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Technical Report

Update on the Fuel Economy Benefits of Inspection and Maintenance Programs

by

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Technical Reports do not necessarily represent final EPA decisions or positions. They are intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position or regulatory action.

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1.0 INTRODUCTION AND SUMMARY

1.1 Purpose

The purpose of this report is to present an updated assessment of the fuel economy benefits of Inspection and Maintenance (I/M) programs, in terms of individual vehicle and fleetwide savings, using the latest EPA test data. An update of these benefits was needed to incorporate the latest available data. In addition, previous analyses [1, 2]* focused mainly on fuel economy improvements for vehicles which fail an I/M test and are repaired, and did not present a fleetwide or national picture of the fuel savings. This report presents the fuel economy benefits which will result from a basic I/M program (no mechanic training or other options) and the incremental benefits due to adding options to the basic program.

The basic or "typical" I/M program analyzed is an annual one with idle emissions inspections of all gasoline powered passenger cars of model years 1968 and newer. The three options which are analyzed are a more effective test -- either the Two-Speed Idle Test or the Loaded Test -- for 1981 and later vehicles, a mechanic training program, and a tire pressure check conducted as part of the I/M inspection.

Fuel economy benefits are shown for the first five years of a typical I/M program assumed to start January 1, 1983 and are presented in three ways: (1) average dollar savings and percent savings to owners of repaired cars during the five years, (2) average dollar savings and percent savings in fuel bills for all I/M car owners, and (3) national fuel savings.

1.2 General Method

For each of the five calendar years covered, a determination of the fuel economy benefit for each model year vehicle was made. It was necessary to account for the fact that there are different numbers of cars in service for each model year, they travel different mileages each year (as cars get older they travel less and less, on the average), and they have different average fuel economies (mpg). Also calculated was the effect the fuel economy improvement among the failed vehicles had on the entire I/M fleet and on national fuel consumption.

1.3 Summary of Key Results

Tables 1 and 2 summarize the annual fuel economy benefits of I/M. Table 1 presents the fuel savings in terms of dollar and percent savings for the basic I/M program and for an optimum I/M program that includes all of the options. Benefits for the basic program are shown separately for repaired vehicles and for all inspected vehicles. The average benefit per inspected vehicle in the basic program is $3, which will offset a significant portion of a typical inspection fee. The average benefit per inspected vehicle is $23 in the optimum program. This would easily pay for the entire cost of an I/M program. Table 2 presents the national fuel savings from the basic I/M program and the optimum I/M program.

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

Table 1

Summary of Annual I/M Fuel Economy Benefits 1/

Program Type	Benefits per Repaired Vehicle 2/		Benefits per Inspected Vehicle 3/	
	Dollars Saved	Fuel Saved	Dollars Saved	Fuel Saved
Basic Program	$7	0.8%	$3	0.3%
Optimum Program	N/A 4/	N/A 4/	$23	2.5%

1/ In 1980 dollars.
2/ In 1985.
3/ Average annual benefits for the five year period 1983 through 1987.
4/ The optimum program includes tire inflation (and the associated fuel savings) for some vehicles which pass the I/M test and do not get repaired. Benefits therefore cannot be properly expressed on the basis of repaired vehicles.

Table 2

Nationwide Annual Fuel Savings from I/M 1/

Program Type	Gallons Saved (Millions)
Basic Program	83.6
Optimum Program	701.4

1/ Average annual savings over the five year period 1983 through 1987.

2.0 BASIC I/M FUEL ECONOMY BENEFITS

2.1 Description of the Basic I/M Program

The basic I/M program was selected to be typical of new I/M programs which will begin operation in 1982 or 1983. The basic program has the following features:

Test Type - The test consists of a simple idle tailpipe emissions test for hydrocarbons (HC) and carbon monoxide (CO). A vehicle must have lower emissions than the limits for both pollutants in order to pass the test.

Inspection Standards and Failure Rate - For pre-1981 model year vehicles, the analysis assumes that the I/M program officials select inspection cutpoints which result in a 20% failure rate. For 1981 and later vehicles, the analysis assumes that the program officials select cutpoints of 1.2% CO and 220 ppm HC. With the idle test, these cutpoints are expected to fail between 5 and 10 percent of the 1981 and later vehicles. Where a specific failure rate for 1981 and later vehicles was needed in this analysis, 7% was used. The results of the analysis are also applicable to I/M programs with looser cutpoints for 1981 and later vehicles since the failure rate for these vehicles does not vary much with cutpoints in the range of 1.2-3.0% CO and 220-300 ppm HC.

Starting Date - The analysis assumes that I/M starts January 1, 1983. Fuel economy benefits are calculated for the first five years of the program, through December 31, 1987.

Mechanic Training - No mechanic training occurs in the basic program.

Annual Inspections - All vehicles are inspected annually. New vehicles are inspected at the first anniversary of their entry into service.

Vehicle Coverage - The basic program assumes all 1968 and newer gasoline powered passenger cars have mandatory inspections; no trucks, motorcycles, or diesel powered passenger cars are inspected.

Cost Waivers -- No repair cost waiver provisions are assumed.

2.2 Fuel Economy Benefits for Repaired Cars

2.2.1 Method of Fuel Economy Measurement

A combination of city and highway driving was chosen to measure fuel economy benefits. The combination is the EPA combined figure of FTP (city) and HFET (highway) driving cycles, which weights the city cycle 55% and highway cycle 45%. This is the same combination on which the new car fuel economy standards is based. It was chosen so as to reflect all driving conditions. It should be noted that the fuel economy changes measured on only the FTP would have shown larger I/M benefits, however that cycle does not reflect all driving conditions.

2.2.2 No Fuel Economy Benefit for Pre-1981 Cars Without Mechanic Training

Substantial data from the EPA Portland Study, which studied the operating I/M program in that city, show no net change in the average fuel economy of pre-1981 vehicles due to maintenance of failed vehicles as it is currently performed by the commercial repair industry[1].

2.2.3 Fifteen Percent Fuel Economy Benefit for 1981 and Later Cars Which Have Certain Failure Modes

For 1981 and later vehicles the fuel economy benefit from certain I/M repairs will be is relatively large. Most 1981 and later vehicles are expected to employ microprocessor-based engine control systems. These systems have been found in the field to be vulnerable to fuel system failures which result in high emission levels and reduced fuel economy. I/M will pinpoint vehicles with these failures and cause them to be repaired. EPA estimates that in the absence of I/M, 5% of the 1981 and later fleet will have experienced such a failure at 10,000 miles and that an additional 2% of the fleet experiences a failure in every 10,000 mile increment. For this analysis I/M was assumed to identify 50% of these failures with the idle test. (The idle test also fails some vehicles for other problems, bringing the total failure rate to 5-10%.) The only way for these vehicles to pass an I/M retest is to have their fuel system restored to proper operation. A significant fuel economy benefit, 15%, has been observed to accompany such repairs[3].

2.3 Fleet Average Fuel Consumption Benefits

2.3.1 Average Benefits for All 1981 and Later Vehicles

In order to determine the year-by-year benefits for these vehicles a special modification of an EPA computer program named MOBILE2 was used. MOBILE2 normally is used to calculate I/M emissions reduction benefits, but was modified to calculate fuel economy benefits. First, the average fuel consumption of the 1981 and later fleet without I/M was calculated. Second, the average fuel consumption with I/M was calculated using the 50% identification rate for the vehicles with fuel system failures. Both averages accounted for deterioration in fuel economy with mileage. The two were then compared to yield a fleetwide fuel economy benefit for each year. For a more complete description of these calculations, see Reference 3.

Due to the projected growth rate of vehicles experiencing a system failure, and the fact that there will be more and more of these vehicles in service each year, the fuel economy benefit for the 1981 and later fleet increases each year. The benefits for each year of the assumed program are given below.

Table 4

Basic I/M Fuel Economy Benefit for 1981 and Later Vehicles (Idle Test)

Calendar Year	Fleet Fuel Economy Improvement
1983	.42%
1984	.54%
1985	.64%
1986	.78%
1987	.86%

2.3.2 Pre-1981 Vehicles Averaged with 1981 and Later Vehicles

Pre-1981 vehicles receive no benefit in the basic program. Their average fuel consumption is averaged with the 1981 and later vehicles in the with-and without-I/M cases to yield the fleet fuel consumption with and without I/M.

The general method is to determine the vehicle miles travelled (VMT) of each model year subject to I/M for each calendar year. Dividing each model year's VMT by the estimated fuel economy (without I/M) for that model year yields the total gallons consumed. The summation of each model year's consumption yields a fleetwide consumption without I/M. To get the fleet fuel consumption with I/M, the percent benefit can be applied to the 1981 and later vehicles, and a new summation calculated.

Details of the calculation are presented in the Appendix.

2.3.3 Gasoline Price

Estimated prices are based on a 1980 dollar level so as to show a stable reference for the fuel cost savings. The estimated price increase in gasoline over and above increases due purely to general inflation, according to the Congressional Budget Office, is 2.4% per year through the 1980's. For the five year period of this paper, the estimated price is shown in Table 5.

Table 5

Estimated Gasoline Prices in 1980 Dollars

Calendar Year	Price per gallon
1983	$1.54
1984	$1.58
1985	$1.62
1986	$1.66
1987	$1.70

2.3.4 Average Annual Savings For I/M Repaired Vehicles

Owners of vehicles which fail the I/M test want to know what fuel savings they will receive as a result of having their cars repaired. As stated in Section 2.2 there are no fuel economy benefits for pre-1981 vehicles and a 15 percent average benefit associated with repair of certain failure modes for 1981 and later vehicles which fail the I/M test. There are also other types of failure modes expected to occur on 1981 and later vehicles which may yield no fuel economy benefit with repairs. Therefore, the average benefits for 1981 and later vehicles which fail are composed of one group receiving 15% benefit and another receiving no benefit. For the purposes of this analysis the total failures are estimated to be 7% of the 1981 and later fleet.

To calculate the individual vehicle benefits, it was necessary to look at only one representative calendar year. The 1985 calendar year was chosen, because it is the middle year and therefore the most represenatative. During that year it turns out that of the 7% of 1981 and later vehicles which fail, 1.68% are estimated to be of the type which receive a 15% fuel economy benefit and 5.32% of the vehicles have other types of failures which receive no benefit. The average benefit for all the failures of 1981 and later cars is therefore 3.61%. To get an average benefit for all failed vehicles, the percent changes were weighted for the number of expected failures for pre-1981 vehicles (20% of the total number of those vehicles) and for 1981 and later vehicles (7%). The dollar and percent benefits are shown in Table 6.

Table 6

Basic I/M Fuel Savings in 1985
Repaired Vehicles Only

	Dollars Saved	Fuel Saved
Pre-1981 Vehicles	0	0
1981 and Later Vehicles	$ 32.08	3.61%
Overall	$ 6.88	0.77%

2.3.5 Average Annual Savings for Inspected Vehicles

It is important to be able to estimate the annual fuel savings to all owners of vehicles involved in I/M. A reasonable way of presenting the savings is simply the average per inspected vehicle (the sum of the savings divided by the total number of vehicles inspected). Note that the savings do not apply to vehicles that are too new to be inspected or those older than the 1968 model year. Savings for the basic program are shown below in Table 7. The annual savings shown in the table are the averages for the five year period 1983 through 1987.

Table 7

Basic I/M Annual Fuel Savings Per Inspected Vehicle

Dollar Savings	Fuel Savings
$2.74	0.29%

2.3.6 National Savings

Section 2.3.2 outlines the method used to calculate the fleet fuel consumption with and without I/M. To determine the national benefits it is necessary to know how many vehicles will be in I/M areas. Based on State Implementation Plans (SIP's) submitted to EPA in 1979 and 1980, EPA estimates that 45% of the national vehicle population will be in I/M areas, and therefore that 45% of the VMT are contributed by vehicles in the I/M areas. The number of gallons saved is obtained from the VMT per model year, the average miles per gallon for each model year without I/M, and the percentage fuel consumption decrease due to I/M. The national fuel savings per year are shown in Table 8.

Table 8

Nationwide Annual Fuel Savings from the Basic I/M Program

Calendar Year	Gallons Saved (millions)
1983	27
1984	50
1985	80
1986	117
1987	144
Average	83.6

3.0 OPTION 1: EXTRA FUEL SAVINGS FROM USE OF THE TWO-SPEED IDLE TEST OR LOADED TEST ON 1981 AND LATER VEHICLES

The use of either the Two-Speed Idle Test or the Loaded Test[4] for 1981 and later vehicle results in an identification rate of 70% [3] of the fuel system failures mentioned in Section 2.2.3 versus the 50% rate for the simple idle test.

The Two-Speed Idle Test consists of vehicle operation at 2500 rpm (in neutral gear) as well as at normal idle. The Loaded Test consists of vehicle operation at constant 30 mph with a dynamometer load of 9.0 hp, as well as at normal idle. The 70% identification rate assumes that cutpoints of 1.2% CO and 220 ppm HC are applied at both speeds for either test and that vehicles must pass both pollutant cutpoints at both speeds to pass the I/M test.

The average benefits for 1981 and later vehicles using either of these two tests are given for each calendar year in Table 9. These benefits for 1981 and later vehicles were calculated in the manner described in Section 2.3.1. Table 9 also shows the incremental benefit relative to the basic benefits for these vehicles shown in Table 4.

Table 9

I/M Fuel Economy Benefit for 1981 and Later Vehicles
Using the Two-Speed Idle Test or Loaded Test

Calendar Year	Fleet Benefit	Incremental Benefit Relative to Idle Test
1983	.55%	.13%
1984	.75%	.21%
1985	.97%	.33%
1986	1.07%	.29%
1987	1.22%	.36%

The incremental benfit for 1981 and later vehicles from Table 9 for each calendar year was applied to the fuel consumption of all 1981 and later vehicles in that calendar year. The resulting fuel savings in gallons and dollars were converted to a fleetwide basis by averaging the benefits for 1981 and later vehicles with the zero benefits for the pre-1981 vehicles. This calculation followed the steps described in more detail in Sections 2.3.2 and 2.3.3 and the Appendix. The results of the calculation are the incremental annual fuel savings (averaged over five years) per inspected vehicle due to the use of the Two-Speed Idle Test or Loaded Test instead of the Idle Test used in the basic I/M program. These incremental benefits are shown in Table 10. Table 10 also shows the incremental nationwide fuel savings in gallons, calculated as described in Section 2.3.6.

Table 10

Incremental I/M Annual Fuel Savings Per Inspected
Vehicle from Using the Two-Speed Idle Test or Loaded Test

Dollar Savings	Fuel Savings	Nationwide Gallons Saved (Millions)
$1.11	0.12%	33.8

4.0 OPTION 2: EXTRA FUEL SAVINGS FROM MECHANIC TRAINING

The incremental fuel savings achievable through a formal mechanic training program will depend on the type of repair approach used in the I/M area. The fuel economy benefit for a pre-1981 vehicle which fails I/M and is repaired by a mechanic who has received formal training is estimated to be 0.8% for conventional training programs. Although training results in mechanics performing certain types of repairs which improve fuel economy, other repair practices which may degrade fuel economy remain. However, there is the net beneficial effect of 0.8% which is not seen without training. For I/M programs and training programs which result in repairs consisting of only carburetor adjustments (and other types of repairs which do not degrade fuel economy), the fuel economy benefit has been shown to be 4% per failed vehicle.

These mechanic training benefits for pre-1981 repaired vehicles are based on data from EPA studies. The benefit of 0.8% is taken from two sources: a mechanic training study in Portland[5] and an analysis of vehicles with I/M repairs which did not have their ignition timing settings grossly maladjusted in the "retarded" direction[6]. The latter analysis is relevant in estimating mechanic training benefits, because proper ignition timing adjustment is an important aspect of mechanic training. The two sources both yielded a benefit of 0.8% for failed vehicles.

The benefit of 4% for failed vehicles receiving only carburetor adjustments is based mainly on an EPA study in Houston in which contractor personnel repaired vehicles by adjusting the carburetors simply to a specific idle CO level[8]. This is a practical and realistic approach which yields full CO emission reduction benefits and partial, but substantial, HC emission reduction benefits. This approach may not require extensive mechanic training; a very brief training course and/or an enforcement mechanism to assure that the vehicles are set to the proper idle CO level and to discourage or eliminate repair practices which degrade fuel economy may be all that is necessary. Further details of this approach may be found in Reference 9. Several other EPA studies confirmed the ability of repairs to result in a 4% improvement [1,5,7]. Repairs were often extensive in these latter programs, however carburetor adjustments were the most common repairs performed and were responsible for most of the fuel economy benefit. The figure of 4% appeared repeatedly in these programs.

No deterioration of the above fuel economy benefits between inspections is anticipated. This conclusion was reached from an analysis of vehicles which were tested quarterly for a period of one year after they received repairs to pass the I/M test in Portland. Data from 93 repaired vehicles which had a mean fuel economy increase due to maintenance showed no loss in fuel economy during the following year. The fuel economy was very stable and level throughout the time period[10].

A typical failure rate for pre-1981 vehicles, and the one used in this analysis, is 20%. Thus, the fuel economy benefits averaged over all the pre-1981 I/M vehicles are 0.16% and 0.8%, respectively, for the 0.8% and 4% cases described above.

To determine average savings for pre-1981 vehicles due to mechanic training in each year and over the five year period the same method was used as for the basic program benefits. The consumption in gallons of all pre-1981 vehicles without I/M was calculated first and then the benefits applied, once for each estimate.

No additional fuel economy benefit from mechanic training over the basic benefit is expected for 1981 and later vehicles. This is because even without training, mechanics must correctly and fully repair these vehicles' fuel systems in order for them to pass the I/M reinspection.

Table 11 shows the incremental fuel savings (averaged over five years) from mechanic training. The high end of the range of savings is based on the 4% benefit for failed vehicles receiving only carburetor adjustments and is available in I/M programs which achieve this type of repair through training or some other means.

Table 11

Incremental I/M Annual Fuel Savings per Inspected Vehicle from Mechanic Training

Dollar Savings	Fuel Savings	Nationwide Gallons Saved (Millions)
$0.83-$4.18	0.09-0.46%	26.2-130.2

5.0 OPTION 3: FUEL SAVINGS FROM TIRE PRESSURE CHECKS AT I/M STATIONS

Fuel economy benefits from I/M are usually thought of as being associated with engine tune-ups. However, large benefits can also come from proper tire inflation. An inspection program is a good opportunity to achieve this potential benefit.

Tire rolling resistance is greatly increased when the tire pressure is lower than optimum. The lower the pressure the greater the amount of bending in the tire that takes place, taking more energy and therefore fuel. Each one pound-per-square-inch loss in tire inflation pressure reduces fuel economy by three-tenths of one percent[11].

Two assumptions used in this analysis are that the current average in-use tire pressure is 24.8 psi, which is 1.8 psi below the average pressure specification, and that this discrepancy will remain constant in the future in the absence of I/M pressure checks. These values come from pressure measurements of nearly 2000 vehicles in recent EPA test programs[12]. Another assumption is that tires deflate at an average rate of 1.0 psi per month between checks and will continue to do so.* The latter assumption is based on a consensus of conversations with industry, but no specific studies.

Minimum Benefit Scenario - The minimum benefit scenario calls for an increase to a "cold" inflation pressure of 28 psi of all tires which are found to be below that during the I/M test. (A "cold" inflation pressure is the pressure the tire would have at ambient temperature.) Because some tires will be higher than 28 psi when checked at the I/M lane and will be left that way, the fleet average tire pressure immediately after inspection becomes 28.4 psi. This is far below the maximum pressure recommended on the sidewall of the tires and should have no effect on ride quality. The result of this is a 3.6 psi increase over the present average which would yield a 1.08% fuel economy increase if no deterioration occurred.

To calculate deterioration, it is assumed that owners will fill their tires every three months, but that they will only fill the tires to an average of 27 psi for two reasons: (1) out of habit, some owners will fill the tires to the lower pressures to which they are accustomed; (2) some tires will be filled when warm, which results in a lower equivalent cold inflation pressure. The average lower fill pressure coupled with deterioration results in a yearly tire pressure average of just 1.0 psi higher than the current level, representing a 0.3% fuel economy benefit.

Maximum Benefit Scenario - The maximum-benefit scenario calls for an increase to a cold inflation pressure of 32 psi of all tires found to be below that during the I/M test. This pressure is generally the maximum inflation pressure for current tires recommended by the tire manufacturers and should be considered perfectly safe. (The Tennessee Valley Authority has successfully used the maximum tire manufacturer recommended pressures on its vehicles for many years and reports no safety problems.) It is possible, however, that this could cause ride harshness in some vehicles and possible adverse handling effects on some older vehicles with large differences in recommended front and rear pressures such as older VW Beetles. The exclusion of such vehicles may be appropriate, therefore, but because of the relatively small number of vehicles excluded, the fuel economy benefits are not expected to be noticeably reduced.

The fleet average tire pressure immediately after inspection becomes 32.1 psi as a result of this program. Without deterioration this would translate to a 2.19% fuel economy increase. It is assumed that a good public awareness program is mounted and that this will help maintain tire pressures between the annual I/M tests. For example, leaflets could be handed out at the I/M station explaining the importance of frequent checks and high pressures. In this case it is assumed that owners will fill their tires every two months on

* It is interesting to note that with these average values for in-use pressure, specifications, and deflation rate, the "average tire" appears to be checked and reinflated to its specified pressure once every 3.6 months.

the average and that they fill them to an average of 31 psi (cold). Over a one year period the average tire pressure would then be 30.2 psi which is 5.4 psi over the present average, resulting in a 1.62% fuel economy increase (1.59% fuel consumption benefit) for the fleet.

The percentage benefit of each scenario is applied to the base fuel consumption of the entire fleet of vehicles, since the checks will be performed on all inspected vehicles. Table 12 shows the incremental fuel savings (averaged over five years) from the two tire pressure check scenarios.

Table 12

Incremental I/M Annual Fuel Savings per Inspected Vehicle from Tire Pressure Checks

Scenario	Dollar Savings	Fuel Savings	Nationwide Gallons Saved (Millions)
Minimum Benefit	$ 2.74	0.30%	84.8
Maximum Benefit	$14.88	1.59%	453.8

6.0 SUMMARY OF OPTIONS AND THE OPTIMAL PROGRAM

This section consolidates the results for the basic I/M program and for the three options for increasing the fuel savings from I/M, and presents the fuel savings from an optimal program.

Table 13 shows the combined incremental fuel savings from the three options. The mechanic training option is shown as having a range of benefits. The low end of this range is achievable in any I/M program by implementing a conventional training program; the high end of the range is achievable only if repairs consist only of carburetor adjustments (and other repairs that can be expected not to degrade fuel economy), a situation that may be achieved by special forms of training and/or an appropriate enforcement mechanism.

The tire pressure check option is also shown as having a range of benefits. The low end of this range is based on a minimum benefit scenario which should be reproducible in any I/M program. The high end of the range can be achieved only if the optimal tire pressure for fuel economy -- 32 psi -- is used in the I/M stations and if the public awareness campaign is adequate to motivate owners to check and inflate their own tires to within one psi of this pressure every other month.

Table 13

Annual Fuel Economy Benefits for Inspected Vehicles Due to I/M Options 1/

Option	Dollar Savings	Fuel Savings	Nationwide Gallons Saved (Millions)
(1) More Effective Test 2/ for 1981 and Later Cars	$1.11	0.12%	33.8
(2) Mechanic Training 3/	$0.83- $4.18	0.09- 0.46%	26.2-130.2
(3) Tire Pressure Checks	$2.74- $14.88	0.30- 1.59%	84.8-453.8
All Options Combined	$4.68- $20.17	0.51- 2.17%	144.8-617.8

1/ Average annual benefits for the five year period 1983 through 1987. 1980 dollars.

2/ Two-Speed Idle Test or Loaded Test.

3/ The maximum benefit shown is only available for a specific type of repair approach. See Section 4.0 and Reference 9.

An optimal I/M program would incorporate all three options in addition to the basic I/M program. For the two options which have a range of possible benefits, the form of the option with the highest fuel economy benefit would be implemented. Specifically, the optimal I/M program for fuel savings

(1) uses the Two-Speed Idle Test or the Loaded Test for inspecting 1981 and later vehicles,

(2) includes a mechanic training program and/or an enforcement mechanism which has the effect of eliminating repair practices which degrade fuel economy, leaving only carburetor adjustments -- which cause a 4% improvement in fuel economy -- and other repairs which can be expected not to degrade fuel economy, and

(3) checks the pressure of each tire on each vehicle receiving an I/M test, inflates those which are below 32 psi (cold) to 32 psi, and successfully encourages vehicle owners to do the same themselves (within one psi) every other month.

The fuel economy benefits of this optimal I/M program are shown in Table 14.

Table 14

Annual Fuel Economy Benefits Per Inspected Vehicle From the Optimal I/M Program 1/

Components of the Optimal I/M Program	Dollar Savings	Fuel Savings	Nationwide Gallons Saved (Millions)
Basic I/M Program	$ 2.74	0.29%	83.6
More Effective Test	$ 1.11	0.12%	33.8
Mechanic Training	$ 4.18	0.46%	130.2
Tire Pressure Checks	$14.88	1.59%	453.8
Total for Optimal Program	$22.91	2.46%	701.4

1/ Average annual benefits for the five year period 1983 through 1987. 1980 dollars.

References

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10. "Deterioration of Fuel Economy Benefits in I/M Programs," memo from R. Bruce Michael to Tom Cackette, EPA I/M Staff, March 13, 1981.

11. "The Effects of Tire Inflation Pressure on Passenger Car Fuel Consumption," SAE paper #810068, Thompson, Reinimann and Grugett, February 1981.

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APPENDIX

METHODOLOGY FOR REPORT

APPENDIX - METHODOLOGY FOR REPORT

1.0 INTRODUCTION

The information in Table 1 of the report was derived from the calculation of fuel consumed for each calendar year studied. Savings, both in terms of gallons saved and dollars saved are based on this.

As mentioned in Section 1.2 of the report, it is necessary to make calculations for each model year (MYR) of vehicles for each calendar year studied due to several factors which vary by year. For example, since the average vehicle miles traveled of a MYR varies with time and the average miles per gallon (mpg) achieved by that MYR is unique, the gasoline consumption of the MYR changes every calendar year and is independent of every other MYR.

There are five basic facts needed in order to calculate each MYR's basic (non-I/M) fuel consumption for a given calendar year. Once this is calculated, the savings due to I/M and the options are applied, and all MYR's summed. The five items needed are:

- Registration fraction of all passenger cars contributed by the MYR
- Average miles traveled by the MYR
- Fraction of diesel cars in each MYR
- The total U.S. VMT for all passenger cars for the calendar year
- Average mpg of each MYR

Details of the calculations for each of these five are presented in Section 2.0 of the Appendix. Also presented are the calendar year fleet sizes, which are necessary in determining the savings per vehicle.

2.0 DATA NECESSARY FOR FINAL CALCULATIONS OF FUEL CONSUMPTION

2.1 Registration Fractions of Each MYR

These fractions relate to numbers of vehicles and are necessary in determining fuel consumption of the MYR. The fractions vary for each MYR over time, getting smaller due to vehicles retiring from service.

EPA's standard estimates of the national distribution were used. These are based on historical patterns and are available in such papers as Automotive News. The data had to be modified for a January 1 date (instead of the July 1 date usually found, since this report assumes the I/M program begins on January 1). The estimate assumes that the fractions stay constant throughout the calendar years studied. For example, the fraction for the first model year index, .025, applies to the 1983 MYR in 1983, the 1984 MYR in 1984, etc. Table A-1 presents the registration fractions in the order of newest to oldest vehicles. Note that the fraction for the first year is small, because on January 1 of any year only about one-fourth of that model year has been sold (vehicles usually go on sale in October of the preceding year). For example, on January 1, 1983, the first model year index represents the 1983 model year, part of which has already been sold.

2.2 Average Miles Traveled for Each MYR in the Preceeding 12 Months

Consumption is dependent on the distance traveled. EPA estimates were used and were again based on historical patterns. The analysis assumes that the travel rates stay constant through the calendar years studied, e.g. vehicles one year old are always driven the same amount, on the average. The mileage accumulations are presented in Table A-1. The first year's accumulation is very low, because these vehicles have been driven at most three months out of the last year. The second year accumulation is also fairly low, because about three-fourths of the vehicles in this group have been driven less than one year.

Table A-1

Automobile Registrations and Mileage Accumulation Rates

Model Year Index	Registration Fraction	Mileage Accumulation During Previous 12 Months
1	.025	1800
2	.106	8984
3	.096	14025
4	.074	13522
5	.096	12953
6	.108	12425
7	.093	11922
8	.074	11353
9	.069	10825
10	.062	10322
11	.050	9353
12	.037	9225
13	.031	8722
14	.024	8153
15	.016	7625
16	.011	7122
17	.006	6553
18	.004	6025
19	.002	5525
20+	.016	5022
	1.000	

2.3 Fraction of Diesel Cars in Each MYR

Since diesel cars are not inspected in the typical I/M program used in this report, they have to be subtracted from the total number of light-duty vehicles. Otherwise, savings due to I/M and the options would be incorrectly applied to these vehicles and the national fuel savings would be overstated. EPA estimates of diesel sales fractions are applied. Table A-2 presents the estimates by model year. For ease of calculation of the total consumption, the gasoline car sales fraction is shown, not the diesel car fraction. The percentages are less than 100% back to 1975 only, since diesels do not contribute a noticeable sales fraction earlier than that.

2.4 Average Miles Per Gallon (MPG) of Each MYR

The fuel economy (mpg) is needed for each MYR in order to calculate the fuel consumed. For 1979 and earlier MYRs the estimates are based on in-use testing. These results yield lower numbers than EPA new car certification calculations and DOE fuel economy standards. The comparison of in-use data to certification data shows a substantial shortfall in fuel economy. The analysis of this shortfall was used to forecast future MYRs' fuel economies; this is possible because the certification design fuel economies can be accurately estimated from the new car fuel economy standards.* The fuel economies are shown in Table A-2.

* "Passenger Car Fuel Economy: EPA and Road," EPA 460/3-80-010, August, 1980.

Table A-2

Gasoline Powered Vehicle Sales Fractions and Average Fuel Economy By Model Year

Model year	Gasoline Car Sales Fraction	Fuel Economy (mpg) *
1988	.824	21.7
1987	.835	21.5
1986	.862	21.3
1985	.886	21.1
1984	.905	20.8
1983	.911	20.6
1982	.925	19.8
1981	.953	19.0
1980	.966	18.1
1979	.972	16.87
1978	.991	15.81
1977	.995	14.72
1976	.997	14.11
1975	.998	13.83
1974	1	13.23
1973	1	13.19
1972	1	13.40
1971	1	13.33
1969	1	13.56
1968	1	13.53
1967 & earlier	1	13.53

* From "Passenger Fuel Economy: EPA and Road", EPA 460/3-80-010, August 1980. Values for the 1986-88 model years were extrapolated, since this reference gives estimates only through the 1985 model year.

2.5 Fleet Size and Total Vehicle Miles Traveled (VMT) of All Passenger Cars

The VMT of each model year needs to be calculated in order to determine gallons of fuel consumed by that model year. The fleet size (total number of passenger cars in the U.S.) is needed only after the consumption calculations to determine the savings per vehicle.

The fleet sizes for each of the study years was based on Federal Highways Administration (FHA) data for 1979 and an average growth rate of 1.6% based on projections in a Department of Energy paper for the Society of Automotive Engineers (SAE 790226). Likewise, the VMT for all passenger cars was based on FHA data for 1979 and a growth rate of 1.4% from DOE projections. The estimated fleet size and VMT are presented in Table A-3.

Table A-3

National Passenger Car Fleet Size and VMT By Calendar Year

Calendar Year	Passenger Car Fleet Size	Passenger Car VMT (Billion)
1987	138.7	1292.5
1986	136.5	1274.7
1985	134.4	1257.1
1984	132.3	1239.7
1983	130.2	1222.6

3.0 FUEL CONSUMPTION CALCULATION

Data from the preceding sections can be used to calculate the travel fraction of each model year of gasoline powered cars during each calendar year. Each fraction is then multiplied by the total VMT for that calendar year and divided by the average fuel economy of the vehicles of that model year to yield gallons consumed. The fuel economy benefits (alternatively, the fuel consumption reductions) are applied to each year and then the sum is calculated to yield a single fuel economy benefit for the whole fleet.

A particular situation had to be accounted for in the calculations. In any given calendar year, none of the vehicles of the first model year and only one-fourth of the vehicles of the second model year are subject to I/M. For example, on January 1, 1984 all of the 1984 model year vehicles which have been sold and about three-fourths of the 1983 model years (the ones less than one year old) would not have been inspected. This is due to the assumption that vehicles will not be tested until they are one year old. Benefits were therefore not applied to these vehicles.

Another situation was also accounted for. The one-fourth of the vehicles of the second MYR which are inspected have been in service a full year and therefore have traveled a farther average distance than is depicted in Table A-1. The mileage accumulation for the third index year was applied to these vehicles to calculate their consumption. This resulted in using the equivalent of 39% of the miles traveled by the entire second MYR instead of just 25%.

4.0 CALCULATION OF BENEFITS

There are six benefits which can be considered: low and high situations each for the basic I/M program, a mechanic training program, and tire pressure checks. The first four of these have to be applied differently according to whether the vehicles are 1981 and later, or pre-1981. Therefore, it is simplest to calculate the base consumption for the 1981 and later fleet and the pre-1981 fleet separately, and then apply the benefits accordingly.

Benefits were always applied to the base case (non-I/M) consumption rather than to the consumption with another option. For example, the tire pressure check benefits were applied to the consumption of the base case rather than to the consumption with the I/M program and mechanic training. In this way the options can be kept separate. The calculation for tire pressure check benefits is slightly incorrect due to this, because the benefits are applied to the base case of slightly higher consumption than the I/M case. Applying the benefits to the basic I/M program consumption, which is slightly lower, shows an indetectable difference, however. The mechanic training options yield entirely correct results when applied in this manner. This is because mechanic training only has benefits on pre-1981 vehicles and the consumption for these vehicles is the same whether with or without the basic I/M program. The benefits associated with each option and calendar year are summarized in Table A-4.

Table A-4
I/M Fuel Economy Benefits

- - - - Fleet Percent Fuel Savings - - - -

Calendar Year	Models Covered	Basic Program (Idle Test)	More Effective Test *	Mechanic Training: Conventional Programs	Mechanic Training: Carburetor Adjustments Only	Tire Pressure MIN	Tire Pressure MAX
1983	1968-80	0	0	.16	.80	.30	1.62
	1981-later	.42	.55	0	0	.30	1.62
1984	1968-80	0	0	.16	.80	.30	1.62
	1981-later	.54	.75	0	0	.30	1.62
1985	1968-80	0	0	.16	.80	.30	1.62
	1981-later	.64	.97	0	0	.30	1.62
1986	1968-80	0	0	.16	.80	.30	1.62
	1981-later	.78	1.07	0	0	.30	1.62
1987	1968-80	0	0	.16	.80	.30	1.62
	1981-later	.86	1.22	0	0	.30	1.62

* Two-Speed Idle Test or Loaded Test on 1981 and Later Vehicles.

5.0 SAMPLE CALCULATION

A sample calculation for the 1987 calendar year will be explained.

The first step is to determine the registration percentage of gasoline vehicles in each model year. This is accomplished by multiplying the registration fraction in Table A-1 by the gasoline car sales fraction in Table A-2, for each model year. This yields gasoline vehicle registration fractions (RF). (The summation of these yields the fraction of all passenger cars which are gasoline powered, .922 in the sample case in Table A-5, which is needed for a later step.) These fractions are multiplied by the corresponding mileage accumulations of Table A-1 to yield what can be called "registration fraction miles traveled" (FMT). The summation of the FMT is needed for the following calculation. The next step determines the gasoline vehicle travel fractions, i.e., the fraction of all miles traveled by the gasoline powered vehicles of each model year. This is obtained by multiplying each FMT by the sum of the RF (to account for the fact that the gasoline vehicles do not travel all of the miles) and dividing by the sum of the FMT.

At this point we have the travel fractions of all of the gasoline powered vehicles, but these need to be modified before we can calculate the consumptions. This is because not all of the vehicles are subject to inspection.

The next step, therefore, is to determine the travel fractions of only the I/M vehicles. None of the latest MYR, only a portion of the second latest MYR and no vehicles earlier than the 1968 MYR will be inspected. Therefore, all of the travel fractions for those MYR's will be changed to zero, except for the second MYR. As explained in Section 3.0 of this Appendix, this latter fraction becomes approximately 39% of its original value.

The final step in determining the base fuel consumption of each MYR of vehicles subject to I/M is to multiply the resultant travel fractions by the VMT of all vehicles in I/M areas (45% of total U.S. VMT) and divide by the appropriate miles-per-gallon figure for the MYR. These numbers can then be summed into two groups, one for the 1981 and later vehicles, and another for the pre-1981's. The reason for doing this is that all of the I/M benefits, except tire pressure checks, are dependent on these categories. The next series of steps is simply to apply the estimated option savings to the base fuel consumptions to determine the gallons saved. When all of these are calculated, the savings per vehicle can be calculated by dividing the gallons saved by the number of vehicles subject to I/M and then applying the estimated price per gallon of gas. Calculations are shown for the 1987 calendar year in Table A-5.

Table A-5

Sample Calculation for Calendar Year 1987

Estimates: Total VMT of all U.S. passenger cars = 1274.7 billion miles
Total passenger cars in U.S. = 136.5 million
Price per gallon of gasoline in 1980 dollars = $1.70 per gallon

MYR	(A) Registr. Fraction	(B) Gasoline Vehicle Sales Fraction	(A*B) Gasoline Vehicle Registr.	(C) Mileage Accum.	(A*B*C*) FMT	(A*B*C*)* (.922) / (10,004.1) Travel Fractions	Modified Travel Fractions	Fuel Economy mpg	Base Consumption
1988	.025	.824	.0206	1800	37.1	.003	0	–	
87	.106	.835	.0885	8984	795.1	.073	.028	21.5	0.747
86	.096	.862	.0828	14,025	1161.3	.107	.107	21.3	2.882
85	.074	.886	.0656	13,522	887.0	.082	.082	21.1	2.229
84	.096	.905	.0869	12,953	1125.6	.104	.104	20.8	2.868
83	.108	.911	.0983	12,425	1221.4	.113	.113	20.6	3.147
82	.093	.925	.0860	11,922	1025.3	.095	.095	19.8	2.752
81	.074	.953	.0705	11,353	800.4	.074	.074	19.0	2.234
									Subtotal 16.859
80	.069	.966	.0667	10,825	722.0	.067	.067	18.1	2.123
79	.062	.972	.0603	10,322	622.4	.057	.057	16.87	1.938
78	.050	.991	.0496	9353	454.0	.042	.042	15.81	1.524
77	.037	.995	.0368	9225	339.5	.031	.031	14.72	1.208
76	.031	.997	.0309	8722	269.5	.025	.025	14.11	1.016
75	.024	.998	.0240	8153	195.7	.018	.018	13.83	0.747
74	.016	1.00	.016	7625	122.0	.011	.011	13.23	0.477
73	.011	1.00	.011	7122	78.3	.007	.007	13.19	0.304
72	.006	1.00	.006	6553	39.3	.004	.004	13.40	0.171
71	.004	1.00	.004	6025	24.1	.002	.002	13.33	0.086
70	.002	1.00	.002	5525	11.1	.001	.001	13.63	0.042
69	.002	1.00	.002	5022	10.0	.001	.001	13.56	0.042
68	.001	1.00	.001	4500	4.5	.0004	.0004	13.53	0.017
67-	.013	1.00	.013	4500	58.5	.005	0	–	
	1.000		.922		10,004.1	.922	.869		Subtotal 9.696

Table A-5 (continued)

Sample Calculation for Calendar Year 1987

Fuel Savings in Billion Gallons During 1987 from Basic I/M Program and Each Option
(Using Percent Savings from Table A-4)

MYR	Base (No-I/M) Consumption	Basic I/M Program (Idle Test)	More Effective Test for 1981 and Later	Mechanic Training: Conventional	Mechanic Training: Carburetor Adjustments Only	Tire Pressures: MIN	Tire Pressures: MAX
1981 and Later	16.859	0.144	0.203	0.0	0.0	0.050	0.269
Pre-1981	9.696	0.0	0.0	0.015	0.077	0.029	0.155
TOTAL	26.555	0.144	0.203	0.015	0.077	0.079	0.424