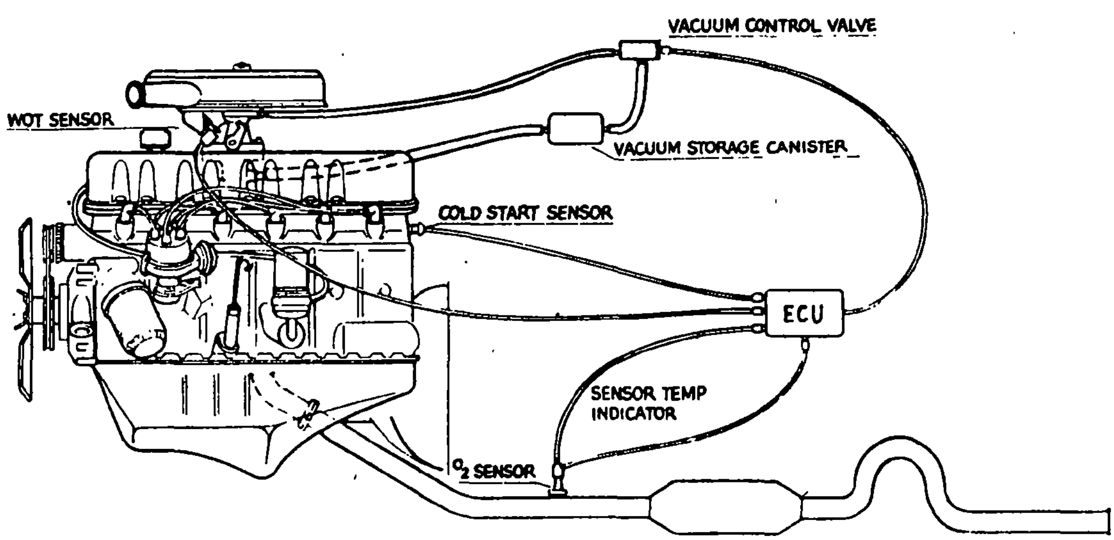

Figure 3-3 - Holley Feedback System

The basic components of the closed loop system are the exhaust gas sensor, electronic control unit (ECU), vacuum control valve and the feedback carburetor.

The exhaust gas sensor, a zirconium dioxide (ZrO_2) sensor, is located in the exhaust stream between the engine and the catalytic converter. The sensor produces a voltage signal dependent on the

*"The Feedback Carburetor-Closed Loop Control of Fuel Metering," Holley Carburetor, Submission to EPA, March 1976.

partial pressure of oxygen in the exhaust. This signal is the main control input to the electronic control unit. The control unit produces a square wave output signal of constant frequency and variable band width to the vacuum control valve which regulates the vacuum applied to the carburetor. The vacuum signal operates the metering systems in the carburetor, Figure 3-4 shows a schematic of the feedback carburetor employed in Holley's system.*

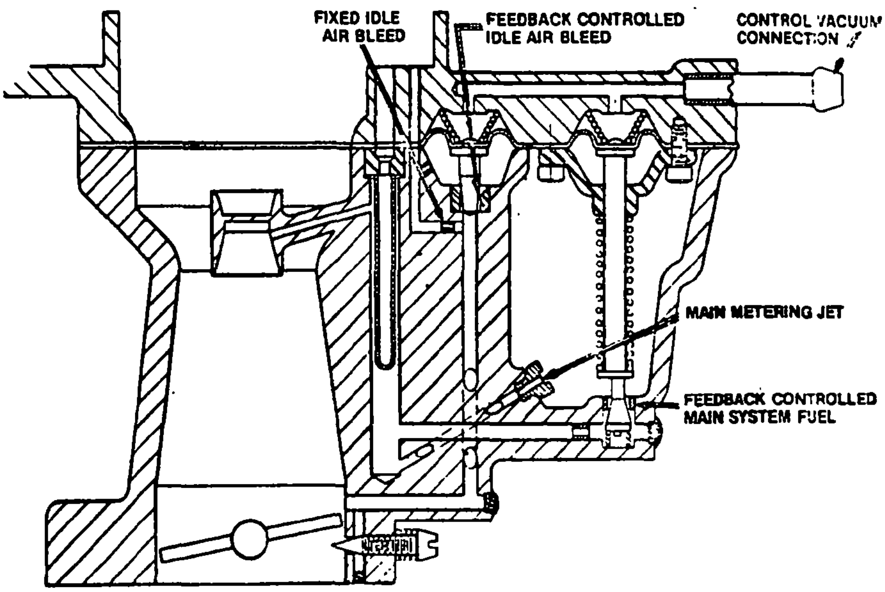

Figure 3-4 - Feedback Carburetor

Control of the main system is accomplished by varying the size of the fuel orifice in parallel with the main metering jet. The idle system is controlled by a variable air bleed in parallel with a fixed air bleed. When a high vacuum signal is applied to the carburetor, it will meter lean and as the vacuum decreases, the metering will richen. Under certain conditions such as cold starts and wide open throttle, sensors are used to indicate to the control unit that these conditions exist and the exhaust gas sensor is overridden by one of these auxiliary sensors.

The feedback system development may not completely solve the carburetor maladjustment problem, but it does offer several features. The capability to meet the fuel metering accuracy requirements of advanced emission

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*"The Feedback Carburetor-Closed Loop Control of Fuel Metering," Holley Carburetor, Submission to EPA, March 1976.

control systems and a simple design which uses vacuum operated metering elements makes this system a potential component of future emission controlled vehicles. The automatic metering of fuel may reduce the possibility of maladjustment.

A non adjustable idle circuit, if it were a requirement, may generate much discussion. Idle adjustment is currently provided, (according to those who maintain the nonadjustable approach may not work) for the following reasons: (1) to compensate for gumming, (2) to allow the carburetor to be tailored to different engines, (3) to allow for production tolerances, and (4) to permit adjustment after engine "break-in".

The degree to which the above reasons are technically valid, and cannot be overcome by design improvements, cannot be definitively determined at this point in time. However, some information on this issue can be found from the 1976 EPA certification durability results. In this testing, no GM vehicle required idle mixture adjustment for 50,000 miles. The idle mixture was not adjusted to compensate for break-in, an adjustment of idle RPM was sufficient. According to the maintenance instructions, idle mixture adjustments are not required for the vehicles in the field.

This promising demonstration must be weighted against the potential requirements for some adjustability should something go wrong, and adjustments and/or repairs beyond scheduled maintenance be required. This possibility that adjustment might be needed for extraordinary conditions, might mitigate against eliminating the adjustability feature altogether, as might be inferred from the GM results.

EPA could approach the adjustability issue by following the approach said to be under consideration by Canada and possibly by Austria. Such an approach would be to set an idle CO limit that could not be exceeded. For example, either three times the specification or the specification plus 0.5% CO whichever is lower, could be used. For example on the Chryslers, the two approaches would yield 0.9% and 0.8% idle CO for a specification of 0.3%. A test procedure that could be used would generate discussion. EPA mechanics could try to maladjust the vehicles. Those vehicles that could be adjusted to idle CO values in excess of the performance standards would fail and not be certified. Since the government maladjusters would have nearly a free hand, this might encourage the design and introduction of non-adjustable idle circuits.

Some choke adjustments are relatively easy to alter. On the external bi-metal choke like Ford uses, it takes less than one minute to adjust the choke extremely rich. These adjustments could be eliminated with internal posts that prevented turning the cap, or restricted the motion to ± 2 notches, which may be acceptable for a wide variety of ambients. The ease of removing the electrical wire for the electrical choke heater could also be reduced via performance standards of the same nature as the idle adjustment maladjustment described above.

Other Redesigns

Current vacuum routings could be improved because simple reconnection of vacuum hoses can have a negative emissions impact. For example, re-routing vacuum hoses to provide full vacuum advance to the distributor at all times may be a common in-use practice. The systems could be redesigned to make hoses different sizes, or make hoses with different fittings on the ends. This approach may not solve the pinching off, or blockage of, for example, EGR hoses. EGR hoses could be made of metal but these could still be pinched. Making the metal hose not easy to be replaced, (welded on) would reduce EGR line blockage. Another approach would be to redesign the intake and exhaust manifolds to make the EGR valve and plumbing completely hidden and out of sight. This might involve manifold casting changes.

Some air pumps are tampered with by cutting the drive belt. The drive could be modified so that the belt that drives the air pump also drives an accessory considered more necessary (like the alternator or the water pump). The air pump lines could also be cast into the block and head and the pump be put under a cover, so that it was relatively inaccessible. New castings might also be required for this approach.

In order to prevent maladjustment by replacing centrifugal advance springs and/or weights, the distributor mechanism could be sealed at the factory and be replaceable only as a unit.

Air cleaners could be redesigned so that the top cover cannot be inverted. This appears to be a common in-use "fix" which many believe helps, when all it really does is eliminate some inlet air filtration and render ineffective some evaporative control systems.

The degree of altering or removing the catalyst itself is unknown but if removal of catalyst pellets or substituting a straight pipe for a monolith catalyst are shown to be common, then the catalyst could be put in the same casting as the exhaust manifold. This is expected to be a significant design challenge.

A recent survey of owners voluntarily participating in EPA emissions factors program indicated a percentage (9%) of owners had used leaded fuel regularly in their catalyst-equipped vehicles. While subsequent interviews with these owners suggested misunderstanding or confusion over the survey question, it is not difficult to envision defeat of the fuel filler inlet restriction through purchase of a plastic funnel or similar adaptor (one such device is legally sold and provided by some dealers in Canada) in the hardware section of numerous stores. If there is shown to be a significant catalyst poisoning problem, one obvious solution may be in a change in the price structure of gasoline so that leaded fuels are equal or greater in price than unleaded.

Another re-design that falls under the general reduced maladjustment potential category deals with ambient conditions, especially pressure. Vehicles certified for high altitude are usually designed in a way that could make them run poorly at low altitude. To eliminate any need to have one's car adjusted for altitude or have a high altitude car adjusted for low altitude, air-fuel ratio and spark advance could be fully altitude compensated. This could prevent a possible loss of mobility of that part of the population that buys vehicles at high altitude and finds that those vehicles are not suitable for low altitude operation without costly repairs.

The same approach could be used for temperature variations expected in the field, but the technical solutions to make a car meet the emission standards at $0^{o}F$ or $90^{o}F$, for example, are not as immediately apparent as they are for altitude.

3.2 Maintenance Technology Improvements

This section deals with improving maintenance capabilities through technology. Other approachs that might help the capability of the service industry are not considered here.

Make Vehicles Easier to Maintain

The complexity of today's vehicles, caused to some extent by the types of emission control systems used by the manufacturers have tended to make some maintenance more complicated than was the case ten years ago.

The situation could be improved by setting a performance standard that would involve determining an acceptable time to perform emissions-related maintenance. This might encourage designs that were more maintainable and help to eliminate maintenance difficulties like jacking up of an engine off its mounts to change a spark plug.

Making vehicles easier to maintain could also involve eliminating the need for special tools which are sometimes only practically available from the dealer. Special generally unavailable wrenches could be eliminated, for example, and maintenance that required tools more specialized than those generally deemed to be available could not be permitted.

Minimum tolerances around specific components could be set so that access is easier. Making apparently simple changes like standardized, easy-to-see timing marks that could be seen easily and only indicated the correct value of timing could be effective.

Better Information Dissemination

There can be literally hundreds of running changes made during a model year to a large manufacturer's fleet. Many of these running changes involve calibrations that must be known by the mechanics if the vehicles are to be maintained properly. If the detailed data are not available to the mechanic, he cannot be expected to do it properly. Asssuming that the tune-up specifications on the required sticker are not enough, two approaches could be taken. First, the information on the specific vehicle could be required to be a part of the owner's manual. Second, there could be more use of today's advances in communications. It is not inconceiveable to consider that a toll-free telephone number be set up for anyone (dealer mechanic, independent mechanic, or owner) to call. Upon identifying the VIN all the maintenance information would be transmitted to the mechanic and provisions could be made to answer specific questions.

Standardized Practices

There are different ways to tune up different vehicles. Consider idle adjustment; some use propane addition, some use the "lean drop" and some use smooth idle to set the idle mixture. This, coupled with different idle CO requirements for different vehicles, could be leading to massive confusion by the mechanics in the field. One single method could be recommended for use on all vehicles. Such a method would have to be universally adaptable. The lean drop appears to be somewhat more implementable than propane addition, although it would not overcome the tendency of some mechanics to limit enleanment (i.e. RPM drop) in favor of smooth idle.

Similar procedures could be used for setting timing. A standardized procedure could involve having the same hoses connected or disconnected, for example.

Better Diagnostic Technology

The first step here would be to improve diagnostic equipment of the type already in the field. Performance of dwell tachometer could be improved so that they were more accurate and consistent for example. As far as emissions measuring equipment goes the current performance is not good. Current instruments, idle HC/CO meters in particular, are not adequate, if California's experience is any indication. A study done in California found that 80 percent of the meters did not work properly. Assuming that the nationwide performance is like that in California, it is apparent that improvements are needed in these instruments.

Section 4

Conclusions and Recommendations

The conclusions listed herein apply to the timeframe, Summer 1976, when this report was being prepared and they reflect the interpretations of the limited amounts of data available.

Conclusions

1. There exists a relationship between idle CO levels and the ability of the vehicle to pass either the 1975 FTP or various state inspection tests.

The EPA Emission Factors Program has shown that there is a good probability that a vehicle with an idle CO level higher than specification, or greater than 0.5 idle CO in the absence of a specification, will fail an FTP test. Maladjusted idle air/fuel mixture is the most common cause of high idle CO levels. The frequency of idle maladjustment, the reasons for it or who is responsible for the maladjustment cannot be established with certainty. Isolated studies have indicated idle limiter caps may have been removed from 25 to 30+% of the 1975 vehicles investigated, but none of the studies were able to identify why or by whom the idle caps were removed. This report speculates that the caps were removed to enrichen the idle fuel mixture for vehicle driveability improvements.

2. Maladjustment of the carburetor idle circuit, which results in high idle CO levels, needs to be prevented.

Some technically feasible approaches to a nonadjustable idle circuit are proposed and discussed in this report. However, there exist some technical questions which need to be resolved concerning the nonadjustable idle circuit among which are: gumming, production tolerance, and the necessity of adjustment due to engine break in.

3. There exists a probability, possibly as high as 37%, that a vehicle with low (less than 0.5% idle CO) could also fail the FTP.

This could be an indication that maladjustment of carburetor chokes may also be a cause for failure on the FTP. However, more data are required to determine that choke maladjustments are as important as maladjusted idle CO. Currently, maladjusted chokes appear to be a lesser problem. Idle rpm and ignition timing show little relationship to FTP failure rates.

4. There is no general agreement on the cause(s) of poor in-use vehicle emissions performance.

Two probable reasons for poor emissions performance are due to a lack of service industry capability or poor vehicle driveability, but the entire in-use performance problem is a multifaceted relationship which may make impossible the identification of a single source that is immediately amenable to corrective actions.

The question remains as to why so many emission control components are maladjusted. The appearance is given that "someone" has been tinkering with these controls, but the motivations behind the tinkering remain obscure. Is it poor instructions in the field? The business relationship between the vehicle owner and service industry representative? Ignorance of emission controls? Apathy? Mis-manufacture? Vehicle driveability?

5. More information is needed to more properly assess the in-use problem, before an attempt can be made to demonstrate solutions to the problem.

EPA has initiated a program, titled Restorative Maintenance (RM) within its Emission Factors Program, aimed at providing information concerning the magnitude, frequency, and types of emission control components maladjustment and/or failure. Cooperation has been elicited and received from the automotive industry. Data from the currently in process Restorative Maintenance Program was not available for this report.

Recommendations

Considering the complexity of the in-use vehicles emission performance problems outlined in this report it is not surprising that there could be a wide range of recommendations generated by discussing these problems. While it is realized that no single answer to this problem exists, it is equally evident that additional work must be conducted and aimed at both understanding this problem and validating the proposed solutions. In this context, the following recommendations are proposed.

1. Nonadjustable carburetor idle circuit

Because of the accessibility and apparent frequence of maladjustment of the idle circuit, it is recommended that a nonadjustable idle circuit be considered seriously. While the current adjustability idle circuit may be considered to be necessary by the some due to corrections of production tolerance stack up, the in-use results indicate that the idle circuit is regarded as a convenient "correction" to in-use vehicles.

The desirability of a nonadjustable idle circuit is clear, but the degree of nonadjustability remains open for discussion. This discussion centers around the unanswered questions of the effects of production tolerance stack up, fuel gumming, the carburetor industry's capability, and most importantly the necessity for adjustment during and after vehicle break-in and extended operation. However, potential solutions to the idle circuit maladjustment problem exist.

Also to be resolved are the alternatives of increased idle circuit complexity versus complete nonadjustability after carburetor installation. A sealed idle circuit, would be beneficial, but those who indicate that idle adjustments are a necessity suggest that a more complex idle circuit to deter "tinkering" with the idle could be the desired approach. Both approaches deserve further study and demonstration.

2. No adjustment of idle during certification durability testing

Attention should be given to the certification durability test procedure, especially those maintenance portions involving the carburetor idle adjustment. Records compiled by an EPA* report indicate that of the 162 engine families reported on during the 1974 Certification cycle fully one third of them did not require, for whatever reason, an idle mixture adjustment. The remaining engine families were adjusted, with the result that on the average there were 1.4 idle adjustments per engine family during 50,000 durability miles. It is interesting to note that this same report indicates that the owners manual suggests that the same engine families perform idle adjustments on the average of 3.5 times during the same mileage period. There would appear to be a disparity between (1) certification and (2) in-use vehicle instructions and (3) potentially what is actually needed.

In view of apparent widespread maladjustment of idle circuits, strong consideration should be given to not allowing the manufacturers to adjust idle, other than possibly idle rpm, during the 50,000 mile durability portion of certification testing. This restriction could be used as interim feature to (1) be a forcing function for the adoption of a nonadjustable idle circuit in production carburetors, (2) reduce number of recommended idle adjustments required in the owner's manual, (3) be an example to the industry of the desirability, worth, and benefits for nonadjustment over 50,000 miles.

3. Inclusion of a Driveability test in the Certification Procedure

The fact that driveability is a subjective factor does not lessen its importance when studying in-use vehicle problems. Elsewhere in this report it is argued that driveability may be a forcing function that

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*Actual and Recommended Maintenance Practices for Light-Duty Vehicles for 1975 and Later Model Years, EPA-460/3-75-009, August, 1975.

causes or is an indirect cause of in-use vehicle idle circuit maladjustment. Since this type of maladjustment can cause gross increases in emissions, especially for CO, it should be mentioned that the approach of assuring that driveability is acceptable is to make engines less adjustable. This approach would restrict engine designers from picking engine specifications for emission testing that the designer know (or should know) will cause customer complaints, with assurance that the complaints will be easily remedied in the field by the making of simple adjustments.

Consideration should be given to the introduction of a standardized driveability test to be performed in conjunction with the Certification program. The driveability ratings could be published as a consumer guide and/or possibly posted on the vehicle as a label in a voluntary industry program such as was the case for fuel economy in 1975 and 1976.

Introduction of a standardized driveability test will not be easy. Potentially, the CRC driveability test could be incorporated into the Certification procedure as a common basis for driveability judgements. The CRC driveability test provides a test procedure which judges cold start driveability in a manner comparable to in-use vehicle operations.

It should be emphasized that it is suspected that much of the driveability problems encountered by the consumer become manifested at ambient temperatures lower than the ambient temperatures at which the certification test procedure is conducted. Therefore, the inclusion of a driveability test in the certification process will require ambient temperature ranges reflecting ambient temperatures closely representing those experienced by in-use vehicles. It should also be noted that EPA has not conducted studies quantifying the temperature ranges necessary or the detailed procedures required for lower ambient temperature testing for driveability. Approximately one year will be necessary to develop such procedures.

A driveability test could be included in the certification verification testing done by the EPA Ann Arbor laboratory. However, the inevitably subjective nature of this test will require increased education and training of personnel to conduct the CRC driveability test, as well as some increase in staffing. Expanded facilities, possibly to the extent of needing a test track may be required. Preliminary estimates indicate that at a minimum for a test track facility it will be necessary to allow nine to twelve months for the development of a suitable driveability test plus the training of drive raters. Also the addition of eight people to the present laboratory complement and 600,000 dollars to the budget is necessary. If a dynamometer procedure were to be developed for inclusion in the present certification cycle, twelve to fifteen months are necessary to develop the procedure and train drive raters. Six additional people would be necessary as well as 1.9 million dollars added to the budget.

Initially, a minimum drive number could be established by EPA for acceptable drive performance to serve as a guideline for industry and consumer. This minimum guideline might tend to reduce any tradeoffs of driveability for lower emissions levels which apparently fosters the widespread maladjustments of the emission control systems.

4. Driveability Standards May be Required

If a voluntary approach such as outlined in Recommendation 3 above does not prove workable an approach toward reducing the problem in this area might be Federally mandated driveability standards. Of course, a thorough study of the regulatory impacts of such standards is required.

5. Service Industry/Owner Interfacing

It would seem appropriate to determine the extent of vehicle owner insistance for "fixing it to run right" which is responded to by the service industry by adjusting engines other than to specifications. A limited report done on willful tampering* conducted by EPA suggests that the service industry may in many cases respond to owner's wishes for "corrections". If this phenomenon is as widespread as is suspected, then the manufacturers may need to be required to develop relatively nonadjustable emission control systems for their vehicles.

6. Use of "Available" Maintenance During the Certification Process

It is suggested that EPA consider using EPA mechanics (which could be contractor personnel) to factor some approximation of in-use maintenance into the certification procedure. These average or typical mechanics could be given the tools presently available to mechanics in the typical service industry facility. Implementing this recommendation may foster development of maintenance free emission control systems more quickly than might be otherwise expected. It is realized that a thorough study of the regulatory issues involved, including cost of compliance, lead time and cost-effectiveness would be required to determine the viability of this approach.

Standardize Tune-up Adjustment Methods

One potential approach toward reducing the problem could be the standardization of adjustment levels between all vehicle manufacturers. For example, there presently are three methods of idle adjustment specified by the major automobile manufacturers; idle CO measurement before the catalyst, the lean drop method, and propane addition. As can be seen by these differences, idle adjustment procedures have increased. Some procedures are so complex that the do-it-yourselfer or small maintenance shop may not be able to perform his own adjustment without large capital outlay for test instruments. A standardized idle adjustment may help alleviate this problem. Additionally, if a standardized idle adjustment was employed, field instructions might be more easily simplified and better understood.

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*A Study of Fuel Economy Changes Resulting from Tampering with Emission Controls, TAEB Report 74-21 DWP.