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Low-Cost Approaches to
Vehicle Emissions Inspection and Maintenance

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Notice

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1.0 INTRODUCTION AND SUMMARY

1.1 Introduction

The cost of automobile Inspection and Maintenance (I/M) programs is one of the main topics in any discussion of I/M as a strategy for reducing in-use automobile emissions of hydrocarbons (HC) and carbon monoxide (CO). While I/M is a cost-effective means to reduce these pollutants in urban areas, there are aspects of the most common -- or "conventional" -- approaches to I/M which could be varied and which would reduce the cost of repairs necessary to pass I/M and, in some cases, the inconvenience which I/M causes vehicle owners. This report will focus on possible approaches to I/M which inherently can be expected to have lower repair costs than the conventional approaches to I/M or which can be expected to result in fuel savings which will offset some of the cost of the I/M program. The report evaluates the emission reductions that can be obtained from each of these approaches relative to the conventional approach.

The low-cost forms of I/M are basically only modifications of the conventional form, and fall into two categories. First, there are I/M programs which have the same basic inspection and reinspection requirements as a conventional I/M program but include improvements which aim at reducing the number of inappropriate and unnecessary repairs, thereby lowering the average repair cost to vehicle owners. I/M programs such as these will achieve lower costs with no loss in emission reduction effectiveness.

Second, there are I/M programs which differ from conventional I/M in that no HC cutpoint is used in the inspection and reinspection. This reduces the number of vehicles which fail inspection and changes the type of repairs required for failed vehicles to pass reinspection. The result is a lower overall repair cost. This cost reduction is accompanied by a partial loss in emission reduction effectiveness for HC. There are, however, some improvements and add-on procedures which are helpful in increasing the overall HC emission reductions from this second type of low-cost I/M program and which are discussed in this report. These improvements can make this type of I/M program more acceptable as a substitute for a conventional I/M program in urban areas which need HC reductions in order to attain the National Ambient Air Quality Standard for ozone. Some of these improvements and add-on procedures can also be used in a conventional I/M program to increase its HC effectiveness, and are therefore of general interest.

Because both forms of low-cost I/M are only variations from the conventional I/M program, the agency responsible for planning, implementing, and operating a low-cost I/M program will need to perform all the tasks it would in a conventional I/M program. These tasks include:

- Development of an Implementation Schedule.

- Preparation of draft legislation, if adequate legislative authority does not yet exist or is not compatible with the low-cost approach.

- Initiation of a Public Information Program.

- Initial notification of the repair industry of program plans and schedule.
- Development and award of any necessary contracts.
- Construction of facilities if necessary (including challenge stations in a decentralized program).
- Adoption of testing procedures and guidelines.
- Selection of geographic coverage, vehicles subject to inspection, and inspection cutpoints.
- Licensing of test facilities and testing equipment.
- Development of test facility auditing procedures and schedules.
- Purchase and delivery of necessary equipment.
- Initiation of mechanic training programs.
- Hiring and training of inspectors.
- Phase-in of mandatory program.

These tasks are defined in more detail in EPA's I/M policy memo of July 17, 1978 [1].* In addition, the improvements which seek to lower repair costs by eliminating inappropriate and unnecessary repairs require additional involvement by the responsible agency.

In this report's discussion of various approaches to I/M there will often be a distinction made between pre-1981 model year vehicles and 1981 and later model year vehicles. This distinction is necessary to account for the significant technology differences between these two groups. These technology differences cause differences in the frequency and types of emission control system maladjustments and malfunctions and the types of repairs needed to correct these problems. There are also differences in warranty coverage between these two groups of vehicles. These differences are primarily caused by the more stringent Federal standards for CO and NOx emissions and the implementation of Parameter Adjustment[2] and Emission Performance Warranty regulations[3] beginning in the 1981 model year. The effect of these differences will be discussed in greater detail later in this report. There is more information available at this time about the costs and effectiveness of various I/M strategies on pre-1981 vehicles than on 1981 and later vehicles and this will be reflected in the detail with which the two technology types are covered.

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* Numbers in brackets refer to references at the end of the report.

It is expected that the failure rate of 1981 and later vehicles will be low (5-10%) and some of the repair costs of these vehicles will be covered by the new warranty regulations [2]. There will also be relatively few 1981 and later vehicles in the fleet in the early years of a new I/M program. Therefore as the programs begin the repair cost for 1981 and later vehicles will not be as important to the overall cost of an I/M program as the repair cost for pre-1981 vehicles.

1.2 Summary of Key Results

The most far reaching conclusion in this report is that inspecting cars only for carbon monoxide (CO) emissions will not reduce the CO emission reduction of an I/M program and will reduce the HC emission reduction by only a moderate amount.

Repairs will be much simpler and cost much less in an I/M program that uses only idle CO cutpoints (the "idle CO I/M program"). Carburetor adjustments will usually be the only necessary repair for pre-1981 vehicles. These will cost between $6 and $10, compared to average repair costs from $18 to $30 in conventional I/M programs. For 1981 and later vehicles, using only a CO cutpoint means that only cars which are suffering a malfunction in the computer-controlled fuel system will fail the inspection; in the conventional program, some cars fail for high HC due to other types of malfunctions. Repair of fuel system malfunctions causes a sizable fuel economy benefit, while repair of other malfunctions often does not. Consequently, the same overall fuel savings will be achieved in an idle CO I/M program as in the conventional program but the failure rate, and consequently the total repair cost, for 1981 and later vehicles will be less.

The bottom line for any low-cost approach to I/M programs is not only a more favorable cost-effectiveness value, but an adequate reduction in total HC and CO emissions from automobiles. This reflects the need of areas requiring I/M programs to reduce these pollutants to attain the National Ambient Air Quality Standards for ozone and CO. The tables in this section will provide information which can help I/M program planners assemble a low-cost I/M program using the idle CO I/M approach as a base and adding various emission or cost enhancement options. Options can be selected from the tables in this section to meet an area's individual needs regarding design, costs, and benefits. Following sections of this report provide substantiation and derivation of the benefits presented in these tables.

The methods used in this section to compute the costs and emission benefits from the various options are identical to those used in "Update on the Cost-Effectiveness of Inspection and Maintenance".[4] The estimates of fuel economy benefits are derived using the methods described in "Update on the Fuel Economy Benefits of Inspection and Maintenance Programs".[5] Each table assumes a standard fleet of one million light duty gasoline powered passenger vehicles subject to the I/M program. All operating conditions (speed, temperature, etc.) are national averages.

Table 1 compares the basic idle CO I/M program to a conventional I/M program using information from Section 6.0. Both programs would have the same idle CO cutpoints, but since the idle CO program does not use an idle HC cutpoint, all of the vehicles which would have failed for idle HC only in the conventional I/M program will pass in the idle CO program. Therefore, while the conventional I/M program has stringency of 20% for pre-1981 vehicles the idle CO program has a stringency of about 13% using the same idle CO cutpoints. Both programs use the idle test for 1981 and later vehicles.

Table 1

Comparison of Basic Idle CO and Conventional I/M Programs

	Stringency for Pre-1981 Vehicles (Percent)	Percent Benefit on Dec. 31, 1987		Five Year Emission Reduction (Thousands of Tons Removed)		Five Year Program Cost[1] (Millions of $)	Cost-Effectiveness[2] ($/ton)	
		HC	CO	HC	CO		HC	CO
Conventional I/M	20	34.9	33.1	46.50	526.8[3]	54.10	581	51[3]
Idle CO I/M	13	24.2	33.1	31.31	526.8	40.19	642	38

1: Costs include inspection fee and repair costs less any fuel economy benefits from repairs.

2: Program costs are divided equally between the two pollutants.

3: These values have been recalculated and are nearly but not exactly the same as reported in "Update on the Cost-Effectiveness of Inspection and Maintenance".[4]

Since only those I/M repairs which effect CO emissions will be required the basic idle CO I/M program will provide the same CO benefit as the conventional I/M program, but with overall repair costs for pre-1981 model year vehicles reduced by about 70%. Since repair costs are only one part of overall program costs, overall program costs in the basic idle CO program are about 26% less than for a conventional I/M program. This reduction is entirely in out-of-pocket repair expenses to vehicle owners. The cost-effectiveness of the basic idle CO program is better for CO than the conventional approach to I/M and slightly worse for HC. An idle CO program, however, lends itself to several optimizations which will greatly increase the cost-effectiveness of the program and will provide other unique benefits to vehicle owners. These optimizations are described briefly in this section and example low cost I/M programs using these options are described in Section 1.3.

Overall, each enhancement option strives to increase the effectiveness and/or cost-effectiveness of an idle CO I/M program. There are three basic methods to achieve this goal: (1) achieve greater emission or fuel economy benefits from each failing vehicle, (2) fail more of the vehicles which are inspected, (3) inspect more vehicles in the I/M area. Each of the following options will use one or more of these methods.

Better Test for 1981 and Later Vehicles

Although the basic idle CO I/M program provides the same CO benefit as a conventional I/M program, there is a considerable shortfall in HC benefit. One of the simplist ways to increase the HC benefit of idle CO programs is to use an inspection test for 1981 and later vehicles which is more effective in identifying vehicles with full-rich fuel system failures. This is discussed in Section 7.1. Increasing the failure rate of these vehicles will provide large HC and CO emission benefits for each repair dollar spent. Also, studies have shown that repairs of vehicles with full-rich fuel system failures result in a 15% fuel economy benefit.[6] The fuel savings from the repair more than offset the expected average repair cost of about $30. Using the Two-Speed Idle or Loaded Test for 1981 and later vehicles instead of the idle test is expected to increase the identification rate of 1981 and later vehicles with fuel system failures from 50% to 70%. Because at each inspection less than 5% of 1981 and later vehicles are expected to have a fuel system failure, their failure rate on the I/M test will still be only a few percent.

Table 2 presents the additional benefits associated with the use of a better test for 1981 and later vehicles. When combined with the basic idle CO program, the HC benefit is increased 2.4 percentage points from 24.2% to 26.6% and the CO benefit increases 5.8 percentage points from 33.1% to 38.9%. The averaged cost-effectiveness of the I/M program with this option is improved to $527/ton for HC and $30/ton for CO (not shown in the table, but can be calculated from the information in the tables). The overall HC benefit with this enhancement alone is still less than for a conventional I/M program.

Table 2

Better Test for
1981 and Later Vehicles[2]
in an Idle CO Program

Additional Percent Benefit on Dec. 31, 1987 HC	CO	Additional Five Year Emissions Benefit (Thousands of Tons Removed) HC	CO	Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness ($/ton) of Option
2.4	5.8	2.03	60.4	-5.05	NA[3]

1: Costs include additional repair costs less any fuel economy benefits from repairs.
2: Using the Two-Speed Idle or Loaded Test instead of the idle test will increase the identification rate of 1981 and later vehicles from 50% to 70%.
3: The 15% fuel economy benefit savings in fuel more than offset repair costs for 1981 and later vehicles with full rich fuel system failures. Overall program costs are reduced by the amount shown.

Increased Stringency

Another way to improve the cost-effectiveness of an I/M program is to fail more of the inspected vehicles. This can be done in an idle CO program by increasing the stringency for pre-1981 vehicles. This is discussed in Section 7.2. This will not increase inspection costs but will increase overall repair costs. Up to a point, the increase in stringency will result in increases in HC and CO emission benefits at a lower incremental cost per ton than the basic program, since the inspection costs have already been paid.

Table 3 presents the additional benefits from increasing the stringency in an idle CO I/M program. The costs include only the costs resulting from additional repairs. The basic idle CO program has already absorbed all of the inspection cost. Note that increasing the stringency from 30% to 40% does not substantially increase the HC and CO benefits but will cost as much as increasing the stringency from 20% to 30%. This is the point where failing more vehicles will result in less cost-effective emission reductions than in the basic program. For this reason a stringency of more than 30% is not recommended for an idle CO I/M program unless no other option to increase HC and CO emission benefits is found acceptable.

Table 3

Increasing Failure Rates
in an Idle CO Program

Option	Additional Percent Benefit on Dec. 31, 1987		Additional Five Year Emission Reduction (Thousands of Tons Removed)		Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness[2] ($/ton)	
	HC	CO	HC	CO		HC	CO
Higher Stringency for Pre-1981 Vehicles							
Increased from 13% to 20%	2.4	3.3	5.07	80.6	2.06	203	13
Increased from 20% to 30%	3.1	2.8	7.23	85.2	2.95	204	17
Increased from 30% to 40%	1.1	0.8	2.03	30.4	2.95	727	49

1: Costs include additional repair costs less any fuel economy benefits from repairs.
2: Program costs are divided equally between the two pollutants.

Better Repairs for Pre-1981 Vehicles

Better repairs for pre-1981 vehicles deserve special attention primarily as a cost-saving measure, although they are also an HC and CO enhancement. Better repairs therefore deserve attention from any area considering an idle CO I/M program, not just those that might need it as an HC or CO enhancement. Better repairs for pre-1981 vehicles will produce fuel economy savings on these vehicles which will offset a large part of the cost of the I/M program.

EPA studies have shown that a fuel savings of 4% is achieved by carburetor adjustments to pre-1981 vehicles which have failed an I/M test, even if the adjustments are not performed precisely to specification. It is necessary that adjustments be performed closer to specification than they would be in a basic idle CO or conventional I/M program, and that other types of repairs which can degrade fuel economy be avoided. Because carburetor adjustments will usually be the only necessary repair for pre-1981 vehicles in an idle CO I/M program, the types of repairs which can degrade fuel economy are naturally avoided in this type of program. Section 4.4 describes a number of approaches that I/M administrators can take to improve the quality of carburetor adjustments, two of which are mechanic training and a tight idle CO reinspection cutpoint. The fuel savings which will result are well worth the effort, since an additional 4% savings for each pre-1981 vehicle which is failed and repaired translates into a total annual savings of about $36. This offsets a large part of the program costs. Also, a small improvement in the HC and CO emission reductions accompanies the fuel savings. Section 7.3 discusses the HC and CO benefits. The overall effect is a major further improvement in the cost-effectiveness of the idle CO I/M program.

Table 4 presents the additional benefits of better repairs in an idle CO I/M program. Once a stringency has been chosen, Table 4 will provide the additional benefit that can be achieved with better repairs. For example in the basic idle CO program with a 13% stringency the HC benefit in 1981 can be increased 0.6 percentage points from 24.2% to 24.8% and the CO benefit can be increased 2.7 percentage points from 33.1% to 35.8%. Overall costs can be reduced $13.27 million as a result of fuel savings from repaired vehicles. The result is an overall cost-effectiveness of $411/ton for HC and $22/ton for CO (not shown in the table). However, the HC benefit in 1987 from the basic idle CO program with this option alone is still not as large as the HC benefit of a conventional I/M program. One or more other HC enhancements are also necessary to equal the HC benefit of a conventional program.

The benefits from better repairs for 1981 and later vehicles cannot be estimated at present. It appears that the requirement for vehicles to pass the reinspection test alone will force a high quality repair on these vehicles, unlike the case for pre-1981 vehicles, leaving less room for improvements via special programs of training, etc. This occurs because most repairs to 1981 and later models involve parts replacement instead of adjustments.

Table 4

Better Repairs for Pre-1981 Vehicles in an Idle CO Program

Stringency for Pre-1981 Vehicles (Percent)	Additional Percent Benefit on Dec. 31, 1987 HC	CO	Additional Five Year Emission Reduction (Thousands of Tons Removed) HC	CO	Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness[2] ($/ton)
13	0.6	2.7	1.40	74.5	-13.27	N/A
20	1.3	3.3	2.28	98.3	-20.40	N/A
30	1.9	2.7	3.29	78.9	-30.60	N/A
40	2.1	2.0	4.18	56.6	-40.80	N/A

1: Costs include additional repair costs less any fuel-economy benefits from repairs.
2: Since there is a net savings, no incremental cost-effectiveness has been calculated. Overall program costs are reduced by the amount shown.

Tampering Checks

Table 5 presents the incremental benefits from the addition of tampering checks to an idle CO I/M program. These checks are discussed in detail in Section 7.5. The costs shown in Table 5 are entirely repair costs, since none of the tampering checks is expected to significantly increase the assumed inspection costs. The checks may, however, pose administrative problems which can seem large to the I/M program managers.

As can be seen from the table, the air pump and evaporative cannister checks, which consists of checking for the presence of these devices, are extremely cost-effective. The incremental cost-effectiveness for the catalyst check for the presence of the catalyst on all model year vehicles is higher than any cost-effectiveness value presented so far in this summary, but is still lower than for many non-I/M HC control strategies.[4] The cost of replacing missing catalysts on older cars is the reason for the high cost-effectiveness value. About 1.4% of vehicles originally equipped with catalysts have had them removed. New OEM replacement catalysts cost from $172 to $320. If all catalysts removed before the I/M program begins in 1983 are waived, and catalyst presence is checked only for 1983 and later models from then on, only very foolish vehicle owners would remove their catalysts knowing that they will be checked. The repair costs for the catalyst check would then be insignificant.

Table 5

Tampering Check Benefits

Option	Additional Percent Benefit on Dec. 31, 1987 HC	CO	Additional Five Year Emission Reduction (Thousands of Tons Removed) HC	CO	Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness[2] ($/ton) HC	CO
Air Pump Check	1.5	4.3	2.56	68.0	0.92	180	7
Evaporative Cannister Check	1.3	0.0	1.94	0.0	0.25	129[3]	-
Catalyst Check (All Vehicles)	0.9	0.5	1.35	10.7	2.00	741	93
Catalyst Check (1983 and Later Model Vehicles)	0.3	0.2	0.20	1.6	0.00	NA[4]	NA[4]

1: Costs include any additional repair costs.
2: Program costs are equally divided between the two pollutants.
3: Since there is no CO benefit, all costs have been allocated to the HC benefit.
4: Since there is no significant cost, no cost-effectiveness has been calculated.

Loose HC Cutpoints

Table 6 presents the additional benefits of including very loose idle HC cutpoints with an idle CO I/M program. This option is discussed in detail in Section 7.4. Data on vehicles with very high idle HC scores are very sparse so that there is a very high degree of uncertainty in all estimates concerning these vehicles. Section 7.4 does make some conclusions concerning these vehicles, however, based on data and experiences with vehicles exhibiting moderately high idle HC scores.

Repairs of vehicles which fail only for idle HC in the Portland program ranged in cost from zero to $207, averaging $41. These repairs range from cleaning or replacing spark plugs to extensive ignition system diagnosis and replacements. Program costs would be increased by the additional cost of these repairs for any vehicles failing a high idle HC cutpoint used in an idle CO program.

There is evidence, discussed in Section 7.4, that repair of severe spark ignition misfire, which often causes very high idle HC measurements, can result in substantial fuel economy benefits averaging from about 7% to 9%. This would save vehicle owners who needed and received such repairs about $72 in fuel costs for that year.

Section 7.4 estimates that, in the best possible case, about half of the vehicles which fail a 1000 ppm idle HC cutpoint will obtain a $72 fuel economy benefit. The repair cost of $41 and the average fuel savings of $36 approximately cancel each other, so in the best case this option has no net effect on program costs. As Table 6 shows, there is an HC benefit. Repairs for vehicles failing idle HC cutpoints in an idle CO program are not expected to increase the CO benefit of the program.

Other factors, however, not considered above, may prevent the best case from occurring and thus affect the cost of this option. There is reason to believe that unnecessary repairs, essentially eliminated by use of only idle CO cutpoints, can become a problem again if any HC cutpoint is used. In the Portland program there are, for example, ignition repairs performed on vehicles which fail the idle test for only CO. Such ignition repairs are not necessary,* but are sold to vehicle owners who are willing to allow mechanics a free hand in performing repair to pass the reinspection. An idle CO program without an HC cutpoint is expected to have very few instances of such unnecessary repairs, since in virtually all cases the only necessary repair will be a carburetor adjustment and vehicle owners can be readily made aware of this fact. Including an idle HC cutpoint makes determination of which repairs are necessary and which are not more unclear. The typical vehicle owner will again be left essentially on his own in determining which repairs should be performed. As a result, the amount of repairs performed, besides carburetor adjustments, will likely be greater than what would be needed to make cars which failed the HC cutpoint pass reinspection. These unnecessary repairs will increase the program costs without significantly increasing HC benefits. This will degrade the cost-effectiveness of this option. If, for example, only 4% of the inspected vehicles receive unnecessary ignition repairs (the same number as do need ignition repairs) and produce no additional HC benefit, the cost per ton of HC for this option can climb from essentially zero to over $3000/ton. Clearly, unnecessary repairs can drastically reduce the cost-effectiveness of any I/M program. Section 3.0 discusses approaches which can be used to reduce unnecessary repairs.

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* This statement is possibly overly pessimistic, since it is possible that ignition repairs performed by the mechanic which would not have been necessary to pass the I/M reinspection may prevent engine problems in the future which would cause an I/M inspection failure.

Table 6

Loose Idle HC Cutpoints

Additional Percent Benefit on Dec. 31, 1987 HC	CO	Additional Five Year Emissions Benefit (Thousands of Tons Removed) HC	CO	Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness ($/ton) of Option
2.0	0.0	2.59	0.0	0 - 8.98	0 - 3467

1: Costs include additional repair costs less any fuel economy benefits from repairs.

Inspection of Light-Duty Trucks

Table 7 presents the additional benefits from inspection and maintenance of light-duty trucks (LDT) as well as passenger vehicles. This option is discussed in Section 7.6. Reduction in HC and CO emissions is not required of LDTs under EPA policy, however any emission reductions gained from LDTs can be used towards total emission reduction goals for passenger vehicles. Since the technology used in most LDTs is very similar to that of passenger vehicles, I/M for LDTs is very similar to I/M for passenger vehicles. A 4% fuel economy benefit has been included for the cases of better repair of pre-1985 LDTs and a 15% fuel economy benefit for 1985 and later LDTs. (Starting in 1985, light-duty trucks will have the types of emission controls used on 1981 and later passenger cars.) Since use of a better test such as the Two-Speed Idle or Loaded Test for 1985 and later LDTs effects very few LDTs by 1987, the effect of selecting that option on the LDT benefits is insignificant.

Table 7

I/M for Light-Duty Trucks
in an Idle CO Program

Stringency for Pre-1985 Vehicles (Percent)	Additional Percent Benefit on Dec. 31, 1987		Additional Five Year Emission Reduction (Thousands of Tons Removed)		Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness[2] ($/ton)	
	HC	CO	HC	CO		HC	CO
Basic							
13	4.2	4.4	5.20	71.7	3.34	642	38
20	4.6	4.9	6.08	84.1	3.53	581	35
30	5.1	5.4	7.27	98.6	3.77	518	33
40	5.3	5.6	7.62	103.0	4.02	527	33
With Better Repairs[3]							
13	4.3	4.9	5.58	84.1	2.29	410	22
20	4.9	5.6	6.61	100.0	1.86	281	15
30	5.6	5.9	8.11	111.4	1.25	154	9
40	5.8	6.0	8.58	113.6	0.62	72	5

1: Costs include additional inspection and repair costs less any fuel economy benefits from repairs. These costs have been estimated from the cost-effectiveness values, which in turn were assumed to be the same as for passenger cars.

2: Program costs are equally divided between the two pollutants. These values have been assumed to be equal to those for light-duty vehicles. Once a stringency has been selected, only one row from the Table may be used, determined by whether or not the program chosen will utilize mechanic training or tight reinspection cutpoints.

3: These additional benefits correspond to basic idle CO programs using tighter reinspection cutpoints or with full mechanic training programs.

Exempting Pre-1975 Vehicles

Another way to improve the cost-effectiveness is to reduce the overall inspection costs by inspecting fewer vehicles. This reduces emission benefits, but they can often be restored by increasing the failure rate of the remaining inspected vehicles and adding other options described in this report. There is, of course, a limit to which this approach can be expected to work. Restricting an idle CO program to only 1981 and later vehicles, for instance, cannot be optimized to provide the same HC and CO benefit as a conventional I/M program, even if all vehicles in need of repair could be identified and repaired.

Table 8 presents the benefits of an idle CO I/M program which exempts pre-1975 vehicles from testing. An area requiring only CO reductions could use such a program with a 30% initial stringency and receive as much CO benefit as a conventional I/M program at a lower overall cost. Areas requiring reductions in HC will find they must add even more options to their idle CO I/M program if they are to achieve the same HC benefit as a conventional program. It is possible however to achieve the same HC benefit as a conventional program with an improved overall cost-effectiveness if enough cost-effective enhancements are used. Since exempting pre-1975 vehicles will often reduce the effectiveness of the options in reducing overall HC and CO emissions, Tables 9 through 12 have been calculated to be used with the results presented in Table 8. The benefits for use of a better test for 1981 and later vehicles in Table 2 are not affected by exempting pre-1975 vehicles and therefore can be combined directly with the results in Table 8 if that option is desired.

Table 8

Idle CO I/M for 1975 and Later Vehicles Only

Stringency for 1975-80 Vehicles (Percent)	Percent Benefit on Dec. 31, 1987		Five Year Emission Reduction (Thousands of Tons Removed)		Five Year[1] Program Cost (Millions of $)	Cost-Effectiveness ($/ton) of Option[2]	
	HC	CO	HC	CO		HC	CO
13	22.4	28.6	29.26	435.7	32.43	554	37
20	24.3	31.6	32.87	502.9	34.00	517	34
30	26.6	34.0	38.08	572.5	36.24	476	32
40	27.5	34.7	39.81	598.7	38.48	483	32

1: Costs include inspection fee and repair costs less any fuel economy benefits from repairs.
2: Program costs are divided equally between the two pollutants.

Table 9

Better Repairs
in an Idle CO Program for 1975 and Later Vehicles Only

Stringency for 1975-80 Vehicles (Percent)	Additional Percent Benefit on Dec. 31, 1987		Additional Five Year Emission Reduction (Thousands of Tons Removed)		Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness[2] ($/ton)
	HC	CO	HC	CO		
13	0.5	2.7	1.07	72.3	-10.14	NA
20	1.3	3.3	2.40	95.9	-15.58	NA
30	2.0	2.7	3.74	74.9	-23.37	NA
40	2.1	2.0	4.28	51.8	-31.16	NA

1: Fuel economy benefits from repairs.
2: Since there is a net savings, no incremental cost-effectiveness has been calculated. Overall program costs are reduced by the amount shown.

Table 10

Tampering Checks
in an Idle CO Program for 1975 and Later Vehicles Only

Option	Additional Percent Benefit on Dec. 31, 1987 HC	CO	Additional Five Year Emission Reduction (Thousands of Tons Removed) HC	CO	Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness[2] ($/ton) HC	CO
Air Pump Check	1.4	3.9	1.78	49.0	0.92	258	9
Evaporative Cannister Check	1.2	0.0	1.43	0.0	0.25	175[3]	-
Catalyst Check (All Vehicles)	0.9	0.5	1.35	10.7	2.00	741	93
Catalyst Check (1983 and later models only)	0.3	0.2	0.20	1.6	0.00	NA[4]	NA[4]

1: Costs include any additional repair costs.
2: Program costs are equally divided between the two pollutants.
3: Since there is no CO benefit, all costs have been allocated to the HC benefit.
4: Since there is no significant cost, no cost-effectiveness has been calculated.

Table 11

Loose Idle HC Cutpoints
in an Idle CO Program for 1975 and Later Vehicles Only

Additional Percent Benefit on Dec. 31, 1987		Additional Five Year Emissions Benefit (Thousands of Tons Removed)		Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness ($/ton) of Option
HC	CO	HC	CO		
1.9	0.0	2.42	0.0	0 - 8.39	0 - 3467

1: Costs include additional repair costs less any fuel economy benefits from repairs.

Table 12

Idle CO I/M for 1975 and Later Light-Duty Trucks

Stringency for 1975-85 LDTs (Percent)	Additional Percent Benefit on Dec. 31, 1987		Additional Five Year Emission Reduction (Thousands of Tons Removed)		Additional Five Year Program Cost[1] (Millions of $)	Incremental Cost-Effectiveness ($/ton) of Option[2]	
	HC	CO	HC	CO		HC	CO
13	3.7	3.4	4.58	52.7	2.54	554	37
20	4.1	3.9	5.22	62.6	2.70	517	34
30	4.4	4.4	6.05	74.3	2.88	476	32
40	4.5	4.5	6.27	78.0	3.03	483	32
With Better Repairs[3]							
13	4.0	4.0	4.96	64.4	1.82	367	22
20	4.4	4.5	5.79	77.6	1.51	261	15
30	5.0	4.9	6.92	86.2	1.07	154	10
40	5.1	4.9	7.27	87.6	0.60	83	6

1: Costs include additional inspection and repair costs less any fuel economy benefits from repairs. These costs have been estimated from the cost-effectiveness values, which in turn were assumed to be the same as for passenger cars.

2: Program costs are equally divided between the two pollutants. These values have been assumed to be equal to those for light-duty vehicles. Once a stringency has been selected, only one row from the Table may be used, determined by whether or not the program chosen will utilize mechanic training or tight reinspection cutpoints.

3: These additional benefits correspond to basic idle CO programs using tighter reinspection cutpoints or with full mechanic training programs.

1.3 Example Designs For Low-Cost I/M Programs

The previous section of this report presented a number of options for reducing the cost of an I/M program and for restoring its emission reduction effectiveness when necessary. This section selects from among these options and assembles them into two examples of low-cost I/M programs. The example programs are tailored to two situations. Program A is an example for all areas which need to obtain only CO reductions from I/M because they are already in attainment with the ozone NAAQS or will attain it by 1982. Program B is an example for areas which require HC reductions from I/M to attain the ozone NAAQS.

The core of the two examples is the idle CO I/M program. Program B for areas needing HC reductions incorporates HC enhancements, described in Sections 1.2 and 7.0. The examples both suggest improvements from Section 3.0 to reduce further the incidence of unnecessary and inappropriate repairs. All cost-effectiveness comparisons in this section use the conventional I/M program described in "Update on the Cost-Effectiveness of Inspection and Maintenance" [4] to represent a typical conventional I/M program and use the methodology presented in that report. This methodology essentially consists of accounting for all of the I/M costs and emission reductions for a five year period from January 1, 1983 through December 31, 1987. Costs include inspection and repair costs less any fuel savings from repairs.

I/M planners who wish to construct their own example program may easily do so using the information in Tables 1-7 or Tables 8-12. The stringency of the program and whether pre-1975 vehicles will be inspected should be the first tentative choice made; options should then be added in turn. When selecting options, better repairs for pre-1981 vehicles (achieved through mechanic training or stringent reinspection limits) and a better test for 1981 and later vehicles should be considered first, since they yield net savings in program costs. Then other options should be considered based on their incremental cost-effectiveness, their ease of implementation and administration, and local preferences. If a satisfactory program in terms of emission reduction benefits does not result, another choice regarding stringency and inspection of pre-1975 vehicles should be made.

1.3.1 Example Program A: Areas Requiring Only Ambient CO Reductions

Example Program A has the following principal design features:

(1) Only 1975 and later model year vehicles are subject to mandatory inspection and repairs.

(2) Idle CO cutpoints are chosen which will fail 13% of 1975 through 1980 model year vehicles at the initial inspection.[7]

(3) The Two-Speed Idle Test or Loaded Test for 1981 and later vehicles with a 1.2% cutpoint on both modes instead of the idle test. This will increase the identification rate of vehicles with full rich fuel system failures from 50% to 70%. Owners qualify for the Emission Performance Warranty [3] if other conditions are also met.

(4) A stringent reinspection idle CO cutpoint of 1.0% for 1975-80 vehicles. This will force better carburetor adjustments resulting in significant fuel economy benefits averaging about 4% as well as additional CO emission reductions. (Similar results could be obtained using mechanic training programs. However, it is difficult to reach every vehicle through mechanic training because some commercial mechanics will not submit to training and some vehicle owners will perform their own maintenance.)

(5) Any improvements from Section 3.0 which are compatible with local conditions.

Example Program A will produce somewhat greater CO emission benefit than a conventional I/M program or the basic idle CO program but with an improved cost-effectiveness and a lower overall cost. Table 13 presents the emission benefit calculations for Example Program A.

Table 13

Comparison of Emission Reductions and Costs of Example Program A and a Conventional 20% Stringent I/M Program

Program	Percent Emission Benefit on Dec. 31, 1987 HC	Percent Emission Benefit on Dec. 31, 1987 CO	Five Year Emission Reduction (Thousands of Tons) HC	Five Year Emission Reduction (Thousands of Tons) CO	Five Year Program Cost (Millions of $)	Source (Section 1.2)
CONVENTIONAL I/M PROGRAM: (20% Stringency, idle test for 1981 and later vehicles)	34.9	33.1	46.50	526.8	54.10	Table 1
EXAMPLE PROGRAM A:						
° 13% Stringent Idle CO I/M exempting pre-1975 vehicles	22.4	28.6	29.26	435.7	32.43	Table 8
° More Effective Test for 1981 and later vehicles	2.4	5.8	2.03	60.4	-5.05	Table 2
° Tight idle CO reinspection cutpoint for 1975-80 vehicles	0.5	2.7	1.07	72.3	-10.14	Table 9
Program A Totals	25.3*	37.1	32.36	568.4	17.24	

* Note: This example is not equivalent to a conventional I/M program in regards to HC benefit.

From Table 13 it is simple to calculate the overall program cost-effectiveness of Example Program A in reducing CO emissions. The total five year program costs are divided by the total five year CO emission reductions resulting in an overall CO cost-effectiveness of $30 per ton. This is about a third the cost per ton for CO of the conventional I/M program. Table 14 compares the benefits and cost-effectiveness of conventional I/M, the basic idle CO I/M program, and Example Program A.

Table 14

Comparison of I/M Programs for Areas Requiring Only CO Reductions

Program	CO Emission Benefit on December 31, 1987	Cost-Effectiveness* ($/Ton CO)
Conventional I/M	33.1	102
Basic Idle CO I/M	33.1	76
Example Program A	37.1	30

* All costs have been allocated to the CO benefits.

It may be of interest to point out that since the fuel savings from repairs more than offset repair and inspection costs when tight reinspection cutpoints (or mechanic training programs) are incorporated in the idle CO program, increasing the failure rate for pre-1981 vehicles over the 13% used in Example Program A would actually reduce the overall cost of the program and the cost per ton of CO. For example if the stringency in Example Program A were increased to 20%, equal to the stringency of the conventional I/M program, the CO emission benefit on December 31, 1987 would be increased to 40.7% eliminating 659.2 tons of CO during the five year period. The total program cost, including the fuel savings, would be reduced to $13.37 million resulting in a cost-effectiveness of $20/ton of CO. It has been assumed in this example that there are local reasons for keeping the failure rate as low as possible and that there is no need for CO benefits beyond the minimum required amount.

1.3.2 Example Program B: Areas Requiring HC Reductions

In areas requiring HC reductions, HC enhancement options from Section 7.0 (and described briefly in Section 1.2) are necessary to make idle CO I/M an acceptable substitute for conventional I/M. Since all of the HC enhancements combined would more than fully compensate for the loss in HC reduction which occurs from eliminating the HC cutpoints, I/M planners can choose among the enhancements based on convenience, practicality, and local preferences. There will be no need for CO emission enhancements, although many of the HC enhancements will also increase CO benefits. The centralized or decentralized formats will make some of the enhancements more convenient and practical than others. High failures rates are not desirable, for example, in a centralized program since each failure implies a fair degree of inconvenience to owners who must make two trips as a result, one to a repair facility and another back to the inspection station. On the other hand, using a tighter CO reinspection cutpoint to force higher quality carburetor adjustments would be quite simple in a centralized program. Tampering checks are also appropriate in a centralized program. It is easier to train the relatively few centralized inspectors to perform tampering checks than it would be to train every operator of a licensed inspection station in a decentralized program. The example program described below is just one possibility. The reader should have no difficulty in constructing other examples. All that is necessary is to select a combination of HC enhancements which will restore HC effectiveness back to that of a conventional program.

Example Program B has the following principle design features:

(1) All model year vehicles 1968 and later are inspected.

(2) Idle CO cutpoints which will fail 30% of pre-1981 vehicles at the initial inspection.[7]

(3) A reinspection cutpoint of 1.0% CO for pre-81 vehicles. This will achieve the same effect as a mechanic training program that reaches every vehicle.

(4) The Two-Speed Idle Test or the Loaded Test for 1981 and later vehicles with a 1.2% CO cutpoint on both modes, increasing the identification rate of high emitters among these vehicles. Owners of 1981 and later vehicles qualify for the Emission Performance Warranty [3] if other conditions are also met.

(5) An air pump inspection.* As described in Section 7.5.2, this is a simple check to perform. Although an air pump check will require opening the engine compartment, this check is prefered over other simple checks such as a catalyst check because the low expected cost of repair of air pump disablements. The extra time needed to open the hood will be unimportant in a decentralized program.

(6) Improvements from Section 3.0 which are compatible with local conditions.

Example Program B is approximately equal in HC reduction effectiveness and exceeds the CO reduction effectiveness of a conventional I/M program with a 20% stringency for pre-1981 vehicles. This is illustrated in Table 15. Although the pre-1981 failure rate in Example Program B is half again as large as in the conventional I/M program, the much lower per-vehicle repair cost and fuel savings will result in a less costly program overall. This is illustrated in Table 16.

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* Any one of the three tampering checks (catalyst, air pump, evaporative control) described in Section 7.5 could be used in this example. Tampering checks for air pumps and evaporative emission control systems would require opening the engine compartment hood on all vehicles. Program B as described here would require the hood to be opened on 1981 and later vehicles anyway if the Two-Speed Idle Test is used instead of the Loaded Test.

Table 15

Comparison of Emission Reductions and Costs of Example Program B and a Conventional 20% Stringent I/M Program

Program	Percent Emission Benefit on Dec. 31, 1987		Five Year Emission Reduction (Thousands of Tons)		Five Year Program Cost (Millions of $)	Source (Section 1.2)
	HC	CO	HC	CO		
CONVENTIONAL I/M PROGRAM: (20% Stringency, idle test for 1981 and later vehicles)	34.9	33.1	46.50	526.8	54.10	Table 1
EXAMPLE PROGRAM B:						
° Basic Idle CO I/M	24.2	33.1	31.31	526.8	40.19	Table 1
° More Effective Test for 1981 and later vehicles	2.4	5.8	2.03	60.4	-5.05	Table 2
° Increased Pre-1981 Stringency						
-13% to 20%	2.4	3.3	5.07	80.6	2.06	Table 3
-20% to 30%	3.1	2.8	7.23	85.2	2.95	Table 3
° Tight idle CO reinspection cutpoint for pre-1981 vehicles	1.9	2.7	3.29	78.9	-30.60	Table 4
° Air pump disablement check	1.5	4.3	2.56	68.0	0.92	Table 5
Program B Totals	35.5	52.0	51.49	899.9	10.47	

Table 16

Cost-Effectiveness Comparison
Between Example Program B
and a Conventional I/M Program
With CO and HC Cutpoints

Program	HC Cost-Effectiveness*	CO Cost-Effectiveness*
Conventional I/M	$581/ton	$51/ton
Example Program B	$102/ton	$ 6/ton

* Some areas which are implementing I/M to achieve HC reductions are doing so only for that reason, i.e., they do not need CO reductions. In such cases, since the costs are equally distributed between the two pollutants in this table, the HC cost-effectiveness number would be doubled.

1.3.3 Example Program C: Maximum Benefit Program

As an exercise to demonstrate the maximum potential benefits of an idle CO program and as a method to show how to apply each of the Tables in Section 1.2, Example Program C will use all of the emission enhancements discussed in this report.

Example Program C has the following principle design features:

(1) All model year vehicles 1968 and later are inspected.

(2) The Two-Speed Idle Test or Loaded Test for 1981 and later passenger vehicles and 1985 and later light-duty trucks with a 1.2% CO cutpoint in both modes increasing the identification rate of high emitters among these vehicles. Owners of 1981 and later vehicles qualify for the Emission Performance Warranty [3] if other conditions are also met.

(3) Idle CO cutpoints which fail 30% of pre-1981 vehicles at the initial inspection.[7] Although a 40% stringency program would provide greater benefits, 30% is probably closer to what most I/M programs consider desirable as a failure rate.

(4) The reinspection cutpoint of 1.0% CO for pre-1981 passenger car and pre-1985 light-duty trucks. This will achieve the same effect as a mechanic training program that reaches every vehicle.

(5) An air pump check.

(6) An evaporative cannister check.

(7) A catalyst check for all inspected 1975 and later passenger cars.

(8) An idle HC inspection cutpoint of 1000 ppm.

(9) Inspection and maintenance for all light-duty trucks below 8500 lbs. GVW.

Example Program C achieves a 45% HC benefit and a 58% CO benefit, much larger than the conventional I/M program with a 20% stringency. This is illustrated in Table 17. The cost-effectiveness of Example Program C is calculated and presented in Table 18. These cost-effectiveness values are slightly more than for Example Program B, but are still well below the conventional I/M program.

Table 17

Comparison of Emission Reductions and Costs of Example Program C and a Conventional 20% Stringent I/M Program

Program	Percent Emission Benefit on Dec. 31, 1987 HC	Percent Emission Benefit on Dec. 31, 1987 CO	Five Year Emission Reduction (Thousands of Tons) HC	Five Year Emission Reduction (Thousands of Tons) CO	Five Year Program Cost (Millions of $)	Source (Section 1.2)
CONVENTIONAL I/M PROGRAM:						
(20% Stringency, idle test for 1981 and later vehicles)	34.9	33.1	46.50	526.8	54.10	Table 1
EXAMPLE PROGRAM C:						
° Basic Idle CO I/M	24.2	33.1	31.31	526.8	40.19	Table 1
° More Effective Test for 1981 and later vehicles	2.4	5.8	2.03	60.4	-5.05	Table 2
° Increased Pre-1981 Stringency						
13% to 20%	2.4	3.3	5.07	80.6	2.06	Table 3
20% to 30%	3.1	2.8	7.23	85.2	2.95	Table 3
° Tight idle CO reinspection cutpoint	1.9	2.7	3.29	78.9	-30.60	Table 4
° Air pump check	1.5	4.3	2.56	68.0	0.92	Table 5
° Evaporative System check	1.3	0.0	1.94	0.0	0.25	Table 5
° Catalyst Check	0.9	0.5	1.35	10.7	2.00	Table 5
° Loose HC cutpoint	2.0	0.0	2.59	0.0	0.0	Table 6
° Light-Duty Truck I/M	5.6	5.9	8.11	111.4	1.25	Table 7
Program C Totals	45.3	58.4	65.48	1022.0	13.97	

Table 18

Cost-Effectiveness Comparison
Between Example Program C
and a Conventional I/M Program

Program	HC Cost-Effectiveness*	CO Cost-Effectiveness*
Conventional I/M	$581/ton	$51/ton
Example Program C	$107/ton	$ 7/ton

* Some areas which are implementing I/M to achieve HC reductions are doing so only for that reason, i.e., they do not need CO reductions. In such cases, since the costs are equally distributed between the two pollutants in this table, the HC cost-effectiveness number would be doubled.

2.0 BACKGROUND ON CONVENTIONAL I/M PROGRAMS

Since 1972 when New Jersey added emission analyzers to its safety inspection stations, I/M has existed as a feasable, effective means to reduce in-use emissions from automobiles. Congress added I/M to the requirements of the Clean Air Act Amendments in 1977 as a reasonable and required air pollution control strategy for those urban areas with serious air quality problems. In all, 30 states are expected to implement some type of I/M by 1983. Some states, such as Oregon, Arizona, and Rhode Island have already begun emission inspection programs. These current programs, while differing from state to state, do have many features in common. This section will describe what can be called a "conventional" I/M program which best describes the type of program now being used in those states with operating I/M programs. Following sections will describe low-cost approaches to I/M primarily by noting the aspects in which they differ from conventional I/M programs.

2.1 Inspection and Reinspection

All currently operating programs[8], both centralized and decentralized, use an emission analyzer to measure the concentrations at idle and/or at a cruise mode (usually only at idle) of hydrocarbons (HC) and carbon monoxide (CO) coming from the tailpipe(s) of vehicles subject to inspection. These measurements are compared to standard levels (cutpoints) for each pollutant established for each vehicle age and type by the state or local agency responsible for the program. If the measurement of either pollutant exceeds its cutpoint, then that vehicle fails the test. The percent of vehicles which fail the emission inspection is refered to as the failure rate. This failure rate is typically 20 to 30 percent. The state or local agency can adjust the program failure rate by adjusting the cutpoints to fail more or fewer vehicles. Vehicles which fail the emission inspection must receive enough repairs to reduce their emissions below the program cutpoints and pass a reinspection. The reinspection cutpoints are identical to the original inspection standards. Most failed vehicles pass the reinspection test on their first try.

There are several ways to provide for inspection facilities. Decentralized programs utilize existing repair facilities which are licensed to perform emission inspections and reinspections. Centralized programs involve use of facilities dedicated to high-volume emission testing with repairs performed elsewhere. These centralized facilities can either be operated directly by the state, by a single contractor, or by multiple private companies under licenses from the state. States should not feel constrained to use only these options. New Jersey combines advantages of centralized and decentralized approaches in their I/M program. All vehicles are inspected initially at state-run centralized inspection facilities. Those vehicles which fail have the option of either returning to the centralized facility for a reinspection or having the reinspection performed at a licensed repair facility. This allows the reinspection to be performed where the repairs are performed in some cases eliminating a trip back to the centralized inspection facility without loading the repair service industry with the initial inspection task.

The inspection requirement is enforced either by withholding registration from vehicles which have not passed their inspection or reinspection or by issuing special stickers to cars when they pass the inspection and issuing citations to cars with missing or expired stickers.

2.2 Types of Repairs Performed

In the majority of cases it has been found that a simple carburetor adjustment on pre-1981 vehicles can reduce the idle emissions of HC and CO from most vehicles sufficiently to pass the reinspection cutpoints used in operating programs. When a carburetor adjustment alone is not enough to reduce both CO and HC idle emissions to pass the program cutpoints then in many cases other simple repairs like new spark plugs or a new air filter element can provide the additional necessary reductions. Other repairs may also be performed in the same visit to the repair facility, at either the owner's or the mechanic's initiative. Table 19 lists the frequency of various types of repairs done on pre-1981 vehicles as observed in the Portland I/M program. Carburetor adjustments are by far the most common repair.

Table 19

Typical Repairs Performed on Vehicles Failing the Oregon State Inspection Test

	Model Year 1972-74 Vehicles	Model Year 1975-77 Vehicles
Total Number of Cars	95	252
Were the following items repaired, replaced, or adjusted? (yes)		
Spark Plugs	35.8%	25.4%
Spark Plug Wires	14.7%	11.9%
Points and Condensor	31.6%	5.6%
Distributor Cap and Rotor	17.9%	6.3%
Spark Timing Control Devices	13.7%	10.3%
Carburetor (Idle Mixture Adjustment)	87.4%	89.3%
Choke	48.4%	21.8%
Intake System	5.3%	4.0%
Air Filter	31.6%	31.0%
Engine Oil	21.1%	15.1%
Idle Speed	48.4%	73.4%
Timing	49.5%	46.0%
Dwell	41.1%	26.6%
Air Injection System	5.3%	3.2%
EGR System	6.3%	4.8%
PCV System	6.3%	7.5%
Valves	7.4%	0.8%

2.3 Cost of Repairs

Average repair costs on pre-1981 vehicles have been reported to be as low as \$18.71 per failed vehicle in the New Jersey program and as high as \$35.00 per failed vehicle in the Los Angeles program.[8] An analysis of repair costs in 1979 in the Portland, Oregon I/M program[9] showed an average repair cost of \$22.00 with half of the repairs costing less than \$14.00. (Over 44 percent of the collective repair bill was due to the 13 percent of the failed cars that had repair costs more than \$50.00.) These low average and median costs are significant since the Portland program has the most stringent cutpoints of all operating programs.

The low average cost of typical I/M repairs on pre-1981 model year vehicles is a reflection of the simple adjustments necessary in most cases to reduce a vehicle's emissions sufficiently to pass the reinspection test.

3.0 REDUCING REPAIR COSTS BY REDUCING INAPPROPRIATE AND UNNECESSARY REPAIRS

Most persons in the service industry are sincere in their efforts to provide effective low-cost I/M repairs to their customers. However, the service industry is not perfect. Problems can occur which cause repair costs to owners to be higher than they would need to be. Some problems result from a lack of knowledge in the repair industry of proper diagnosis and repair procedures for emission related components and systems. Misdiagnosis and ignorance of proper repair procedures can lead to (1) replacement of parts which have not failed, (2) unnecessary adjustments, (3) multiple repair trips to finally correct the emission problem, (4) continued non-compliance with emission inspection standards possibly requiring a waiver, and (5) encouraging the vehicle owner to attempt to acquire a certificate of compliance without completing necessary emission repairs (cheating). In addition, there may also be some cases where (1) a mechanic will knowingly perform more repairs than necessary to pass the emission inspection, some of which would not be considered necessary or useful by any standard, (2) the vehicle owner will be persuaded to purchase services the owner would not have sought otherwise (i.e., brake job, lube, wiper blades, tires, etc.), (3) higher rates will be charged for the repairs than can be justified by the parts and labor costs, and (4) when the emission inspection is performed in the service facility, as in decentralized programs, the vehicle may be deliberately failed incorrectly to generate repair business.

These potential problems increase the repair cost vehicle owners must pay and reduce the cost-effectiveness of the I/M program. It is not possible to determine exactly how frequently these problems may occur, but it is necessary to consider the possibility of these problems in the overall design of an I/M program. If these problems can be made less frequent, the cost of the I/M program can be reduced.

3.1 Improvement 1: Mechanic Training

The most straightforward way to deal with problems associated with emission repairs is to assure that mechanics are able to diagnose the problem and perform the repairs correctly, and that they are aware of the benefits to their customers and their business of correct diagnosis and repair of emission related problems. With this information conscientious mechanics will be better able to avoid any unnecessary or inappropriate repair work during emission related repairs.

3.1.1 Mechanic Training Courses

A short, practical course has been designed by the National Center for Vehicle Emissions Control and Safety of Colorado State University (CSU) which provides mechanics with the basics of diagnosis and repair for vehicles failing I/M test cutpoints. The course was designed to be a maximum of 16 hours in length and could, for example, be taught over several evening sessions. A program to provide this course or a similar course to all mechanics who will perform emission repairs will improve the knowledge of the service industry in vehicle emission control. In addition, EPA is convinced that mandatory mechanic training can result in increased emissions reductions and fuel savings from an I/M program.

3.1.2 Information Distribution

Another, less ambitious, method to inform mechanics of proper I/M diagnosis and repair procedures is to include advice to the mechanic directly on the inspection form. The advice would take the form of a list of the repairs which are most likely needed based on the type of I/M failure (HC-only, CO-only, or both). Table 20 is an example of the type of advice which can be included on the inspection forms. (A portion of the advice in Table 20 is specific to pre-1981 vehicles, but corresponding advice can be developed for 1981 and later vehicles.) In this way the mechanics who will actually perform repairs will have diagnosis and repair information available to them at the time of repair. This information can be supplemented by a full-scale training program or by distribution of more detailed I/M diagnosis and repair manuals.

Table 20

Diagnostic Advice for Use on Inspection Forms

For each emission problem condition, perform the checks and maintenance in the sequence as listed until the idle measurements for both HC and CO are sufficiently below the idle emission standards to assure passing a reinspection.

Condition: Fail Both Idle HC and Idle CO.

Diagnosis: Begin with the maintenance described to correct the idle HC problem. When the idle HC measurement is acceptable, begin performing maintenance described to correct idle CO problems as necessary.

Condition: Fail Idle HC.

Diagnosis:

1. Improper Ignition Timing: Compare with manufacturers specification.

2. Faulty Ignition or Misfire: Check for arcing or disconnected wiring, fouled or damaged spark plugs and insufficient spark voltage.

3. Vacuum Leaks: Check for damaged, missing, or disconnected hoses and check for leaks around the intake manifold and base on the carburetor.

4. EGR System Incorrectly Operating at Idle: Check for proper valve operation.

5. Idle Speed Set Too Low: Compare with manufacturers specification.

6. Air/Fuel Mixture Set Too Lean: Check or set using manufacturers specified procedures. Check the balance in two and four barrel carburetors.

7. Worn Piston Rings or Valves: Perform compression check.

Condition: Fail Idle CO.

Diagnosis:

1. Dirty Air Filter: Clean or replace if necessary.

2. Choke Stuck: Check for proper operation and adjustment.

3. PCV System Plugged: Check valve and hoses for restriction.

4. Air Pump and Control Valve Inoperative: Check belt, bypass valve, hoses, etc.

5. Idle Speed Set Too Low: Compare with manufacturers specification.

6. Air/Fuel Mixture Set Too Rich: Check or set using manufacturers specified procedures.

3.1.3 Problem Facility Identification

If those mechanics who are most in need of emission repair training can be identified, then the training effort can be more effectively focused on this smaller number of individuals. These repair facilities can be identified by a survey of vehicle owner complaints, average repair costs, or waiver rates for service facilities performing emission repairs. Those facilities which deviate the most from the norm could be required or encouraged to send their mechanics for training. This approach could be used as a method to eventually train all the service industry, starting with those most in need of training.

3.2 Improvement 2: Public Awareness

One simple way to protect vehicle owners from inappropriate or unnecessary repairs is a strong public awareness program. This effort should be aimed at telling the vehicle owner what repairs are appropriate for his/her vehicle given it has failed the I/M test in a certain way (HC, CO, or both) and what charges are reasonable for these repairs. This information can be included on the inspection form. Armed with this information, vehicle owners would be better prepared to enquire about and understand the type of repairs mechanics propose to make and to know better to refuse any unnecessary repairs.

3.3 Improvement 3: Price Competition

The repair industry may take advantage of the lack of information about appropriate repairs and their costs in the beginning of a mandatory I/M program to sell repairs at inflated prices.

An effort could be made as part of the I/M program to encourage comparison shopping by vehicle owners in need of emission repairs. Repair facilities could be encouraged to advertise their fees for various emission related repairs and give accurate estimates of possible repair costs. This information could be made mandatory. The program could also publish the average repair costs from each facility at frequent intervals to promote price competition by repair facilities and comparison shopping by vehicle owners.

3.4 Improvement 4: Automated Analyzers

In decentralized programs, the possibility of vehicles being deliberately failed incorrectly to increase a service facility's repair business is a worry to some vehicle owners. Even if the instances of such dishonesty are few, the bad publicity and distrust such instances will generate should be avoided. All decentralized programs should have some method to respond to consumer complaints about specific instances of fraud and should also conduct auditing and surveillance programs to detect other instances. However, any method which can make fraud more difficult from the start is also desirable.

Computerized emission analyzers[10] offer a new tool for a decentralized program to reduce errors in the passing and failing of vehicles in an I/M program. These sophisticated analyzers are less prone to improper use. These analyzers can make it nearly impossible for a service facility to deliberately fail a vehicle incorrectly if the vehicle owner at least makes certain that his own vehicle is being tested by the analyzer. These instruments can also reduce administrative costs by automating data collection and reducing the amount of program auditing required. With an automated analyzer, the audit period can be lengthened from one to three months, with a corresponding reduction to the number of auditors which are required[11].

EPA has been impressed by the performance and possibilities inherent in computerized emission analyzers for decentralized I/M programs, and recommends their use over the traditional garage analyzers. In addition, to make it feasible for I/M programs to acquire these analyzers, additional lead time for implementation of a decentralized I/M program using them may be granted if required[11].

3.5 Improvement 5: Challenge Stations

"Challenge Stations" are state-operated or closely supervised emission inspection stations which can be used by vehicle owners to verify their inspection results received at private garages in a decentralized program. These challenge stations will allow vehicle owners who are suspicious of the results they have received from their emission inspection at private garages to be retested by the state before they invest in emission repairs.

Challenge stations increase confidence in the fairness of the I/M program and provide a means to identify inspection stations which are incorrectly failing vehicles through incorrect testing procedures, poor equipment maintenance, or deliberately. By reducing the number of incorrect failures, total repair costs to owners will be reduced. These stations also provide a means for distribution of public awareness material directly to vehicle owners most concerned about the program.

Because of the importance of the challenge function, EPA requires some form of it in any decentralized I/M program. In this sense, challenge stations are an essential part of a conventional I/M program and not an optional improvement. However, an I/M program does have the option of placing far more emphasis on the challenge function than required by EPA.

3.6 Impacts on Costs and Emission Reductions

None of the improvements outlined in this section will decrease emission reductions from the I/M program. Indeed, mechanic training programs can increase emissions reductions. They will reduce the costs of the program to the motoring public, and thus improve the overall cost-effectiveness of the program. The size of the cost savings cannot be quantified, but it is reasonable to assume it will outweigh the administrative costs to the I/M program of implementing the improvements.

3.7 Conclusions

All of the improvements outlined in this section can be applied in one form or another to any I/M program -- including any "conventional" I/M program -- and should be considered whether the program is being designed, implemented, or is already operating.

4.0 I/M FOR PRE-1981 VEHICLES USING ONLY IDLE CO CUTPOINTS

4.1 Description and Summary of Impacts

The improvements described in Section 3.0 attempt to reduce I/M costs by reducing the number of inappropriate, unnecessary, and ineffective repairs. Such repairs constitute "fat" in a conventional I/M program and can be cut without reducing program effectiveness. Further reduction in I/M costs can be achieved only by eliminating some properly performed repairs that are appropriate in a conventional I/M program and which do produce useful emission reductions; this is cutting "lean" from the I/M program. Clearly, the objective of such cuts should be to eliminate or reduce types of repairs that are costly in relation to the emission reductions they produce (less cost-effective) and to maintain or even increase repairs which are cheap in relation to their emission reductions (more cost-effective).

The number and types of repairs which are appropriate in a conventional I/M program are determined by the design of the program, specifically by the inspection and reinspection test procedure and cutpoints. Consequently, the only approach which might have the effect of reducing the number of less cost-effective repairs is to modify the test procedures or the cutpoints. This section examines one such modification: simply eliminating the idle HC cutpoint and retaining only the idle CO cutpoint, with no change in the idle test procedure itself. An I/M program with this modification will be referred to as an idle CO I/M program. The goal of using only an idle CO cutpoint is to virtually eliminate the occurrence of all repair types other than idle mixture and speed adjustments, because idle mixture adjustments appear to be the most cost-effective type of repair in a conventional I/M program for pre-1981 vehicles.

Idle mixture and speed adjustments can be performed cheaply, because there is no need for diagnosis beyond the results of the idle test itself and no replacement parts are needed. This is in contrast to most other types of I/M repairs (excluding perhaps spark timing adjustments), particularly ignition system repairs, in which time consuming diagnosis is needed to pinpoint the exact problem and the fix involves installing a replacement part such as a set of spark plugs or wires, a distributor cap, or a new vacuum hose.

In addition to being relatively inexpensive, idle mixture adjustments produce very sizable emission reductions for both HC and CO on catalyst-equipped vehicles. On such vehicles, a rich idle mixture maladjustment causes the engine to produce higher concentrations of HC and CO. It also depletes oxygen from the engine's exhaust, so the catalyst is less able to convert the HC and CO to harmless CO_2 and water vapor. Correcting the idle mixture therefore has a two-fold effect in reducing HC and CO emitted at the tailpipe.*

* On cars without catalysts, i.e., those sold before 1975, an idle mixture readjustment also has a large effect on CO but its effect on HC is much less.

Table 21 shows a number of examples illustrating how effective idle mixture adjustments are for catalyst vehicles which have failed idle HC and/or CO cutpoints. The examples differ from one another with respect to how the samples were selected and the procedure used in the idle mixture adjustment; the specific details for each example are given in footnotes to the Table. All of the examples support the general effectiveness of this type of repair. Reductions in FTP HC range from 34.1% to 55.6%. Reductions in FTP CO range from 51.8% to 71.5%. For comparison, Table 21 also presents the results achieved by the typical mix of "conventional" I/M repairs performed by field mechanics in the Portland I/M program.

Eliminating repairs other than idle mixture adjustments will decrease the HC emission reductions of an idle CO I/M program compared to a conventional I/M program. Not all of the HC reductions are lost, since idle mixture adjustments account for some of the HC emission reductions in a conventional I/M program.

The fuel economy aspects of an idle CO I/M program will also differ from those of a conventional I/M program, because of the differences in the types of repairs performed. Proper correction of a rich idle mixture maladjustment should always improve fuel economy. If there are no other repairs performed which can decrease fuel economy, a net fuel savings should result from the I/M program.

The following sections examine in more detail the issues of repair types and costs, emission reductions, and fuel economy improvements in an idle CO I/M program. The conclusions from these sections can be summarized as follows:

<u>Repair Types and Costs</u> - Virtually all cars which fail inspection in an idle CO I/M program will be capable of passing the reinspection after having received only an idle mixture adjustment. The average repair cost is expected to be $6 to $10, compared to the range of $18.71 to $35 in the currently operating conventional I/M programs. There will also be a reduction in the failure rate, since cars will no longer fail for high HC emissions. Together these two changes will have a large impact on the overall cost of the I/M program. The total repair cost for pre-1981 cars will be reduced by about 70%, which will in turn reduce the overall cost of a typical I/M program by 19% during the period from 1983 through 1987.

Table 21

Emission Reductions
From Carburetor Adjustments
(1975-1980 Model Year Vehicles)

Program	Vehicles Receiving Adjustments	FTP Pollutant	Before Carburetor Adjustment (g/mi)	After Carburetor Adjustment (g/mi)	Percent Change
FY77 Emission Factor[1] Program	(54)	HC	2.75	1.43	48.0
		CO	42.2	14.6	65.4
Portland Study[2] Carburetor Repairs Only	(76)	HC	2.50	1.65	34.1
		CO	39.4	19.0	51.8
Houston Program[3] Study	(97)	HC	3.54	1.57	55.6
		CO	59.7	20.9	65.0
Houston Program[4] Study	(97)	HC	3.54	1.87	47.2
		CO	59.7	26.5	55.6
Restorative Maintenance[1]	(95)	HC	2.13	1.09	48.8
		CO	41.1	11.7	71.5
FY79 EF Program[1]	(43)	HC	1.93	1.27	34.2
		CO	28.4	13.7	51.8
Portland Task Group 10[5]	(31)	HC	3.26	1.90	41.8
		CO	47.5	20.6	56.7
			Conventional I/M (for comparison)		
Portland Study[6]	(310)	HC	2.82	1.56	44.7
		CO	39.63	19.72	50.2

1: Carburetor adjustment performed by contractor mechanics to manufacturer specifications. Idle HC cutpoint: 225 ppm; Idle CO cutpoint: 1.0%
2: Carburetor repairs performed by field mechanics. Vehicles failing Oregon DEQ cutpoints.
3: Carburetor adjustment performed by contractor mechanics to manufacturer specifications. Vehicles failing Houston Program cutpoints.
4: Idle mixture adjusted so that idle CO is 0.5%. Vehicles failing Houston Program cutpoints.
5: Idle mixture adjusted so that idle CO is 0.2%. Vehicles failing Oregon DEQ cutpoints.
6: Typical mix of conventional I/M program repairs. Vehicles failing Oregon DEQ I/M inspection presented here for comparison.

Emission Reductions - The CO emission reductions from pre-1981 vehicles in an idle CO I/M program will be virtually the same as those from a conventional I/M program which uses the same idle CO cutpoints. The HC emission reductions will be significantly less, but still 75% or more of what they would be in a conventional I/M program. The reduced HC benefits are due to the absence of ignition system and other HC-oriented repairs in the idle CO I/M program.

Fuel Economy Improvements - A fuel economy improvement of about 4 percent can be expected from an idle CO I/M program, if appropriate mechanic training is conducted or if the I/M program has some other mechanism to ensure that idle mixture adjustments are performed approximately correctly. There has been no conclusive evidence that there is any fuel economy benefit associated with conventional I/M programs. This is primarily due to repairs performed in conventional I/M programs which degrade fuel economy offsetting the fuel economy benefits associated with carburetor adjustments alone.

4.2 Repair Types and Costs

4.2.1 Elimination of Idle HC-Only Failures and Repairs

The most obvious effect of eliminating the idle HC cutpoint for pre-1981 vehicles from a conventional I/M program is that cars which would have failed the inspection only for high idle HC emissions will now pass inspection and will not be repaired. Consequently, these cars' contribution to the average repair cost is eliminated. To quantify this effect, the number of HC-only failures and their average repair cost in a conventional I/M program must be known.

In its study of the Portland I/M program, EPA found that among 1975-1977 vehicles, 8 percent of cars failing the idle test in 1978 failed for HC only. This number should not be considered typical of most other I/M programs, for two reasons. First, the Portland program has an unusually low (stringent) idle CO cutpoint, so many cars which would be HC-only failures in other states are HC-and-CO failures in Portland. Second, the cars in EPA's sample were relatively new when they began I/M. The I/M programs which will begin operation in 1982 or 1983 will find that malperformances which cause high HC will be more common due to the greater average age of catalyst-equipped pre-1981 vehicles. Consequently, if they use an HC cutpoint, the fraction of all failing cars which fail only for HC will be larger. EPA estimates that for conventional I/M programs starting in 1982 or 1983 the HC-only failure rate will be about 25% of the overall failure rate.

The impact on average repair cost of eliminating HC-only failures will be greater than suggested by their number. This is because HC-only failures have a higher average repair cost than the remaining failed cars. In EPA's Portland sample, the 1975-1977 HC-only failures had an average repair cost of $31.05. The average for the other failed cars was $23.86. This pattern of costs makes sense, since most of the cars that fail only the HC cutpoint require some sort of ignition system repair. This involves time consuming diagnosis to pinpoint the specific parts in need of replacement, or else replacement of more parts than really necessary. Ignition system repairs should be less frequent among the other failed cars, since idle mixture maladjustment is the only cause of idle test failure for many of them. This explanation is supported by type-of-repair data from the Portland study. Spark plugs and spark plug wires were replaced more often (about twice as often) on the HC-only failures than on other failed cars.

The figures given above for the number of HC-only failures (about 25% of all failures) and for their relative repair cost ($31 versus $24) mean that eliminating HC-only failures should reduce the total I/M repair bill for pre-1981 vehicles by about 30%.

4.2.2 Simpler Repairs for Other Failed Vehicles

Because the vehicles that do fail the idle test in an idle CO I/M program do not have to pass an HC cutpoint on reinspection, in principle they should require simpler repairs than in a conventional I/M program. The only repairs that are possibly needed are those which reduce idle CO emissions; repairs which would reduce idle HC emissions are not necessary. In fact, for virtually all failed cars the only repair that is needed is an idle mixture, and possibly idle speed, adjustment. Argument and evidence in favor of this contention are given in the following paragraphs.

It is well known that the engine parameter which has the largest impact on idle CO is the idle mixture setting, since this is the primary control for the idle air/fuel ratio. Most catalyst-equipped vehicles with a properly adjusted idle mixture have an idle CO level near zero. A rich maladjustment causes idle CO to increase far enough for the vehicle to fail a typical idle CO cutpoint. Even partial correction of the maladjustment will reduce idle CO to below the cutpoint. There are some other malperformances which can increase idle CO, such as blockages and leaks inside the carburetor, defective carburetor floats, severely plugged air filters, crankcase oil which is heavily contaminated with gasoline, and disabled air pumps. Surveillance studies have repeatedly found that such problems are infrequent compared to idle mixture maladjustments [12,13,14]. Consequently, they should be needed only rarely in either a conventional or idle CO I/M program.

Additional evidence to support the claim that idle mixture adjustments are almost always sufficient to allow vehicles which have failed an idle CO cutpoint to pass on reinspection comes from several EPA test programs.* These programs and their findings are summarized in Table 22. All of the programs showed very high pass rates on the idle CO test after an idle mixture adjustment, in the range of 96.4 to 99.0 percent.

* With few exceptions, the report will treat 1975-1980 vehicles as though they are typical of all vehicles made before the 1981 model year. In fact they are not; there are important differences between these and older vehicles. However by 1987 -- the date EPA uses to evaluate the effectiveness of I/M programs -- 1975-1980 vehicles will acount for 83.7% of the inspections and 83.4% of the emissions of all vehicles made before the 1981 model year. Hence their behavior in an I/M program will far outshadow the remaining older cars. In addition, comparatively little data is available on pre-1975 vehicles, so the focus on 1975-1980 vehicles is unavoidable. Where essential, distinctions will be drawn based on the best available information.

Table 22

Idle CO Pass Rate
After Carburetor Adjustment

Program	Initial Sample Size	Initial Idle CO Failure Rate	Idle CO Pass Rate at Reinspection After Only Carburetor Adjustment Among Vehicles Failing Initial Test
Restorative Maintenance Evaluation [1]	145	50.3	97.3
FY79 Emission Factor Program [1]	64	43.8	96.4
Houston Program Study [1]	480	21.7	99.0
Houston Program Study [2]	480	21.7	96.5
Portland Task Group 10 [3]	102	38.2	97.1

1: Carburetor adjustment performed by contractor mechanics to manufacturer specifications.
2: Idle mixture adjusted so that idle CO is 0.5%.
3: Idle mixture adjusted so that idle CO is 0.2%.

As Section 3.0 suggested, it is not necessarily enough to arrange things so that only simple I/M repairs are needed. The lack of understanding by mechanics and owners and the economic interest of repair facilities can result in unnecessary repairs being performed. This is illustrated by the types of repairs which were performed by commercial repair facilities in Portland on cars that had failed only the CO cutpoint. Virtually all of these cars could have passed with only an idle mixture adjustment. Table 22 shows the repairs that were actually performed. The average repair cost for the vehicles was $19.50. This is below the average for the cars that failed the HC cutpoint or both cutpoints, but it still reflects charges for maintenance in addition to idle mixture adjustments.

This additional maintenance will be easier to eliminate in an idle CO I/M program than in a conventional I/M program. In a conventional I/M program there are enough failed cars which actually do need types of repairs other than an idle mixture adjustment that many owners are not surprised and have no recourse when told their vehicles is one of them. Some mechanics may not have learned or may not bother to determine which vehicles do or do not need more maintenance. However, in an idle CO program, owners and mechanics can be told that in virtually all cases only idle mixture adjustments are required to pass reinspection. Owners then have a much simpler job in protecting themselves from repair facilities that recommend more maintenance. The number of cars that require more maintenance will be so small that owners can be advised by the I/M program to always seek a second opinion before agreeing to it. In addition, price competition among repair facilities should be keener in an idle CO I/M program because repairs are more uniform. The price competition will be additional pressure on repair facilities to refrain from performing unnecessary maintenance.

Table 23

Portland Program
Typical Repairs Performed on Vehicles Failing Only Idle CO
in the Oregon State Inspection Test

	Model Year 1972-74 Vehicles	Model Year 1975-77 Vehicles
Total Number of Cars	80	134
Were the following items repaired, replaced or adjusted? (yes)		
Spark Plugs	28.8%	14.9%
Spark Plug Wires	11.3%	4.5%
Points and Condensor	23.8%	5.2%
Distributor Cap and Rotor	16.3%	3.7%
Spark Timing Control Devices	11.3%	6.0%
Carburetor	93.8%	92.5%
Choke	40.0%	11.9%
Intake System	2.5%	3.0%
Air Filter	26.3%	24.6%
Engine Oil	16.3%	16.4%
Idle Speed	56.3%	73.9%
Timing	42.5%	34.3%
Dwell	36.3%	20.1%
Air Injection System	3.8%	3.0%
EGR System	3.8%	3.7%
PCV System	6.3%	4.5%
Valves	5.0%	0.0%

In conclusion, an idle CO I/M program which also adopts the improvements discussed in Section 3.0 will very likely succeed in reducing repair costs for pre-1981 vehicles to the amount which is legitimate for an idle mixture adjustment only. Data from two sources indicate this cost should be in the range of $6 to $10 per car. In the Portland study, 58 1975-77 cars which received only idle mixture and/or speed adjustments were charged an average of $9.50 by the repair facilities. And for 313 1975-79 cars which were taken to commercial repair facilities in various parts of the country as part of EPA's

FY79 Emission Factors Program [14], the average charge for an idle mixture adjustment was $6.29.

It should be mentioned here that passenger cars produced by General Motors Corporation (GM) during the 1979 and 1980 model years were equipped with carburetor idle mixture adjustment screws which are inaccessable without first removing the carburetor. It can be expected that a carburetor adjustment on these vehicles will cost more than has been estimated for other vehicles. However, since the carburetor idle mixture of these vehicles cannot normally be adjusted, the occurrance of idle mixture maladjustments will be lower. In the Houston Program only 3.1% of the 98 1979 and 1980 GM vehicles tested failed the program's idle CO cutpoints. In all, these vehicles will account for only 11% of all pre-1981 vehicles in January of 1983 when all I/M programs are scheduled to be in operation. It is not expected, then, that these vehicles will have any significant effects on the overall repair costs being estimated for idle CO programs.

4.2.3 Net Effect on I/M Costs

It was shown in Section 4.2.1 that by just eliminating HC-only failures, 30% of the total repair bill for pre-1981 vehicles can be saved compared to a conventional I/M program. The cost per vehicle for the remaining vehicles will also be reduced, down to the cost of a carburetor adjustment, about $6 to $10. Using the repair cost of $23.86 from Portland as typical for these vehicles in a conventional I/M program and $10 for an idle mixture adjustment, the net effect is that an idle CO I/M program will have total repair costs for pre-1981 vehicles that are about 70% less than a conventional I/M program with the same CO cutpoint.

EPA has recently estimated all the cost components for a typical (conventional) I/M program design [4]. Averaged over the five years from 1983 through 1987, repair costs for pre-1981 vehicles account for 27% of the total cost of the I/M program. Therefore, an idle CO I/M program costs will be about 19% cheaper than a conventional I/M program with the same CO cutpoint as the result of reduced costs for pre-1981 vehicles alone. Overall program costs will be reduced about 26%, including the savings from 1981 and later vehicles discussed in Section 5.2.

4.3 Emission Reductions

There are several operating programs, such as the Portland program, which provide data that can be used to estimate emission reductions in conventional I/M programs. Since there are no operating idle CO I/M programs, the emission reductions that we can expect from such programs can only be estimated from evidence gathered from a variety of sources that are each only partially relevant. This section will examine the available data which may provide some indication of the possible effects of idle CO I/M programs on HC and CO emission reductions observed in conventional I/M programs.

In order to provide a convenient analytical framework for analyzing emission reductions, a failure group approach will be used. That is, the three groups of "failed" vehicles will be analyzed separately: vehicles which would have failed HC only if there was an idle HC cutpoint but will now pass instead (HC-only failures), vehicles which would have failed HC and CO and will now fail only idle CO (HC-and-CO failures), and vehicles which would have failed idle CO only (CO-only failures).

4.3.1 Carbon Monoxide Emissions

HC-only failures - Any CO emission benefits from vehicles which fail only idle HC cutpoints in a conventional I/M program will be lost in an idle CO I/M program since these vehicles will pass their idle CO cutpoint. However, these vehicles do not produce any CO benefits from repair even in conventional programs and therefore dropping these vehicles from an idle CO I/M program will not reduce the overall CO benefits of the program. This conclusion is supported by data from the Portland Study. In Portland, those vehicles which failed only for idle HC had low FTP CO emissions to begin with and showed no CO improvement from repairs.

HC-and-CO failures - Vehicles which fail both the idle HC and idle CO cutpoints in a conventional I/M program will still fail for idle CO in an idle CO I/M program. It is expected that the CO emission reduction from the repair of these vehicles in an idle CO I/M program will be the same as the CO emission reduction that would be observed from the same vehicles in a conventional I/M program. This is expected since the same repairs used to reduce idle CO emissions in the conventional program will still be needed in the idle CO program in order to pass the idle CO cutpoints.

Also, the additional repairs which reduce idle HC emissions in a conventional program do not significantly affect CO emissions. As mentioned earlier, vehicles in Portland which failed only for idle HC and received repairs to reduce their idle HC emissions showed no improvement in their CO emissions. In an EPA test program where misfire was induced on a sample of eight pre-1981 vehicles an average 11% misfire drastically increased HC emissions but had little effect on CO emissions. A correction of misfire on these vehicles would have resulted in only a small reduction in FTP CO emissions. In the Houston program[15] additional repairs other than carburetor adjustments reduced FTP CO emissions only an additional 1.25 gpm after the carburetor adjustment on those vehicles which failed both idle HC and idle CO. These additional repairs would only have increased the total CO emission reduction from repairs by only 2.4%.

CO-only failures - Those vehicles which would fail only for idle CO in a conventional I/M program will also fail in an idle CO program. These vehicles will receive similar repairs and therefore the same reductions in CO emissions as in a conventional program since the retest requirements will be the same.

The conclusion that can be drawn is that for pre-1981 vehicles, dropping the idle HC cutpoints from a conventional I/M program, to arrive at an idle CO program, will not reduce the overall CO benefits of the I/M program, despite the elimination of idle HC only failures and the additional repairs performed on some CO failures in a conventional I/M program to pass idle HC cutpoints.

4.3.2 Hydrocarbons/Emissions

HC-only failures - In an idle CO I/M program all of the HC emission benefits from vehicles which would have failed the idle HC cutpoints but not the idle CO cutpoint in a conventional I/M program will be lost since these vehicles will not be failed in an idle CO program. For 1976-77 vehicles tested in Portland during 1978 and 1979 in the Portland Study, only 11% of the total HC benefit observed in the program came from the idle HC only failures. However, the idle HC only failure rate and their contribution to the total HC benefit of a conventional I/M program is expected to increase as the pre-1981 vehicles age. By the time I/M programs begin operation in 1982 or 1983 it is estimated that idle HC only failures will account for 26% to 27% of the total HC emission reductions from pre-1981 vehicles in conventional I/M programs. By 1987 idle HC only failures will account for about 29% of the HC benefits from these vehicles.

HC-and-CO Failures - The HC emission reductions from repair of vehicles which fail idle CO in the idle CO I/M program but would have also failed idle HC in a conventional I/M program are expected to be less than the HC reduction observed in conventional I/M programs. Primarily this is due to the loss of additional repairs, such as ignition repairs, necessary in a conventional I/M program to reduce idle HC emissions which will no longer be required in an idle CO program.

While there is no precise information on how much of the HC emission reduction benefit will be lost, this loss can be estimated by examining existing data which compares the HC emission reductions produced by carburetor adjustments and those produced by more complete tune-ups including ignition repairs on vehicles which fail both idle HC and idle CO cutpoints. In the Houston Program additional repairs after the carburetor adjustment increased the total FTP HC emission benefit an additional 9.4% on a small sample of vehicles initially failing both idle HC and idle CO. Also, additional repairs increased the total HC emission benefit another 4.0% in a small sample of vehicles failing both idle HC and idle CO in the FY79 Emission Factor program[14] after a carburetor adjustment. The Restorative Maintenance Evaluation[12] shows an additional 3.8% HC benefit in further repairs on vehicles failing both idle HC and idle CO after a carburetor adjustment. Vehicles in the Emission Factor and Restorative Maintenance samples were reasonably new when testing was done and were not expected to have many problems which would cause high HC emissions. Also, the vehicles in these samples would have received less of the additional repairs in a conventional I/M program. To quantify the loss precisely would require new testing since the existing data only approximates the expected effects of an idle CO I/M program.

CO-Only Failures - Vehicles which fail only for idle CO in a conventional I/M program will also fail in an idle CO program and will receive essentially the same repairs. The HC emission reductions from these repairs in an idle CO program will therefore be the same as in a conventional program.

In conclusion, the total HC emission benefits possible from an idle CO I/M program will not be as great as from a conventional I/M program for pre-1981 vehicles. The loss in HC effectiveness is expected to be even greater on pre-catalyst technology vehicles built prior to 1975, but there is insufficient data to illustrate their loss. An idle CO I/M program will therefore achieve only partial HC emission reduction benefits for pre-1981 vehicles. Quantification of these benefits will be presented in Section 4.3.4.

4.3.3 Deterioration Issues

Between inspections the HC and CO emission reductions produced by an I/M repair will gradually deteriorate. The reasons for this deterioration may include emission component failures due to general gradual wear, maladjustments, and tampering occurring between I/M inspections. The rate of this deterioration affects the net HC and CO emission benefits that can be expected from an I/M program. EPA has done extensive testing to quantify the deterioration rate for conventional I/M programs, however, no testing program has yet been conducted to measure deterioration in an idle CO program. Such a testing program would be difficult to conduct with any validity since there are currently no operational idle CO I/M programs which can be evaluated.

One possible line of speculation is that the deterioration rate will be less in an idle CO I/M program since mechanics will have no need to temporarily adjust carburetors very lean as a cheap way to pass idle HC cutpoints as is sometimes done in conventional I/M programs. However, since a rich idle mixture may be counteracting other problems which may remain unrepaired in an idle CO I/M program, the rate of deterioration of HC and CO emissions may be higher than has been observed in conventional I/M programs if vehicles owners maladjust their vehicles between I/M inspections. A survey of vehicle owners in EPA's Emission Factor Programs a week after they had had their vehicles carburetors adjusted to manufacturers specifications indicates that most vehicle owners are satisifed with the performance of their vehicles after such repairs.[16] Although Emission Factor Programs do not simulate I/M programs and although carburetor adjustments to manufacturers specifications is not exactly the repair at issue, it does indicate that vehicle owners can be satisfied with the performance of their vehicles even after the carburetor is adjusted leaner than they have become accustomed to.

Lacking any relevant data, one can only assume the same deterioration behavior for idle CO I/M programs as for conventional I/M for the purposes of this report.

4.3.4 Emission Reduction Benefits Model for Idle CO I/M Programs for Pre-1981 Vehicles

For pre-1981 model year vehicles, EPA's simulation model for conventional I/M programs can be modified to approximate the effects of idle CO I/M programs. First, the HC benefit attributable to vehicles which fail only HC in a conventional I/M program are omitted. Secondly, the HC benefit attributable to vehicles which fail both pollutants in a conventional program are reduced based on assumptions concerning the cause of failure. An estimate is made of the number of conventional HC-and-CO failures which have high idle HC for reasons other than idle mixture maladjustment. These vehicles are then modeled as receiving little HC reduction. The remaining vehicles in the HC-and-CO group receive the normal (conventional) HC reduction. Finally, the HC benefit attributable to vehicles which fail only CO in a conventional program is retained in its entirety.

Figures 1 and 2 present sample results of this modified simulation. These figures are based on a conventional I/M stringency of 20% and an idle CO I/M stringency of 13%.* The two programs use the same CO cutpoint. The difference in stringency is due to the use of an HC cutpoint in addition to an idle CO cutpoint in the conventional I/M program. Figure 1 presents the composite HC emission factor for pre-1981 vehicles without I/M and with each of the two types of I/M. Figure 2 shows the percent benefits associated with these programs for HC.

4.4 Fuel Economy Benefits

The Portland Study did not indicate any significant overall fuel economy benefit as a result of I/M repairs [17]. This conflicts with data from various restorative maintenance programs which show about a 4% improvement in combined city/highway fuel economy after emission related maintenance[18]. The question is the following: what specific differences in the repair types performed in Portland could cause the disparity.

One piece of the solution is the fact that carburetor adjustments, even when they are not performed exactly as specified by the manufacturer, produce sizable fuel economy benefits on pre-1981 vehicles. This makes sense technically since a vehicle with an overly rich idle mixture is consuming more fuel than it needs and any carburetor adjustment that results in a significantly leaner idle mixture should result in less fuel consumption and better fuel economy. Recent studies in Houston and Portland indicate that significant fuel economy benefits between 1.1% and 4.6% can be obtained if only carburetor adjustments are performed after failing an idle CO cutpoint. Table 24 presents the results of those studies.

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* The term stringency in this report will be used to refer to the selection of appropriate idle HC and CO cutpoints in a conventional I/M program or the selection of idle CO cutpoints in an idle CO I/M program such that the failure rate in the first year of the I/M program will have a failure rate equal to the stringency, i.e., a twenty percent stringency means a twenty percent failure rate in the first year. The cutpoints selected are then used throughout all years of the program's operation.

Figure 1

Comparison of HC Emission Reductions
For Pre-1981 Vehicles

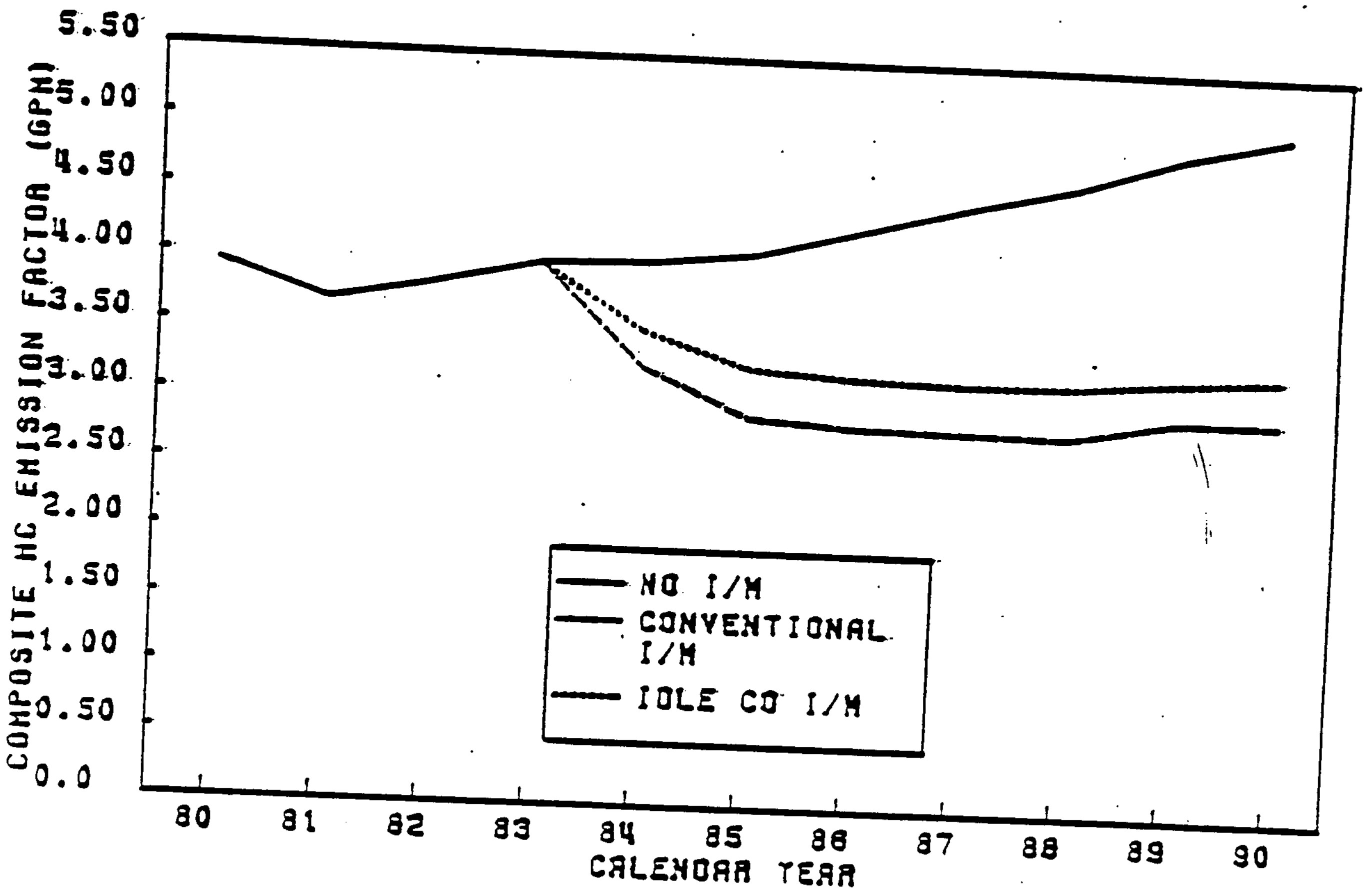


Figure 2

Comparison of HC Benefits
For Pre-1981 Vehicles

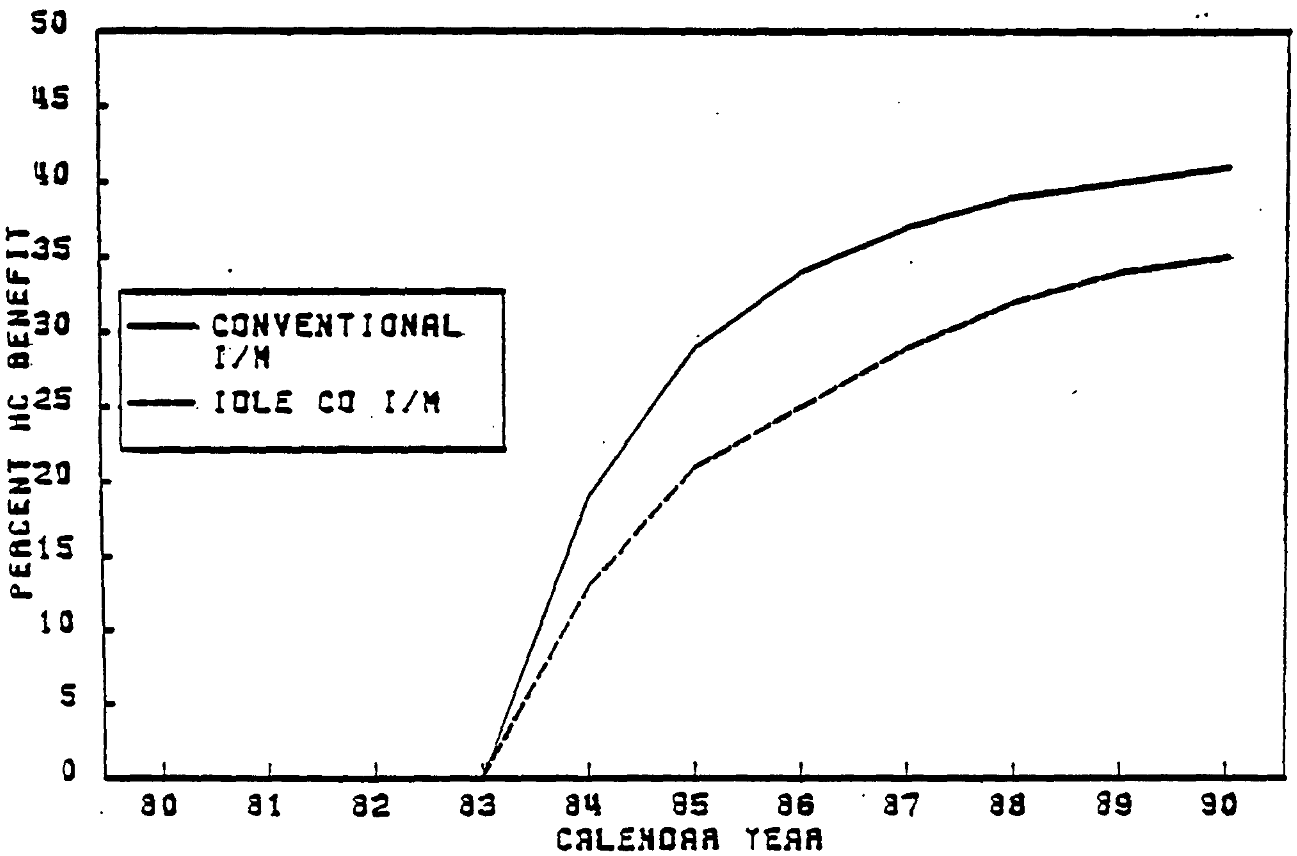


Table 24

Fuel Economy Benefits
from Carburetor Adjustments to
Vehicles Failing Idle CO Cutpoints
(1975-80 Model Year Vehicles)

Program	Number of Vehicles Adjusted	Fuel Economy	Before Carburetor Adjustment (mi/gal)	After Carburetor Adjustment (mi/gal)	Percent Change
Houston Program Study[1]	(85)	City	13.79	14.61	5.9
		Hwy	20.57	21.01	2.1
		Comb	16.19	16.93	4.6
Portland Task Group 10[2]	(31)	City	14.39	14.70	2.1
		Hwy	20.14	20.03	-0.6
		Comb	16.51	16.70	1.1
FY79 EF Houston Site I[3]	(12)	City	14.22	14.74	2.9
		Hwy	21.71	22.29	2.6
		Comb	16.92	17.39	2.8

1: Idle mixture adjusted so that idle CO is 0.5%
2: Idle mixture adjusted so that idle CO is 0.2%
3: Carburetor adjusted by field mechanics; those vehicles passing 2.5% idle CO after carburetor adjustment.

If carburetor adjustments can produce sizable fuel economy benefits and carburetor adjustments are the most common repair in conventional I/M programs, the lack of significant overall improvement in fuel economy observed in Portland must be the result of repairs other than carburetor adjustments which degrade fuel economy and offset the fuel economy improvement provided by the carburetor adjustment. Overly retarded ignition spark timing has been identified as one such repair in the Portland study [19]. Analysis of the available data will continue in order to identify other repairs which may also degrade fuel economy.

In idle CO I/M programs carburetor adjustments will be virtually the only repair necessary to pass the reinspection idle CO cutpoint. It can therefore be stated with confidence that an idle CO I/M program will obtain fuel economy benefits. The size of the fuel economy benefit will depend on how close repair mechanics will adjust carburetors to manufacturers specifications. We do know that if mechanics adjust the carburetor such that the idle CO is 0.5%, the fuel economy benefit may be as high as the 4.6% obtained in the Houston program. This fuel economy benefit can provide significant savings in fuel costs to vehicle owners who must receive emission related repairs.

Mechanics will not normally be expected to adjust carburetors much leaner than the program's idle CO cutpoint, since they only need a reasonable margin of safety in order to be sure to pass the reinspection. In New Jersey, the operating program has an idle CO cutpoint of 3.0% for 1975-80 vehicles and the average idle CO measurement after repair is 0.9%. However, if the reinspection cutpoint is tighter, mechanics will be forced to adjust leaner in order to keep a reasonable margin of safety. In the Portland program most 1975-80 vehicles must pass a 1.0% reinspection cutpoint. The average idle CO measurement after repair in this program is 0.2%. This means that one way to assure that mechanics adjust carburetors so that the idle CO measurement after repair is 0.5% is to impose an appropriately tight reinspection cutpoint. It has been estimated that a reinspection idle CO cutpoint between 1.0% and 2.0% will result in an average after-repair idle CO measurement of 0.5% or less with no adverse side effects. (The Portland I/M program has been using a CO cutpoint of 1% for many years.) This may mean having a reinspection cutpoint which is different than the initial inspection cutpoint. (An initial inspection cutpoint of 2.0% would result in a 37% stringency for 1975-80 vehicles, higher than desired by many I/M planners.) This should cause no conflict, since the purpose of the two cutpoints is different. The initial cutpoint is set to identify those vehicles most in need of repair. The reinspection cutpoint assures that those repairs were effective in reducing the vehicles CO emissions. The inspection cutpoint, therefore, does not necessarily need to be as tight as the reinspection cutpoint.

Another way to assure that most repair mechanics will adjust carburetors so that the idle CO after repair is 0.5% is through mechanic training. Mechanics who do repairs in the I/M program can either be instructed to adjust all cars failing the idle CO cutpoints so that the idle CO is 0.5% as a matter of course or they can be instructed to do so if the vehicle's idle CO measurement exceeds 0.5% after adjusting the vehicles idle mixture using manufacturer specified procedures. Additional information on overall carburetor diagnostics and repair can also be included in the program.

If a tighter reinspection cutpoint or mechanic training is not possible a 0.5% idle CO adjustment target can be mandated by the program as a requirement for vehicles failing the idle CO cutpoint. This approach will require a periodic statistical review by the program administrators of post-repair idle CO measurement records from each repair facility to enforce the requirement. The effectiveness of this approach will depend heavily on how well the requirement can be enforced.

The emission benefits from any of these options which encourage leaner adjustments than would be necessary merely to pass the initial inspection idle CO cutpoint will be discussed in Section 7.3.

5.0 I/M FOR 1981 AND LATER VEHICLES USING ONLY IDLE CO CUTPOINTS

5.1 Background on 1981 and Later Vehicles

There are two significant technology differences between pre-1981 and 1981 and later vehicles. First, the majority of 1981 and later vehicles are expected to employ microprocessor-based, closed-loop engine control systems. These systems rely on a network of sensors to supply information on the operating condition of the engine to an on-board microprocessor. The microprocessor analyzes this information and sends operational commands to various actuators (primarily solenoids) which modify the air/fuel ratio, control the deployment of secondary air, determine spark timing, and on some systems allow or disallow exhaust gas recirculation (EGR). These systems represent a significant departure from earlier, mechanically controlled systems.

Second, the Parameter Adjustment regulations[2] provide that the fuel metering systems on 1981 and later vehicles be designed in such a way so as to discourage tampering or maladjustment of the idle mixture and choke systems. As is widely known, maladjustment of the idle mixture system has been the cause of a significant share of the in-use emissions problem for pre-1981 vehicles. Although even the protected designs can still be maladjusted (after some effort), it is expected that the 1981 and later fleet will be much less subject to idle mixture and choke maladjustment.

Due to these technology differences, the general nature of the expected in-use emission performance of 1981 and later vehicles is different than for earlier model year vehicles. The in-use emissions performance of earlier model year vehicles (pre-1981) is largely affected by the rate of various forms of maladjustment and tampering (chiefly idle mixture maladjustment) as well as phenomena such as problems with the ignition system and catalyst deterioration due to aging or misfueling. By comparison, while 1981 and later vehicles will still experience ignition system problems and catalyst deterioration to some extent, the main phenomenon affecting in-use performance is expected to be failure of the microprocessor-based fuel control system. These failures often result in very rich modes of operation with accompanying very high levels of HC and CO and poor fuel economy. These HC and CO levels are high enough so that even if only a small number of vehicles experience a fuel system failure, they can dominate the emission inventory of the fleet and cause the average emissions of the fleet to exceed the standards. The early data on the in-use performance of microprocessor-controlled vehicles has given significant indication that this type of behavior can be expected for the 1981 and later fleet.

Rich failures of the microprocessor-based fuel control system primarily affect CO emissions--causing them to rise dramatically. These failures also cause HC emissions to rise, but to a somewhat lesser degree. Repair of these rich failures result in significant fuel economy improvements averaging about 15%[6]. The average in-use HC emissions of the 1981 and later fleet are also largely affected by problems with the ignition system (e.g., misfire, fouled plugs, faulty distributor components).

Readers interested in gaining more information on the projected in-use performance of 1981 and later vehicles should refer to "Derivation of 1981 and Later Light Duty Vehicle Emission Factors for Low Altitude, Non-California Areas"[20].

5.2 Idle CO I/M for 1981 and Later Vehicles

Given the preceeding discussion on the expected in-use emissions performance of the 1981 and later fleet, it should come as no surprise that the emission reductions attributed to I/M are expected to primarily come from the identification and repair of vehicles with a rich failure of their microprocessor-based fuel control system. Data from such vehicles in the field indicate that some fraction of them will readily fail an I/M CO cutpoint. The estimate used in this analysis is that 50% of those vehicles with a failure of the microprocessor-based fuel control system will be identified in an idle CO I/M program using the basic idle test. This is the same estimate used for a conventional I/M program. This means that the CO benefits in an idle CO program will be the same as in a conventional I/M program. Since these vehicles also have high HC emissions, their identification and repair in an idle CO I/M program will also result in significant HC reductions. Ignition problems (the other main source of projected HC emissions for the 1981 and later fleet) are not identified by a CO cutpoint, and therefore an idle CO I/M program will not get the HC reduction benefits of their repair.

A conventional I/M using an idle test program is expected to fail about 7% of the 1981 and later vehicle fleet. An idle CO I/M program using the same test will only fail vehicles with microprocessor-based fuel control system failures, or about 1.7% of the 1981 and later fleet. The other vehicles fail in a conventional I/M program for idle HC emissions only. Since all of the fuel economy benefits associated with repair of 1981 and later vehicles comes from these vehicles with fuel control system failures, idle CO I/M programs will achieve the same overall fuel economy benefits from 1981 and later vehicles as conventional I/M programs. This amounts to an average 15% fuel economy improvement for each vehicle experiencing a fuel system control failure which is identified and repaired.

Repair costs for 1981 and later vehicles has been estimated to be about $30 per repair [4]. These repairs include ignition parts replacements as well as repairs to the microprocessor-based fuel control system. For an idle CO program these costs are assumed to be the same, although only fuel control system repairs will be necessary. However, since the failure rate for an idle CO program is only about 25% of the failure rate of a conventional I/M program for 1981 and later vehicles, repair costs are reduced about 75%.

The following section will quantify the emission benefits expected for the 1981 and later fleet in an idle CO program. It will especially document the loss of HC benefit due to not identifying vehicles with ignition problems.

Readers interested in gaining more information on the methodology involved in estimating I/M benefits for the 1981 and later fleet should refer to "Derivation of I/M Benefits for Post-1980 Light Duty Vehicles for Low Altitude, Non-California Areas"[21].

5.3 Emission Benefits Model for Idle CO I/M Programs for 1981 and Later Vehicles

The I/M emission benefits attributed to a conventional program for 1981 and later vehicles come from two sources: the identification and repair of vehicles with rich failures of their microprocessor control system (yielding HC anc CO benefits) and the HC benefits resulting from the identification and repair of vehicles with ignition system problems. As discussed above, the first source of benefits is not diminished in an Idle CO I/M program although the second source would be lost. EPA's computer model which calculates I/M benefits for 1981 and later vehicles in a conventional I/M program can be easily modified to account for this partial loss of HC benefits[20].

Figures 3 and 4 compare the HC and CO emission reduction benefits from a conventional I/M program and a idle CO I/M program. The benefits shown represent those from the 1981 and later fleet only.

Figure 3

Comparison of HC Emission Reductions
For 1981 and Later Vehicles

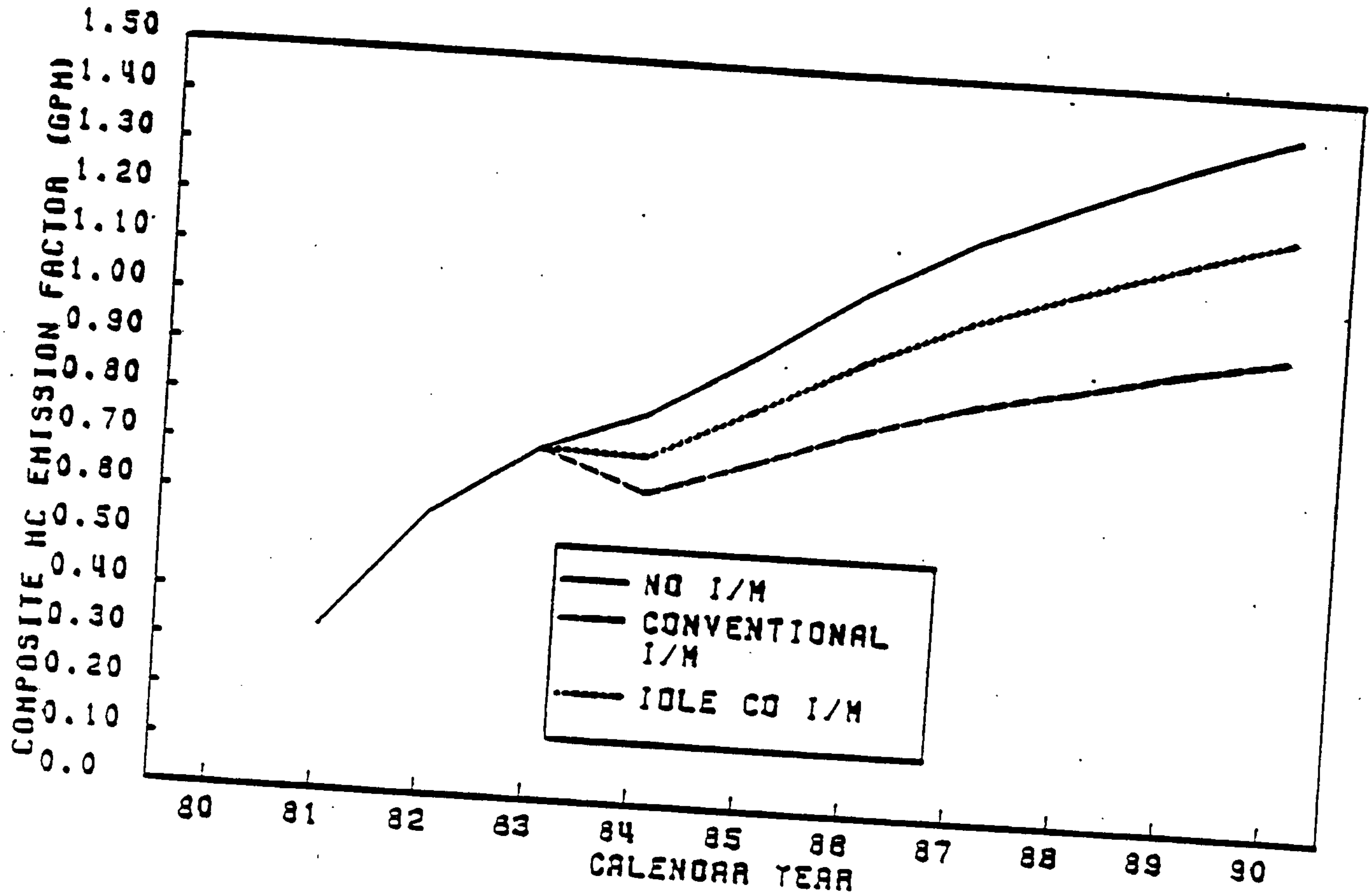
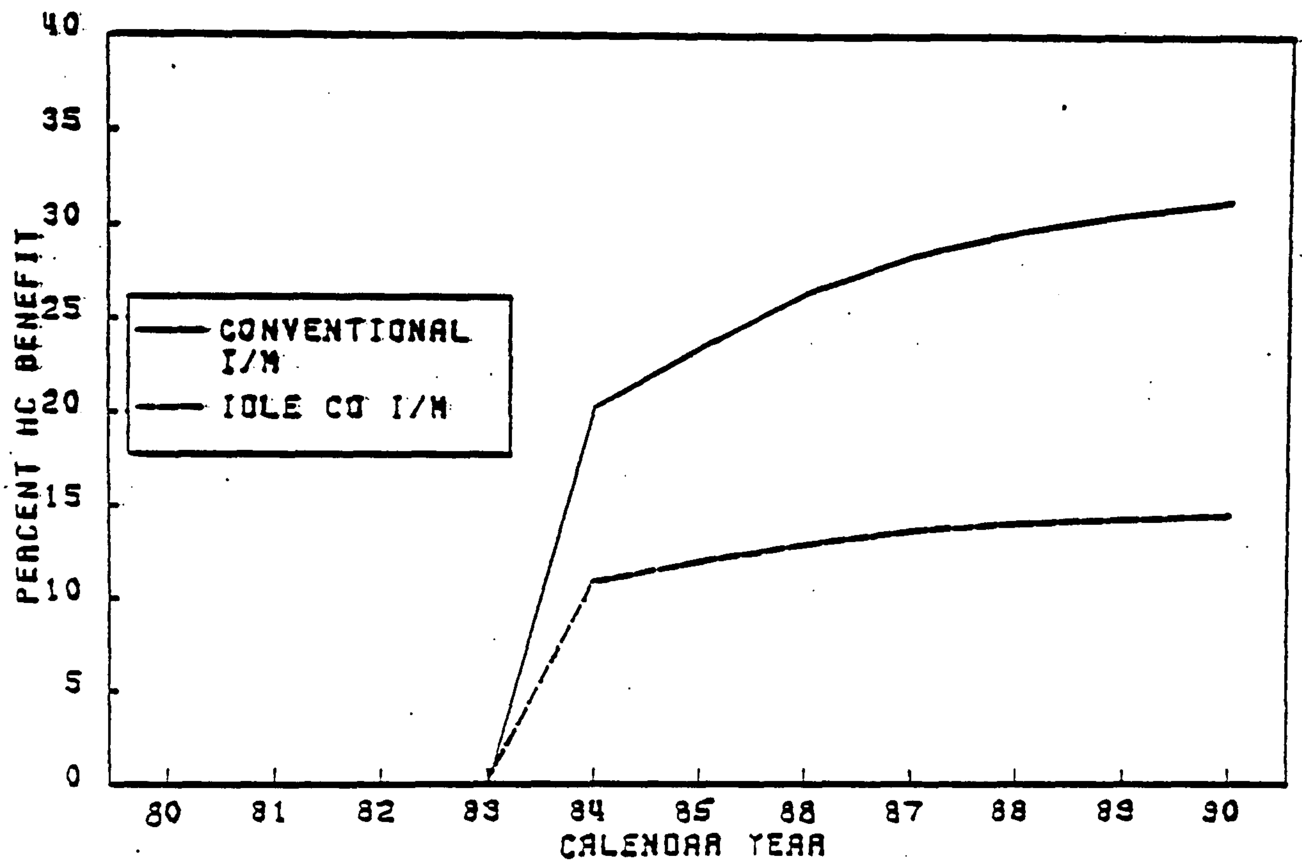


Figure 4

Comparison of HC Benefits
For 1981 and Later Vehicles



6.0 OVERALL EMISSION REDUCTION BENEFITS FOR I/M PROGRAMS USING ONLY IDLE CO CUTPOINTS

The results from models for benefits of idle CO I/M programs for pre-1981 vehicles and 1981 and later vehicles as discussed in sections 4.3.4 and 5.3, respectively, can be combined to determine benefits for the entire fleet.

Benefits for CO in an idle CO I/M program are expected to be the same as for a conventional I/M program if the same idle CO cutpoints are used. The effects for HC are presented in Table 20. The HC benefits on December 31, 1987 for conventional and idle CO programs starting January 1, 1983 with no mechanic training and a simple idle test for 1981 and later vehicles are shown. It should be noted that the idle CO programs presented in Table 25 would have higher CO benefits than the conventional programs since the idle CO cutpoints for a given failure rate idle CO program are lower than the idle CO cutpoints for a conventional program of the same stringency (failure rate).*

It can be seen in the table that areas with ozone non-attainment problems using an idle CO program will likely need to implement measures to increase HC benefits. Methods for increasing HC benefits are discussed in the next section.

If the idle CO I/M program was restricted to only 1975 and later vehicles, the composite HC benefit for idle CO programs would be further reduced. Pre-1975 vehicles account for between 7.4% and 10.7% of the HC benefit in an idle CO I/M program, depending on stringency. The HC benefit in conventional programs would also be reduced if all pre-1975 vehicles were exempted from inspection. Table 25 also presents the emission benefits of an idle CO program which exempts pre-1975 vehicles.

* The term stringency in this report will be used to refer to the selection of appropriate idle HC and CO cutpoints in a conventional I/M program or the selection of idle CO cutpoints in an idle CO I/M program such that the failure rate in the first year of the I/M program will have a failure rate equal to the stringency, i.e., a twenty percent stringency means a twenty percent failure rate in the first year. The cutpoints selected are then used throughout all years of the program's operation.

Table 25

Comparison of HC Benefits for Conventional and Idle CO I/M Programs* Starting in 1983

Stringency for Pre-1981 Vehicles (Failure Rate) **	Percent Benefit on December 31, 1987					
	Conventional		Idle CO		1975+ Idle CO	
	HC	CO	HC	CO	HC	CO
13%	32	30	24	33	22	29
20%	35	33	27	36	24	32
30%	38	36	30	39	27	34
40%	39	38	31	40	28	35

* Further assumption about the I/M programs are no mechanic training and a simple idle test for 1981 and later vehicles.

** At a given stringency (failure rate), the idle CO I/M program has numerically lower CO cutpoints than the conventional program, but has equal stringency overall.

Using the model for emission benefits it is possible to calculate the tons of pollutants that are removed by an I/M program. The methodology for this calculation is presented in "Update on the Cost-Effectiveness of Inspection and Maintenance [4]. Table 26 presents the results of such a calculation for idle CO programs. For comparison a conventional I/M program with a 20% stringency for pre-1981 vehicles produces a 46,500 ton reduction in HC emissions and a 526,800 ton reduction in CO emissions from a base of one million vehicles.

Table 26

Five Year Emission Reductions -

Thousands of Tons Removed* by an Idle CO Program

Stringency for Pre-1981 Vehicles (Percent)	All Model Years		Only 1975 and Later	
	HC	CO	HC	CO
13	31.31	526.8	29.26	435.7
20	36.38	607.4	32.87	502.9
30	43.61	692.7	38.08	572.5
40	45.64	723.1	39.81	598.7

* A vehicle base of one million vehicles is used.

7.0 METHODS TO IMPROVE THE HC EMISSION REDUCTION FROM IDLE CO I/M PROGRAMS

As described generally in Section 4.3.2 and as quantified in Section 6.0, it is expected that a conventional I/M program which simply eliminates the idle HC emission requirements from the program will suffer some loss of effectiveness in reducing HC emissions from automobiles when compared to the conventional progam. Table 20 showed that there is over a 20% percent loss in HC effectiveness even if the CO cutpoint is tightened enough to bring the overall stringency of the program back to that of a conventional I/M program. This will have an impact on areas with ozone air quality problems which must reduce the overall emissions of HC from automobiles and which may wish to use the idle CO I/M program approach. For this reason, this section will examine several methods which can be used to increase the effectiveness of an idle CO program in reducing HC emissions. These methods include:

- Using a more effective test procedure for 1981 and later vehicles.
- Increasing the failure rate of pre-1981 vehicles.
- Assuring better repairs on pre-1981 vehicles.
- Re-establishment of a loose idle HC cutpoint.
- Addition of tampering checks.
- I/M for light-duty trucks.

Many of these improvements are also expected to increase the reduction of CO emissions.

Most of these improvements can also be applied to conventional I/M programs if additional reductions of HC and CO emissions are desirable.

7.1 More Effective Test Procedure for 1981 and Later Vehicles

One means of increasing the HC reductions from an Idle CO program is to use a more effective test procedure for 1981 and later vehicles. The benefits presented in Section 5.0 were based on the use of a basic idle-in-neutral test for 1981 and later vehicles. This test is estimated to catch 50% of the vehicles with rich failures of their microprocessor-based fuel control system. The addition of other pass/fail vehicle operating modes to the overall test procedure has been shown to increase this percentage. For example, the addition of a 2500 rpm test mode (Two Speed Idle Test) or the addition of a 30 mph/9.0 HP loaded test mode (Loaded Test) has been shown to result in a 70% identification rate of the vehicles with a fuel control system failure[21]. This will increase the failure rate for 1981 and later vehicles from about 1.7% to 2.4%. Either of these tests will still qualify vehicle owners for coverage under the Emission Performance Warranty[3]. Since these additional rich failures increase both HC and CO emissions, yet are readily identifiable using only a CO cutpoint, any increase in the number of vehicles identified by the CO cutpoint will cause the HC benefits to increase. Repair of rich failures among 1981 and later vehicles has produced an average 15% fuel economy benefit. The fuel savings from these repairs, therefore more than offset the cost of an average repair cost of about $30.

Figures 5 and 6 show the improvement in HC effectiveness which can be achieved by using the Two Speed Idle Test or the Loaded Test. For purposes of comparison, the HC effectiveness of using the basic idle test is also included. Figures 5 and 6 apply only to 1981 and later vehicles. In fleetwide terms, the use of one of these more effective tests for 1981 and later vehicles can increase the composite HC emission reduction from I/M as of December 31, 1987 by 2.4 percentage points. For example, Table 19 showed a 20% stringent idle CO I/M program will yield an HC reduction of 27% on this date. If a more effective test is used for 1981 and later vehicles, this reduction would be improved to 29%. This option will increase the tons of HC removed by an idle CO program by 2,030 tons and CO by 60,400 tons in a base sample of one million vehicles.

7.2 <u>Higher Failure Rates for Pre-1981 Vehicles</u>

If the idle CO cutpoint is made more stringent more vehicles will fail their initial idle CO inspection, more vehicles will receive repairs, and therefore it is logical to expect that there will be an overall increase in the HC (and CO) benefits of the idle CO I/M program. Also, if the reinspection idle CO cutpoints are identical to the initital inspection cutpoints, tightening the idle CO cutpoints will have the effect of forcing mechanics to adjust carburetors on all failing cars leaner than they would have with looser cutpoints. This effect is discussed in Section 4.4. Since these additional failures will all receive the same repairs as the original failures (carburetor adjustments), the increase in HC benefit to the program will not be as large as the increase in the CO benefit. In addition, there are diminishing returns from failing more vehicles as more and more relatively clean vehicles fail the stringent initial inspection idle CO cutpoints and produce very little HC or CO benefit from repairs. This is evident in Figure 7.

Figure 7 presents the effects of increasing stringency* on pre-1981 vehicles subject to an idle CO I/M program. Figure 7 applies only to pre-1981 vehicles. Table 25 in Section 6.0 presents the HC and CO benefits of increasing stringency on the pre-1981 vehicles and Table 26 presents the tons of pollutants removed.

7.3 <u>Better Repairs</u>

On pre-1981 vehicles, mechanics will on the average only adjust carburetors to just pass an idle CO reinspection cutpoint with a reasonable margin of safety. If the reinspection cutpoint is fairly loose, vehicles after repair

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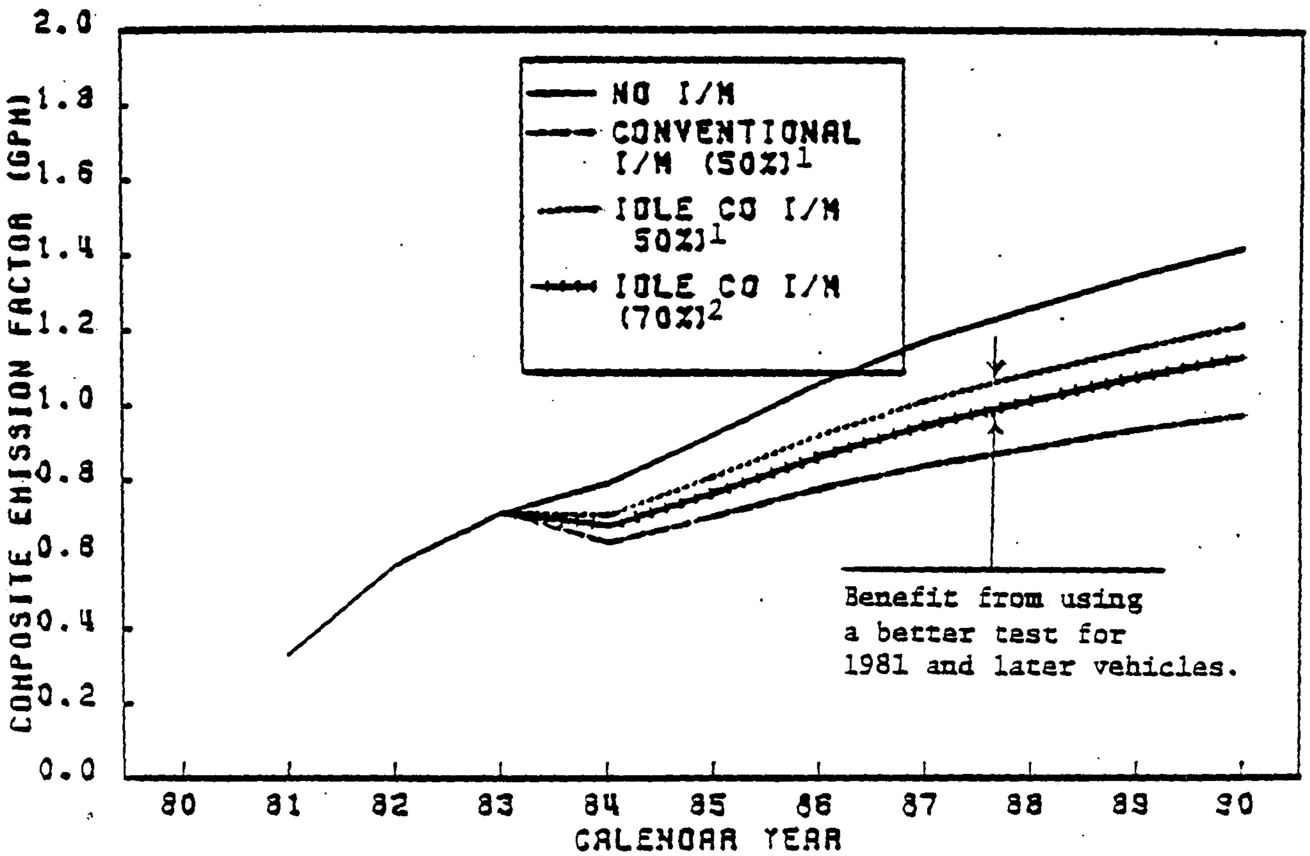
* The term stringency in this report will be used to refer to the selection of appropriate idle HC and CO cutpoints in a conventional I/M program or the selection of idle CO cutpoints in an idle CO I/M program such that the failure rate in the first year of the I/M program will have a failure rate equal to the stringency, i.e., a twenty percent stringency means a twenty percent failure rate in the first year. The cutpoints selected are then used throughout all years of the program's operation.

Figure 5

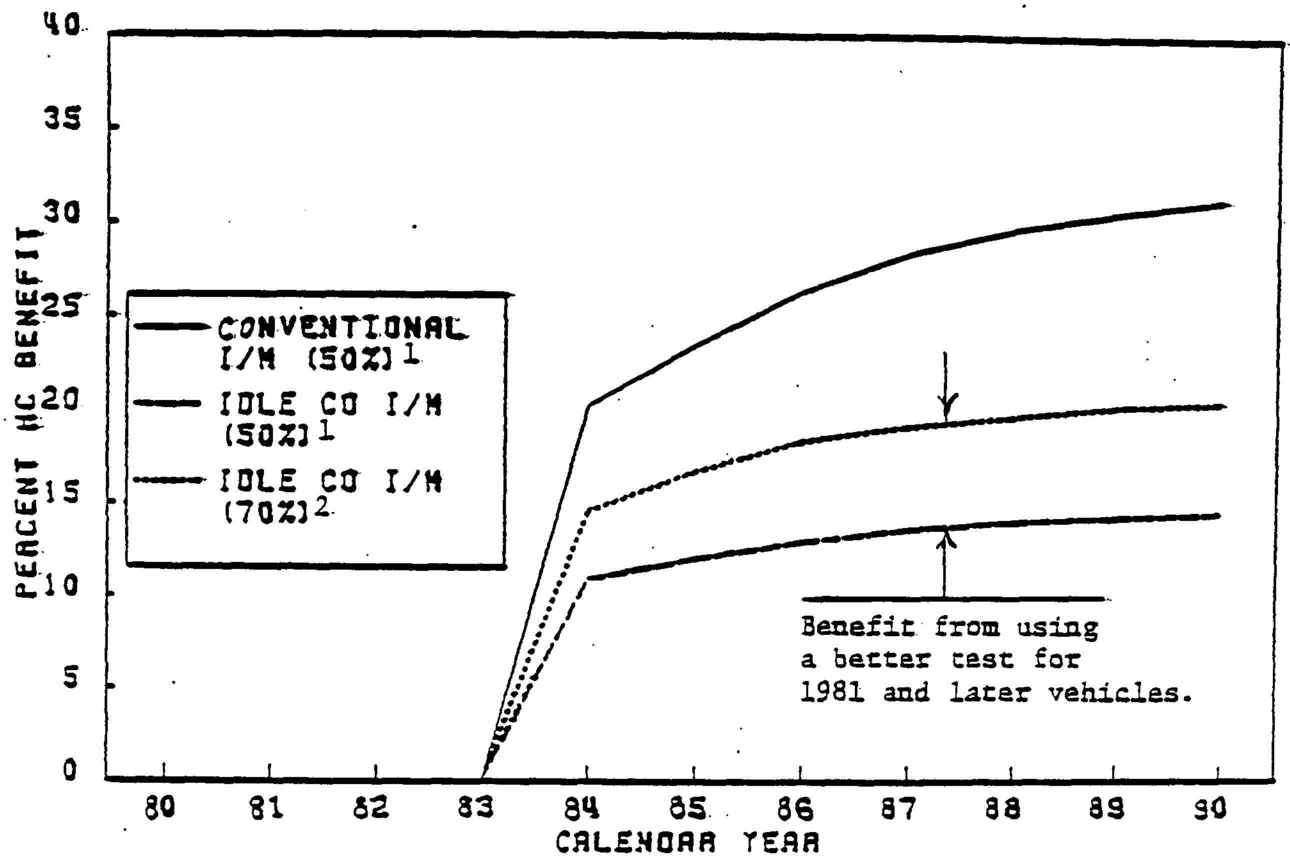
Effect of a More Effective Test Procedure
on the HC Emission Reductions
For 1981 and Later Vehicles



1: Idle CO Test (50% Identification Rate)
2: Two-Speed Idle Test or Loaded Test (70% Identification Rate)

Figure 6

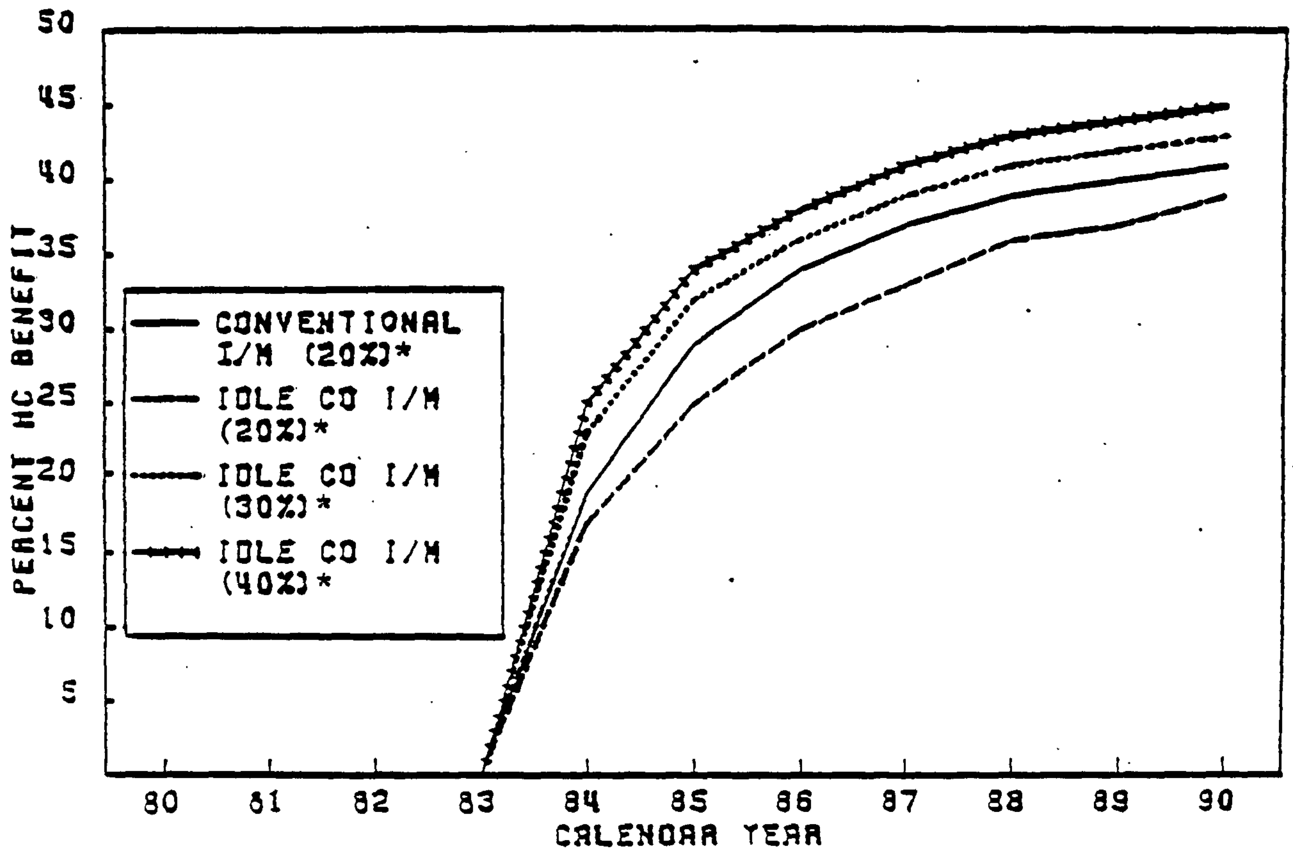
Effect of a More Effective Test Procedure on the HC Benefits For 1981 and Later Vehicles



1: Idle CO Test (50% Identification Rate)
2: Two-Speed Idle Test or Loaded Test (70% Identification Rate)

Figure 7

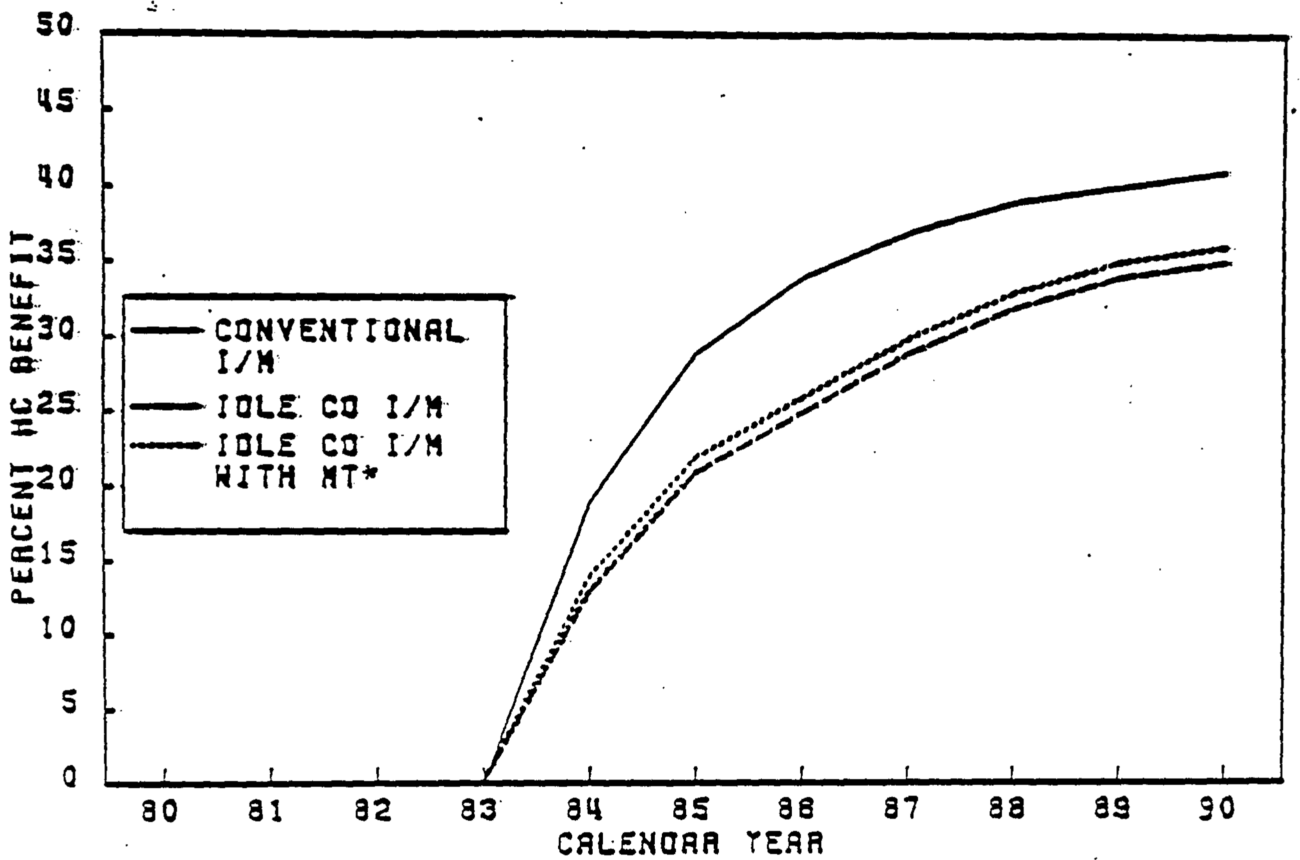
Effect of Increasing Idle CO I/M Stringency
on HC Benefits for Pre-1981 Vehicles



*Program Failure Rate in the initial program year.

Figure 8

Effect of Better Repairs*
on the HC Benefits
for Pre-1981 Vehicles



*Better Repairs are acquired either by tight reinspection idle CO cutpoints or through mechanic training programs that reach nearly all repaired vehicles.

will still have idle mixtures adjusted richer than they would have been if all carburetors were adjusted to manufacturer specifications. In New Jersey's operating program the idle CO reinspection cutpoint for 1975-80 vehicles is 3.0%. After repair the average idle CO measurement of failed vehicles is reduced to 0.9%. In the Portland program, most 1975-80 vehicles must pass a 1.0% idle CO reinspection cutpoint and the average idle CO measurement after repair is 0.2%. The average idle CO measurement of vehicles failing the idle CO cutpoints in the Houston program which adjusted all vehicles using manufacturer specifications had an average idle CO after adjustment of 0.15%. This data indicates that there is some room for improvement in the manner in which mechanics perform carburetor adjustments in I/M programs. Better carburetor adjustments should result in greater HC (and CO) emission reductions from the carburetor adjustments.

For 1981 and later vehicles, however, the logic that improved repair will provide larger benefits does not apply in the same way. This can best be understood by recalling the types of failures expected for 1981 and later vehicles. These failures are truly "system" failures, where the failure or disconnection of one or more of the components which make up the system causes the entire system to malfunction. Proper operation of the system can only be restored once the problem is diagnosed and the responsible components either replaced or reconnected. For 1981 and later vehicles, if a vehicle has experienced a fuel control system failure and fails the I/M test, its emission will be high enough so that it will not be able to pass the I/M test until the problem has been diagnosed and fixed. The benefits accompanying this repair will be total. It will not be possible to increase the benefits by adjusting closer to manufacturer specifications since no adjustments are involved. Thus, it will not be possible to extract more HC benefit from 1981 and later vehicles by striving to improve repairs. Repairs on these vehicles are of an all-or-nothing nature. Improved repairs on 1981 and later vehicles will have advantages in terms of lower repair costs (due to less wasted effort during repair) and less owner inconvenience (due to fewer return trips to the repair facility).

On pre-1981 vehicles, it will be possible to get mechanics to perform carburetor adjustments closer to manufacturer specifications in three ways:

- Mechanic training
- Lower idle CO reinspection cutpoints, and
- Statistical review of idle CO reinspection results.

These approaches are described in Section 4.4. One or all of these approaches can be applied to any I/M program to improve the carburetor adjustments performed in the program. However, it is expected that none of these approaches can do better than the results now being achieved in the Portland program where most 1975-80 vehicles must pass a 1.0% idle CO inspection and reinspection cutpoint. The average idle CO measurement after repair of 1975-77 vehicles in Portland which fail for idle CO (excluding idle-HC only failures) is 0.3%

Better repairs for pre-1981 vehicles deserve special attention primarily as a cost-saving measure, although they are also an HC and CO enhancement. Better repairs therefore deserve attention from any area considering an idle CO I/M program, not just those that might need it as an HC or CO enhancement. Better repairs for pre-1981 vehicles will produce fuel economy savings on these vehicles which will offset a large part of the cost of the I/M program.

EPA studies have shown that fuel savings of 4% are achieved by carburetor adjustments to pre-1981 vehicles which have failed an I/M test, even if the adjustments are not performed precisely to specification. It is necessary that adjustments be performed closer to specification than they would be in a basic idle CO or conventional I/M program, and that other types of repairs which can degrade fuel economy be avoided. Because carburetor adjustments will usually be the only necessary repair for pre-1981 vehicles in an idle CO I/M program, the types of repairs which can degrade fuel economy are naturally avoided in this type of program. Section 4.4 describes a number of approaches that I/M administrators can take to improve the quality of carburetor adjustments, two of which are mechanic training and a tight idle CO reinspection cutpoint. The fuel savings which will result are well worth the effort, since an additional 4% savings for each pre-1981 vehicle which is failed and repaired translates into a total annual savings of about $36. This offsets a large part of the program costs. Also, a small improvement in the HC and CO emission reductions accompanies the fuel savings. Section 7.3 discusses the HC and CO benefits. The overall effect is a major further improvement in the cost-effectiveness of the idle CO I/M program.

The quality of adjustment observed in the Portland study is expected to be achieved in a conventional I/M program with mechanic training. EPA's emission model for conventional I/M programs with mechanic training reflects this judgment and can therefore be modified in the same way as the basic model to predict the maximum effect of better repairs in an idle CO I/M program. This process is described in Section 4.3.4.

Figure 8 presents the maximum effect of better repairs performed in an idle CO I/M program for pre-1981 vehicles. Figure 8 applies only to pre-1981 vehicles. Table 27 presents the possible overall net effect in 1987 of better repairs on pre-1981 vehicles.

Table 27

Effect of Better Repairs for Pre-1981 Vehicles in an Idle CO I/M Program

Stringency for Pre-1981 Vehicles (Percent)	Percent Benefit on December 31, 1987			
	No Mechanic Training		With Mechanic Training	
	HC	CO	HC	CO
13	24	33	25	36
20	27	36	28	40
30	30	39	32	42
40	31	40	33	42

It can be assumed that the program costs associated with better repairs will be minimal since any additional time required to perform a carburetor adjustment more precisely would be insignificant compared to the basic charge for setup and adjustment. When fuel savings are considered, better repairs become a method to reduce overall program costs, since fuel savings from repairs can be used to offset other program costs. These savings have been calculated using figures from "Update on the Fuel Economy Benefits of Inspection and Maintenance Programs" [5] and presented in Table 4 in Section 1.2. The additional tons of HC and CO removed through better repairs have been calculated using the idle CO emission benefit model. These reductions are also presented in Table 4. Exempting pre-1975 vehicles will reduce the benefits of this option. Table 9 in Section 1.2 presents the costs and benefits of better repairs without pre-1975 vehicles.

7.4 Re-establishment of a Loose Idle HC Cutpoint

Much of the loss in HC benefits of dropping the idle HC requirement from a conventional I/M program was due to passing vehicles in an idle CO I/M program which would have failed only for idle HC in a conventional program. These vehicles provide a significant portion of the HC benefit in a conventional I/M program. The effects are discussed in Section 4.3.2.

While re-establishing an idle HC cutpoint may at first seem to defeat the basic idea behind an idle CO I/M program, it is at least worth considering whether a reasonably loose idle HC cutpoint might identify the very worst HC emitters, ones for which repairs to reduce idle HC would be very cost-effective, without losing much of the attractive aspects of the idle CO program.

In the Portland study, the vehicles failing only a hypothetical 500 ppm idle HC cutpoint produced 77.5% of the total HC benefit from all vehicles failing only for idle HC in the Portland study. The vehicles failing the 1000 ppm cutpoint provided 61.3% of the total HC benefit from these vehicles. The two vehicles failing only the 1000 ppm idle HC cutpoint provided this large a percentage of the total HC benefit from the idle HC-only failures because one of them was a vehicle with FTP HC emissions of 26.30 grams per mile. This is more than 17 times the design standard. Although such vehicles are rare, they are present in any fleet and produce very large HC emission reductions when repaired. Because there are few such vehicles, their repair has negligible impact on the overall failure rate and repair cost. Also, because very simple problems, such as one disconnected spark plug wire, can cause very high HC emissions, repairs can often be quite inexpensive.

In an idle CO I/M program with a loose idle HC cutpoint some additional benefit might be obtained from vehicles which fail both the idle CO cutpoint and the loose idle HC cutpoint if after the carburetor adjustment the vehicle's idle HC emission still exceeds the idle HC reinspection cutpoint.

The level of HC benefit observed in the Portland study for loose idle HC cutpoints may not be obtained in an idle CO I/M program, because in many cases all of the repairs necessary to allow the vehicles to pass the stringent

Portland idle HC cutpoints at reinspection will not be needed in order to pass looser idle HC cutpoints. One possible way to assure that adequate repairs are performed is to use a loose idle HC inspection cutpoint (1000 ppm) to identify vehicles most in need of repairs related to high HC emissions, and then apply a more stringent idle HC cutpoint (200-300 ppm) in the reinspection. This approach would be very similar to the one described in Section 4.4 for separate idle CO inspection and reinspection cutpoints.

Using a special modification of its I/M simulation model, EPA has estimated that adding a 1000 ppm idle HC cutpoint to an idle CO I/M program may increase the fleetwide HC benefit of the idle CO program as of December 31, 1987 by as many as two percentage points. For example, Table 25 showed that a 20% stringent idle CO program will achieve a composite HC reduction of 27% on December 31, 1987. If an HC cutpoint of 1000 ppm were added, this reduction would be improved to 29%. This is accomplished with a negligible increase in the stringency of the program, about two to four percentage points.

A valid concern related to a loose idle HC cutpoint is the reintroduction of uncertainty in the repair process. In the idle CO I/M program vehicle owners can be assured that virtually all vehicles can be made to pass with a carburetor idle mixture adjustment, possibly with an idle speed adjustment also. With the addition of even a very loose idle HC cutpoint, some vehicles owners will have to rely on the repair industry to properly diagnose and repair their vehicle without knowing for certain if the repairs were indeed necessary to reduce their idle HC emissions. The number of vehicle owners with this problem will be small, however, since the failure rate for HC will be quite low. In a centralized idle CO I/M program, owners of those vehicles which fail a loose idle HC cutpoint could be given a choice of either passing the retest of idle HC emissions or presenting a signed statement that a state certified mechanic has performed specific ignition system diagnosis and has performed repairs as necessary. This would be similar to the waivers provided in some I/M programs after a specified "low-emission" tune-up by certified mechanics. The suggestions outlined in Section 3.0 will also help reduce the incidence of unnecessary repairs.

A loose idle HC cutpoint may have fuel economy advantages since it would often identify vehicles with severe ignition system misfire. Severe (11%) induced misfire on 10 vehicles in an EPA test program decreased their overall fuel economy 7.7%. The two vehicles in the Portland study identified as idle HC-only failures by a 1000 ppm idle HC cutpoint obtained an overall fuel economy benefit of 9.9% from repair. These instances indicate that there may be a significant fuel economy benefit in the repair of many of the vehicles which exhibit extremely high idle HC emissions. The reduction in fuel consumption for such vehicles can offset the costs of the additional repairs that will be necessary as a result of the addition of a loose idle HC cutpoint. An 8% fuel economy benefit, for instance, provides about $72 per year in fuel savings. Repair costs of the idle HC only failures in Portland range from zero to $207, averaging $41. Not all vehicles requiring repairs as a result of failing a high idle HC cutpoint are expected to receive such large fuel economy benefits, however. Only about half of the vehicles failing a 1000 ppm HC cutpoint are expected to receive large fuel economy benefits from repairs.

The five year tons of HC emissions reduced have been estimated to be 2,590 tons in a vehicle base of 1 million cars. If pre-1975 vehicles are exempt from the program the HC benefit will be reduced to 1.9% on December 31, 1987 reducing HC emissions by 2,420 tons.

Loose idle HC cutpoints could also be instituted on a voluntary basis. An idle CO I/M program could easily measure and report to the vehicle owner the idle HC levels of each inspected vehicle. Vehicle owners whose vehicle's idle HC levels were extremely high could be advised that their vehicle's HC emissions were above normal and their vehicle probably was in need of maintenance in addition to a carburetor adjustment. These repairs will usually involve ignition problems. It could be expected that some vehicle owners would voluntarily seek emission related repairs and reduce their HC emissions.

Generally, the advisory HC limits could be considered as a service offered to vehicle owners warning them when their vehicles are in need of repairs. Emission reductions from this method would be sporadic and very hard to quantify since all repairs would be voluntary and no idle HC retest would be required. However, some vehicle owners would have repairs performed and some HC benefits would be gained without significantly increasing the overall program costs.

7.5 Tampering Checks

7.5.1 Background

Another means of obtaining additional HC reductions in an idle CO I/M program is to perform a visual check of various emission control systems in conjunction with the vehicle's idle CO test. The purpose is to identify those vehicles which have had one or more of their emission control systems disabled or removed. Requiring that these vehicles have their emission control systems restored to proper operation can result in additional HC (and CO) emission reductions.

Of equal importance, performing a tampering check as part of the I/M process can discourage new instances of tampering. This deterrence value of a tampering check can best be understood in qualitative, "common-sense" terms. That is, it makes sense that vehicle owners will be less likely to remove or disable any of the emission control systems on their vehicles if they know that the presence of some or all of those systems will be checked in the I/M program.

There are, however, several drawbacks to performing tampering checks as part of the I/M test. First, the time required to properly perform a tampering check slows down the inspection process and increases the manpower requirement of the I/M station. This, of course, adds to the cost of the I/M program.

Second, while most manufacturers equip at least some of their vehicles with the emission control systems which are suggested below for inclusion in the tampering check, they do not design those systems uniformly. There is significant diversity in what the various systems look like and where they are placed on the vehicle. This will require that the inspectors performing the tampering check receive special training. In addition, there will be a need to determine which vehicles were originally equipped with the system in order to accurately determine whether it has been removed. For example, many vehicles from the 1975-1979 model years were not equipped with air pumps. In order for an air pump tampering check to be made on these vehicles, it is necessary to separate the vehicles originally equipped with air pumps from those not so equipped. It should be noted that these considerations and the difficulties they present apply especially to decentralized programs.

Third, most of the emission control systems recommended for inclusion in the tampering check have been observed in the field to have relatively low rates of tampering (between 1-6%). This means that the number of cars failed in an I/M program on the basis of the tampering check will likely be small. This magnifies any added inspection cost per detected disablement.

Fourth, the replacement cost for some of the components on some systems can be high (e.g. catalyst replacement). This is, of course, particularly undesirable in an I/M program designed with the goal of minimizing costs.

In light of these considerations, tampering checks should be limited to an inspection of those systems with a significant HC effect (based on both the known incidence of tampering with the system and the per-vehicle effect of such tampering on HC emissions). In addition, systems should be included only if they are easy to inspect, relatively cheap to repair and/or have a valuable deterrent effect. The following sections will discuss the systems which best meet these criteria: air pumps, evaporative emission control systems and catalysts.

It is worth noting a fifth drawback of a tampering check. This is the confusion it can cause among vehicle owners. An owner may not understand why it matters if his older car fails the tampering check if the idle test shows that the car has low emissions anyway. It can be difficult to explain the different purposes of the tampering check and the idle test to a layperson in the noise and hurry of the I/M station. Therefore, EPA suggests that passing the tampering check be a prerequisite to receiving a valid idle test. In this way, the owner of a tampered vehicle will not receive the idle CO score from his or her vehicle if it is below the cutpoint as this would only confuse him or her. There is no harm in giving the owner a failing idle CO score, however, and this may save him or her some inconvenience if the repair of the tampering and the carburetor adjustment are performed in the trip to a repair facility.

One way to take advantage of the deterrence value of tampering inspections without the drawbacks associated with inspecting all vehicles is to develop a method to randomly select a sample of vehicles to be inspected for tampering. Only the vehicles sampled would be checked for tampering and all other vehicles would only be given the emissions test. This would greatly reduce the resources needed to conduct tampering inspections. These few vehicles could also be more thoroughly examined than in a program which mandated that all vehicles be inspected for tampering and therefore would be somewhat more likely to discover any disablements. The expected result would be less tampering overall than without any tampering check since vehicle owners may be less likely to allow tampering with their vehicle's emission controls if there is a chance, however small, that they will be detected. Likely there would be more tampering than with an inspection of every vehicle, since at least some owners may prefer to tamper and accept the low risk of being selected for the inspection. If all owners did this, there would be no deterent effect from the checks.

This random selection tampering inspection has drawbacks of its own, however. (1) The program as a whole may be criticized as being "arbitrary" and, since only some vehicle owners are singled out for the tampering inspection, may criticize the program as not equitable. (2) If the number of tampering inspections performed is small, and if the associated penalty for detection is only the repair cost, many vehicle owners may feel it is cheaper to take their chances on being selected and discovered rather than correct any existing tampering or refraining from future tampering.

For this analysis each tampering check it is assumed that once all instances of disconnected or removed emission control components are discovered and repaired in the first year of the program (e.g., a program starting in 1983), only a few isolated instances of tampering will be discovered in following years as vehicle owners become aware that their systems are being checked. This does not reduce the HC and CO emission benefits of the check, but limits the repair costs to the cost of a one-time fix of all tampered systems at the start of the program. Any increase in the inspection costs are considered negligible.

7.5.2 Air Pump Checks

The purpose of the air pump is to supply air to the engine's exhaust in order to promote the oxidation of HC and CO to harmless by-products. The air pump performs this function on both catalyst and non-catalyst vehicles. The air pump is driven by means of a belt which transmits power from the crankshaft as it rotates. This method of powering the air pump is the same as that used to run the alternator and air conditioner compressor. The air pump can therefore be found near or on the same plane as the alternator or air conditioning compressor. Its plumbing distinguishes it.

The percentage of vehicles equipped with air pumps varies by model year. The percentages presented in Table 28 are the ones used in this analysis.

Table 28

Percent of Various Model Year Groupings Equipped
With Air Pumps

Model Year Grouping	Percent Equipped With Air Pumps
1968-1975	100%
1975-1979	40%
1980	100%
1981+	95%

There are three main ways the air pump can be tampered with. First, the belt which drives the pump can be removed. Second, the entire unit -- pump, belt, hoses, and even mounting brackets -- can be removed. Third, the output hose from the air pump can be disconnected and/or the air routing valve can be tampered with. This last form of tampering results in the air pump spinning freely and no air being supplied to the exhaust. All three of these forms of tampering can be identified by trained inspectors in an I/M lane.

The repairs necessary for these various forms of tampering are self-evident. In most cases, repair can be accomplished by simply installing a new belt or reconnecting a hose. An average repair cost of $20 has been assumed for this analysis.

The rate of air pump tampering used in this analysis is that 6.6% of the air pump-equipped fleet has a tampered air pump at any one time. This rate comes from an in-use surveillance program conducted by EPA's Mobile Source Enforcement Division in 1978 [22].*

While various surveillance programs have reported various rates of air pump tampering, the rate from this program was chosen since the surveillance techniques employed in the program should have resulted in the most random vehicle sample from among the various programs. In addition, the time spent in inspecting each vehicle for tampering was roughly what might be spent in an operating I/M program.

The HC and CO emission increases which accompany air pump tampering for 1975-1979 model year vehicles were quantified by examining data from 11 vehicles (1975-1979 model years) tested with and without their air pumps operational. Nine of these vehicles came from the 300 car Restorative Maintenance program [12]. The other two came from a test program which examined regulated and unregulated exhaust emissions from catalyst vehicles[23]. These data indicate that the average HC emission level increases 1.2 g/mi upon air pump tampering and the average CO emission level increases 28.0 g/mi. (One source of uncertainty in the analysis has to do with the fact that the 11 vehicles used to determine the emission effects of air pump tampering were all in tuned-up condition. The emission increases due to air pump tampering on vehicles in less perfect condition may vary.)

There is some uncertainty as to the HC and CO effects of air pump tampering for pre-1975 model year vehicles. However, these vehicles contribute only a very small share of the fleet's emissions at the date of interest to this analysis (December 31, 1987). They were assumed to show the same percentage effect due to air pump tampering as 1975-1979 vehicles. This assumption is reasonable and due to the small contribution made by these vehicles, does not significantly affect the analysis.

* The rate of 6.6% is an overall rate for the air pump system and does not appear in Reference 22, which gives rates only for individual components of the air pump system. The rate of 6.6% was determined from the original data base used to prepare Reference 22.

For 1981 and later model year vehicles, the effects of air pump tampering were quantified by examining the results of EPA laboratory programs which took 4 vehicles representative of 1981 and later technology and tested them with and without their air pumps operational. In addition, one representative 1980 Ford vehicle tested in an EPA surveillance program in California was found to have its air pump disabled due to having one of the vacuum control hoses kinked closed. This vehicle was tested as-received (air pump disabled) as well as after having the air pump repaired (vacuum hose unkinked). Data from these five vehicles indicate that the average HC emission level increases 0.5 g/mi upon air pump tampering for 1981 and later vehicles and the average CO emission level increases 15.0 g/mi.

No comparable test data are available for 1980 model year vehicles. 1980 model year vehicles were assumed to have the same emission effects for air pump tampering as 1981 and later vehicles. This is because the 1980 emission standards (0.41 g/mi HC; 7.0 g/mi CO) are closer to the 1981 standards (0.41 g/mi HC; 3.4 g/mi CO) than to the 1975-1979 standards (1.5 g/mi HC; 15 g/mi CO).

Given the assumed rate of air pump tampering (6.6%) and given the emission increases which accompany air pump tampering for the various model year groupings, fleetwide emission benefits and costs of identifying and repairing tampered vehicles can be calculated. It is assumed that all vehicles with tampered air pumps are identified and repaired.

The calculations involved in determining a fleetwide benefit will not be presented. Basically the procedure involves calculating the emissions projected to be contributed by the various model year groupings (i.e. pre-75, 1975-1979, 1980, 1981 and later) on December 31, 1987. The emission reductions which would result from the repair of vehicles with tampered air pumps is then calculated (also within each model year grouping at a December 31, 1987 date). The final step involves calculating a fleetwide percent benefit by taking the emission reductions due to repairing vehicles with tampered air pumps and dividing it by the total (non-I/M) emissions of the fleet. Table 29 presents these figures of percent benefit for both HC and CO. For an example, Table 25 showed that an idle CO I/M program with a 20% stringency will achieve a composite HC reduction of 27% on December 31, 1987. If an air pump tampering check were added to the program the total HC reduction would be about 29%. The total additional five year program cost has been estimated to be $0.92 million for a fleet of one million vehicles. Exempting pre-1975 vehicles will reduce the benefits. These benefits are presented in Table 10 in Section 1.2.

Table 29

Composite Percent Benefit due to Air Pump Tampering Check

Pollutant	December 31, 1987 Percent Benefit	Additional Five Year Emission Reduction * (Thousands of Tons Removed)
HC	1.5%	2.56
CO	4.3%	68.0

* A vehicle base of one million vehicles is assumed.

7.5.3 Evaporative Emission Control System Check

The evaporative control system is intended to capture the gasoline fumes which are naturally given off wherever gasoline is stored and used. These fumes are made up of pure hydrocarbon (HC) emissions. Although not emitted from the exhaust they represent a significant portion of a vehicle's total HC emissions. The evaporative control system captures the fumes given off by both gasoline in the fuel tank and the gasoline present in the carburetor (early systems dealt only with evaporative losses from the fuel tank). These fumes are stored in a charcoal cannister mounted in the engine compartment and then routed to the engine for burning at appropriate times.

Especially for early model year vehicles, on which evaporative controls were first introduced, tampering with the system has been observed to be fairly common. The 1978 Tampering Study[22] described earlier found 8.2% of 1973-1974 model year vehicles had tampered evaporative control systems and 1.3% of 1975-1977 model year vehicles had been tampered. This tampering can take the form of disconnected or cut hoses, missing cannisters or removal of the entire system. Once again, these forms of tampering are identifiable by trained inspectors. An average repair cost of $10 has been assumed.

The calculation of the emission benefit due to the identification and repair of vehicles with tampered evaporative control systems was performed in the same way as for air pump tampering. The fleet was broken down into appropriate model year groupings, an HC emission increase due to evaporative tampering and a tampering rate was assigned to each grouping and the fleetwide benefit on January 1, 1988 was calculated. Since evaporative control technology has evolved along a different timescale than air pump or catalyst technology, the model year groupings used for the evaporative analysis differ: pre-1971, 1971, 1972-1974, 1975-1977, 1978-1980, 1981 and later.

The emission increases assigned to each grouping to represent a tampered system come from an EPA emissions model — MOBILE2 — which models the emission contributions (both evaporative and exhaust) from all model years and classes of mobile vehicles (e.g. passenger cars, trucks, motorcycles). The assumption used to determine the increase in emissions due to tampering was that any tampering would return the vehicle to uncontrolled levels (pre-1971) of evaporative HC.

The rates of tampering used in the analysis were that 8.2% of 1971-1974 vehicles and 1.3% of 1975 and later vehicles are tampered. These rates reflect the data from the 1978 Tampering Study[22]. A separate study conducted in California confirmed the large difference in tampering rates between pre-1975 and 1975 and later vehicles, although the exact rates were not duplicated.

Given the above model year groupings, tampering rates and emission increases due to tampering, a figure for cost and percent benefit on December 31, 1987 can be calculated. Once again, this calculation assumes that all instances of tampering are identified and repaired. Table 30 presents the HC benefit which results. (Obviously, since evaporative systems are only concerned with HC emissions there is no CO benefit.) Five year program costs are expected to increase $0.25 million.* Exempting pre-1975 vehicles from the program will reduce these benefits to 1.2%, reducing emissions of HC by 1,430 tons.

Table 30

Composite HC Benefit Due to Evaporative Tampering Check

Pollutant	December 31, 1987 Percent Benefit	Additional Five Year Emission Reduction * (Thousands of Tons Removed)
HC	1.3%	1.94

* A vehicle base of one million vehicles has been made.

It is important to note that this benefit refers to the comparable percent reduction of the fleet's exhaust HC emissions represented by the reduction in evaporative HC emissions. As described earlier, the total HC emissions from a vehicle come from both exhaust HC and evaporative HC. The percent benefit presented in Table 30 is the gram-per-mile reduction in evaporative HC divided by the fleet's exhaust HC (in gram per mile) in the absence of I/M. While most discussions of I/M emission reductions deal only with exhaust HC emissions, it is equally valid to examine reductions in evaporative HC. This is because the ultimate goal of the I/M program is to reduce total emissions (exhaust and evaporative). Since I/M policy statements have traditionally been expressed in terms of percent reduction in exhaust HC, the HC reductions due to an evaporative tampering check should be expressed in terms of the comparable reduction in exhaust HC as has been done in Table 29. The HC benefit in Table 30 can therefore be added to the HC emission reductions for idle CO I/M programs in Table 25. For example, the 27% HC benefit for a 20% stringency idle CO I/M program can be increased to about 28% with the addition of an evaporative emission control check.

7.5.4 Catalyst Removal Check

As is well known, automotive catalysts lower HC and CO emissions in the exhaust by catalytically promoting the oxidation of HC and CO to harmless by-products. (Catalysts on most 1981 and later vehicles also help reduce NOx emissions.) Catalysts are normally mounted on the underside of the vehicle, along the exhaust pipe and before the muffler. Some vehicles have catalysts mounted inside the engine compartment. If a catalyst is not observed by checking underneath a 1975 or later model year vehicle, it will be necessary to open the engine compartment hood and either locate the catalyst there or confirm from the emissions label put on every vehicle that the vehicle was not equipped with a catalyst at the factory.

Tampering with the catalyst takes the form of simple removal of the catalyst and replacement with a straight exhaust pipe. Since this is very easy to detect, it was assumed that all instances of catalyst removal are identified through an I/M tampering check.

Repair of this form of tampering obviously requires installation of a new catalyst (or reinstallation of the old one if it was saved). This could be a relatively expensive repair. It was decided, however, to include it in this report since many states might be interested in checking for catalyst removal since it is such a flagrant form of tampering. In addition, a catalyst check has a valuable deterrent effect which costs nothing. New catalysts now cost between $172 and $320, most of which is dealer and distributor markup. A market for lower-priced used catalysts may appear, if new catalysts are not a requirement of the program. In any event, lower-priced replacement catalysts are possible if any demand is created by a catalyst check. An average cost of $200 per catalyst has been assumed in this analysis.

The rate of catalyst removal used in this analysis was the rate observed in the 1978 Tampering survey: 1.4%[22]. This rate was applied to the entire 1975 and later fleet.

The HC and CO emission increases which accompany catalyst removal were determined by examining the engine-out (before the catalyst) emissions of a number of vehicles involved in several misfueling test programs. Before the vehicles were misfueled, they received both baseline tests (all components functional) and tests with the catalyst removed. By comparing the results of the two tests the percent increase in emissions which accompanies catalyst removal can be calculated. Four vehicles from the 1975-1979 model year grouping and six vehicles representative of the 1981 and later model year grouping were tested. 1980 model year vehicles were assumed to have the same percent increase as 1975-1979 vehicles. This was done because the catalysts used on 1980 vehicles are more like those used on 1975-79 vehicles than those used on 1981 and later vehicles. The figures of percent increase were combined with the projected zero-mile emission levels of the various model year groupings in order to calculate the following figures of gram-per-mile increase: 3.06 g/mi HC and 24.16 g/mi CO for 1975-1979; 0.67 g/mi HC and 7.36 g/mi CO for 1980; 0.93 g/mi HC and 7.11 g/mi CO for 1981 and later.

As was done for the air pump and evaporative control analyses, the rate of catalyst removal, the emission increases due to catalyst removal, and the relative contributions of the various model year groupings were combined to calculate figures of percent benefit at January 1, 1988. Table 31 presents those figures. As with the benefits presented in Tables 29 and 30, the HC benefit in Table 31 would be added to the HC benefit in Table 25, for example, to find the overall benefit of an idle CO I/M program that includes a catalyst removal check. Total five year program costs will be increased by about $2 million.*

Table 31

Composite Percent Benefit Due to Catalyst Removal Check

Pollutant	Benefit on December 31, 1987	Additional Five Year Emission Reduction * (Thousands of Tons Removed)
HC	0.9%	1.35
CO	0.5%	10.7

One alternative way to implement a catalyst check which helps avoid the repair cost problem mentioned earlier would be to restrict the check to those vehicles sold after the I/M program begins. That is, vehicle owners who had removed the catalyst on their earlier model year vehicles (before I/M start-up) would not be required to install a new catalyst, while owners of newer model year vehicles would. This approach, if coupled with an effective public awareness program, should provide an effective natural deterrent. Many vehicle owners would be dissuaded from removing their catalyst under such an approach and those that removed their catalyst anyway and were subsequently identified in an I/M program would at least have been forewarned. There is not expected to be, therefore, any significant additional program cost associated with this program.

* A vehicle base of one million vehicles is used.

This approach does, of course, reduce the emission benefits associated with a catalyst check. Table 32 presents the emission benefits which result if the catalyst check is restricted to 1983-1988 model year vehicles (assumes a January 1, 1983 I/M start-up).

Table 32

Composite Percent Benefit Due to a Catalyst Removal Check Restricted to 1983 and Later Vehicles

Pollutant	Benefit on December 31, 1987	Additional Five Year Emission Reduction * (Thousands of Tons Removed)
HC	0.3%	0.20
CO	0.2%	1.6

* A vehicle base of one million vehicles is used.

7.6 <u>Inspection and Maintenance for Light Duty Trucks</u>

Light duty trucks (LDTs) such as pickups, vans, and light delivery vehicles are susceptible to the same types of maladjustments and emission component failures as most pre-1981 passenger vehicles. The HC and CO emissions from LDTs are a significant fraction of emissions from all mobile sources in urban areas. While EPA policy does not require inspection of LDTs in I/M programs, any emission reductions from repairs of LDTs in an I/M program will contribute towards attainment of air quality standards, just as do emission reductions among passenger vehicles (LDVs). Therefore, an idle CO I/M program can include LDTs and use the HC emission reductions from those additional vehicles to improve the program's overall HC emission reduction benefits.

The most obvious advantage to this approach of enhancing an idle CO I/M program is that it will require fewer additional design and administrative complications than some of the other HC benefit enhancements in this section. In addition, the added HC benefits will generally be larger than any of the other HC enhancements since the additional HC and CO emission reductions are derived by testing more vehicles rather than by squeezing more benefits from the same vehicles.

LDTs can be broken down into two major subgroups which will be considered separately. LDTs with gross vehicle weights (GVW) below 6000 pounds will be refered to in this report as LDT1. All LDTs between 6000 pounds and 8500 pounds GVW will be LDT2. In addition, in order to discuss the effects of better tests and better repairs, the technology level of each LDT corresponding to an equivalent LDV (passenger car) technology will be determined. Table 33 presents the technology levels and the corresponding model years of LDVs, LDT1s, and LDT2s which correspond to those levels.

Table 33

LDT Technology Level Equivalents

Technology Level	Model Years Included LDV	LDT1	LDT2
Pre-Catalyst	Pre-1975	Pre-1975	Pre-1979
Oxidation Catalyst	1975-1980	1975-1984	1979-1984
Three-Way Catalyst	1981 and Later	1985 and Later	1985 and Later

LDV: Light duty gasoline vehicles
LDT1: Light duty trucks below 6000 pounds GVW
LDT2: Light duty trucks between 6000 and 8500 pounds GVW

The additional HC and CO emission benefits in tons of pollutants that are possible by including LDTs in an idle CO I/M program depend on the emission reductions per LDT, the number of LDTs in the I/M area, and the number of miles they drive. Table 34 presents the HC and CO emission benefits in an idle CO program among the two groups of LDTs with and without other enhancements.

Table 34

HC Reductions Among Light Duty Trucks
in an Idle CO I/M Program

LDT1 (0-6000 pounds GVW):

Stringency for Pre-1985 Vehicles (Failure Rate)	Reduction on December 31, 1987: Idle CO Test Alone		With Better Test *		With Better Repairs **	
	HC	CO	HC	CO	HC	CO
13	29.6	35.4	30.0	36.2	31.2	40.1
20	32.8	40.1	33.2	41.0	35.3	45.7
30	36.8	44.5	37.2	45.4	40.6	49.1
40	38.1	45.7	38.5	46.6	42.3	49.5

LDT2 (6000-8500 pounds GVW):

Stringency for Pre-1985 Vehicles (Failure Rate)	Reduction on December 31, 1987: Idle CO Test Alone		With Better Test *		With Better Repairs **	
	HC	CO	HC	CO	HC	CO
13	22.1	32.1	23.2	34.6	23.3	34.9
20	24.2	34.9	25.3	37.4	25.8	38.0
30	27.3	37.8	28.4	40.3	29.7	40.3
40	28.2	38.5	29.3	41.0	30.8	40.8

* Better Test: Two-Speed Idle Test or Loaded Test for 1985 and later LDTs.
** Better Repairs: Full mechanic training or more stringent reinspection cutpoints for Pre-Catalyst and Oxidation Catalyst LDTs.

The emission reductions from LDTs in Table 34 can be converted into passenger-vehicle-equivalent HC and CO emission reductions and applied to overall passenger vehicle emission reduction goals. This is done by first calculating the gram per mile reduction in the emission factors for HC and CO from I/M on December 31, 1987. Next these reductions are weighted by the vehicle miles traveled of LDTs versus passenger cars in that year. Finally these weighted reductions are divided by the appropriate passenger vehicle emission factors for the case without I/M giving the additional HC and CO benefits from I/M for LDTs. Table 35 presents the results of such calculations using standard national LDT densities and mileage accumulations. Using the Two-Speed Idle or Loaded Test for 1985 and later LDTs provides only an additional 0.1% benefit for both HC and CO emissions.

Table 35

Passenger-Vehicle-Equivalent
Emission Benefits from Light-Duty Trucks

Stringency for Pre-1985 Vehicles (Percent)	Additional Percent Benefit on December 31, 1987 for Passenger Vehicle Idle CO I/M			
	Idle CO Test		With Better Repairs	
	HC	CO	HC	CO
13	4.2	4.4	4.3	4.9
20	4.6	4.9	4.9	5.6
30	5.1	5.4	5.6	5.9
40	5.3	5.6	5.8	6.0

For example, a basic idle CO I/M program from Table 25 in Section 6.0 with a 13% stringency can increase the program HC benefits by 4.2% and the CO benefits by 4.4% for passenger vehicles by including light-duty trucks in the I/M program. This would increase the benefits of a 13% stringency idle CO program from 24.2% to 37.5% for CO. The five year program costs and tons removed for this option have been estimated in Section 1.2 and presented in Table 7. Exempting pre-1975 LDTs from the program will reduce both the HC and CO benefits. Table 12 in Section 1.2 presents the benefits and costs of LDT I/M exempting pre-1975 vehicles.

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