EVALUATION OF MOTOR VEHICLE EMISSIONS INSPECTION/MAINTENANCE PROGRAMS FOR MICHIGAN

EXECUTIVE SUMMARY

CONTRACT NO. 68-02-2536
Task Order No. 7

Pacific Environmental Services, INC.

EVALUATION OF MOTOR VEHICLE

EMISSIONS INSPECTION/MAINTENANCE

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Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY

Region V

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1.0 OVERVIEW

Pursuant to United States Public Law 95-95, otherwise known as the Clean Air Act as Amended (1977), all states are required to demonstrate the attainment by December 1982 of the national ambient air quality standards for carbon monoxide (CO) and ozone (O_3) in every part of the state. This demonstration is part of a State Implementation Plan (SIP) to be approved by the United States Environmental Protection Agency (EPA) no later than July 1, 1979. For most states, this has required the adoption of special pollution control measures in order to attain the standards and maintain them beyond 1982. If an area is unable to demonstrate attainment of standards by the stated date, despite implementation of various controls, an extension of the attainment deadline to 1987 may be granted to the state under certain conditions specified in the Act. One of these conditions is that an emissions Inspection/Maintenance (I/M) program for motor vehicles be initiated in all areas of the state that will fail to meet the standards by December 31, 1982. It is EPA policy that the latest permissible start-up date for such a program is December 31, 1981 if vehicle inspections are to be conducted at decentralized (private) facilities, and December 31, 1982 if the inspections are to be performed at centralized special testing stations operated either by the state or by a private contractor.

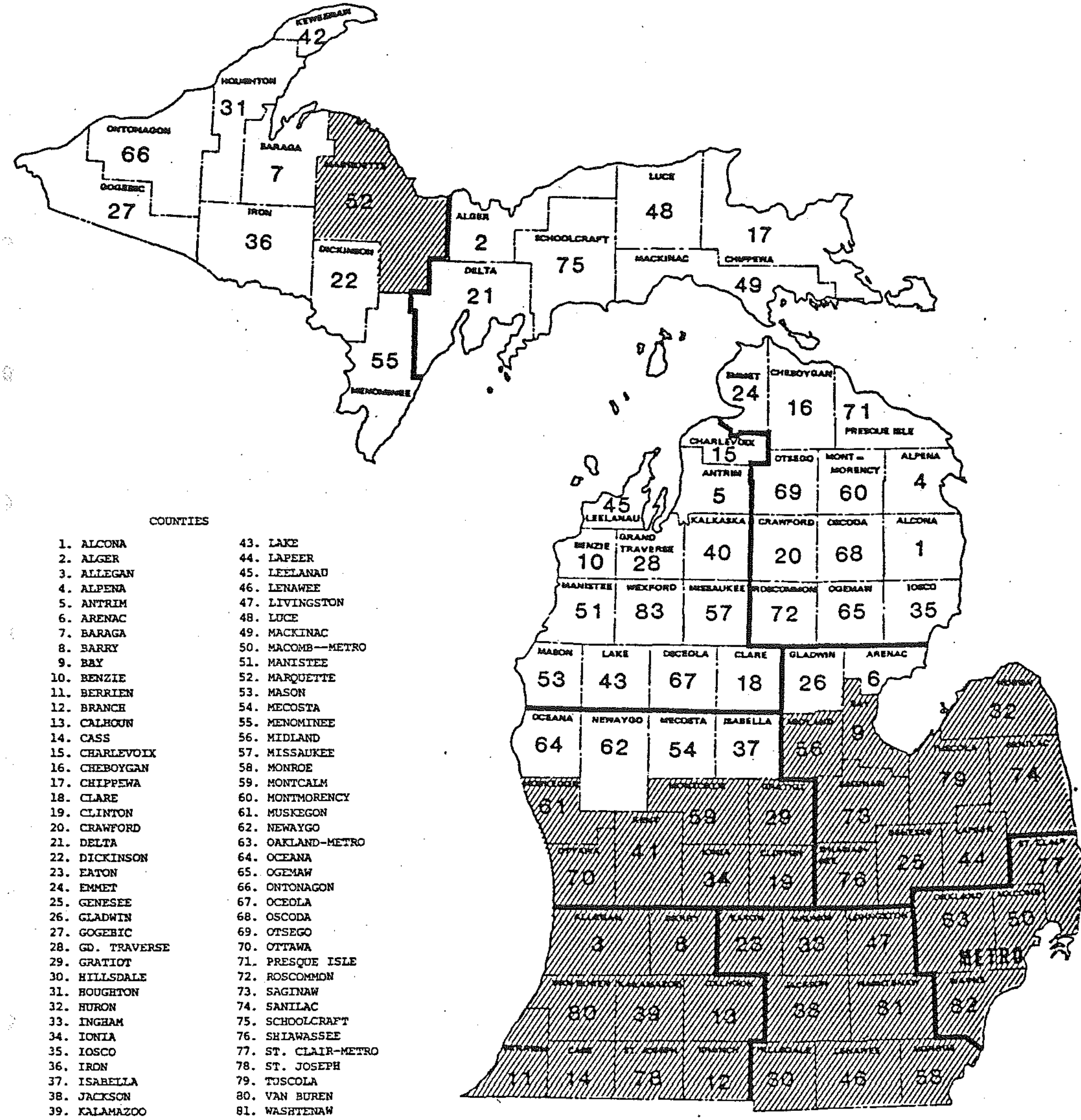
The purpose of I/M is to identify vehicles with pollutant emissions in excess of levels considered acceptable. It is required that vehicles so identified must be repaired or adjusted. I/M may be considered a quality assurance mechanism in support of the Federal Motor Vehicle Control Program which since 1970 has set new vehicle emissions standards for present and future model years and requires emission control equipment on new vehicles.

The State of Michigan must consider candidate I/M programs for implementation in all or parts of the State, because the five-county Detroit metropolitan area, at least, is expected to be unable to meet applicable air quality standards prior to the 1982 deadline. Officially, 37 counties of southern Michigan, as well as Marquette County in the Upper Peninsula, have been designated ozone nonattainment counties (Fig. 1). EPA has determined that reduction of emissions of reactive hydrocarbons (HC), a major portion of which is attributable to the operation of motor vehicles, is necessary for the reduction of ambient O_3 levels, and can be achieved through I/M. Failure to address the issue of I/M could result in disapproval of the Michigan SIP, which in turn would result in the imposition of restrictions on industrial growth and possible federal funding sanctions on the State. Because of the significant effort involved in developing the information needed to meet the Clean Air Act requirements that mandate legal authority for I/M no later than July 1, 1979, EPA provided funding for Michigan to secure contractual assistance for the performance of necessary technical studies of I/M. Pacific Environmental Services, Inc. (PES) and Systems Control, Inc. (SCI) were selected to evaluate a range of possible I/M program configurations to assist in the identification of a short list of alternatives that would be appropriate in Michigan. The findings of the evaluation are presented in the two volume study that accompanies this summary.

1.1 STUDY OBJECTIVES

There were five principal objectives of this study.

1. Explore a broad range of program options.
2. Perform a comprehensive evaluation of the costs and benefits of seven principal or "base" options that together incorporate all the unique properties of program configurations suggested by representatives of the State of Michigan.



COUNTIES

1. ALCONA
2. ALGER
3. ALLEGAN
4. ALPENA
5. ANTRIM
6. ARENAC
7. BARAGA
8. BARRY
9. BAY
10. BENZIE
11. BERRIEN
12. BRANCH
13. CALHOUN
14. CASS
15. CHARLEVOIX
16. CHEBOYGAN
17. CHIPPEWA
18. CLARE
19. CLINTON
20. CRAWFORD
21. DELTA
22. DICKINSON
23. EATON
24. EMMET
25. GENESEE
26. GLADWIN
27. GOGEBIC
28. GD. TRAVERSE
29. GRATIOT
30. HILLSDALE
31. HOUGHTON
32. HURON
33. INGHAM
34. IONIA
35. IOSCO
36. IRON
37. ISABELLA
38. JACKSON
39. KALAMAZOO
40. KALKASKA
41. KENT
42. KEWEENAW
43. LAKE
44. LAPEER
45. LEELANAU
46. LENAWEE
47. LIVINGSTON
48. LUCE
49. MACKINAC
50. MACOMB—METRO
51. MANISTEE
52. MARQUETTE
53. MASON
54. MECOSTA
55. MENOMINEE
56. MIDLAND
57. MISSAUKEE
58. MONROE
59. MONTCALM
60. MONTMORENCY
61. MUSKEGON
62. NEWAYGO
63. OAKLAND-METRO
64. OCEANA
65. OGEMAW
66. ONTONAGON
67. OCEOLA
68. OSCODA
69. OTSEGO
70. OTTAWA
71. PRESQUE ISLE
72. ROSCOMMON
73. SAGINAW
74. SANILAC
75. SCHOOLCRAFT
76. SHIAWASSEE
77. ST. CLAIR-METRO
78. ST. JOSEPH
79. TUSCOLA
80. VAN BUREN
81. WASHTENAW
82. WAYNE—-METRO
83. WEXFORD

Figure 1. MICHIGAN OZONE NONATTAINMENT COUNTIES

3. Develop estimates of program costs and consumer fees for a matrix of 24 program configurations expanded from the base options and differentiated by administrative mode, inspection mode, and scope.

4. As a result of this comparative analysis and consultation with concerned representatives of Michigan, eliminate from the matrix those candidate programs determined to be either unsatisfactory or inappropriate for the State.

5. Prepare a program plan for further detailed study of a specific inspection/maintenance program for Michigan.

Volume 1 of the report addresses the first objective, while Volume 2 presents the results of the analyses undertaken for objectives 2, 3, and 4. The recommended program plan for further study has been submitted under separate cover.

1.2 BASIC FEATURES OF INSPECTION/MAINTENANCE

Volume 1 of the report introduces the basic elements and issues of an I/M program.

EPA policy requires that an approvable I/M program must be able to produce by the end of 1987 a 25 percent net reduction in emissions of HC and CO from light-duty vehicles (LDV) compared to what these emissions would be without this program. Additional emission reductions may be achieved if a state includes testing of other vehicle categories, such as heavy-duty gasoline trucks. Vehicle categories that a state may consider for emissions testing in an I/M program include the following:

a. Light-duty vehicles weighing less than 6,001 pounds
b. Medium-duty vehicles (generally trucks) weighing from 6,001 to 8,500 pounds
c. Heavy-duty (greater than 8,500 pounds) gasoline vehicles (HDG)
d. Heavy-Duty (greater than 8,500 pounds) diesel vehicles (HDD)
e. Motorcycles

The overall potential for emissions reduction is also sensitive to the geographical scope of program coverage. Six geographic areas of

Michigan have been identified as meeting appropriate criteria for implementation of I/M. These areas are listed below in descending order of size. Again, it should be noted that an I/M program is mandatory only in a region in which attainment by 1982 of CO and/or O_3 standards cannot be demonstrated. Nonetheless, it is true that more comprehensive geographic coverage results in greater total emissions reduction.

Potential geographic coverage:

a. Entire state (83 counties)

b. Ozone nonattainment counties of lower peninsula (37 counties)

c. Ozone nonattainment metropolitan counties
Detroit (Macomb, Monroe, Oakland, Washtenaw, and Wayne) - also includes CO nonattainment area
Lansing (Clinton, Eaton, and Ingham)
Grand Rapids (Ottawa and Kent)
Flint (Genesee)

Two elements of candidate I/M programs that do not affect the magnitude of emissions reduction, but nevertheless, are the principal characteristics distinguishing one candidate from another are the administrative arrangements and method of emissions inspection. These elements are discussed below.

Several possible administrative approaches have been evaluated for the State of Michigan. These arrangements describe the operational format of the inspection phase of I/M, and would be characterized by one of the following.

- State-owned/operated centralized facilities, in which a public authority of the State of Michigan would manage and operate publicly-owned test facilities.

- Contractor-owned/operated centralized facilities, in which a private firm or other entity selected through competitive bidding would be delegated operational responsibility for inspection. The contractor and not the State would assume financial responsibility for constructing and operating test centers. Administrative overview and monitoring would remain the responsibility of a public authority.

- Inspection of a statistical sample of vehicles at state- or contractor-owned/operated facilities, in which a stratified, randomly-sampled percentage of the Michigan vehicle population would be tested to determine if the vehicles are tuned and operating generally within manufacturers specifications. The objective of this approach would be to establish whether or not a full-scale I/M program is needed in Michigan, and if such a program would accomplish its intended goal of emission reduction.

- Privately-owned/operated decentralized facilities, in which the State of Michigan would certify qualified establishments (independent service garages and dealerships) to perform inspections. The State would oversee and regulate the program to ensure that I/M requirements and provisions are met.

All I/M programs currently in operation utilize either centralized facilities operated by public authority or contractor or decentralized private garages for vehicle inspection. For all administrative approaches except statistical sampling, repair of vehicles which fail an emissions inspection would be mandatory. Repairs would be performed by dealerships, service garages and independent operators comprising the automotive service industry.

Three emission inspection procedures have been evaluated for implementation in an I/M program for Michigan. These are:

- the idle-mode test,
- the loaded-mode test, and
- an engine parameter/device inspection (EPDI).

Moreover, it has been proposed that an inspection for safety defects and excessive noise be incorporated into the emissions inspection procedure. That is, safety and noise tests would be performed at emissions inspection stations, most likely at positions specially equipped for such testing.

The idle mode test consists of measuring tailpipe exhaust emissions with the vehicle idling in neutral gear. Hydrocarbon and carbon monoxide levels are measured at both normal and high-idle speed. The test at the normal-idle speed is conducted at the vehicle manufacturer's recommended idle (600 to 1,000 revolutions-per-minute) while the high-idle test is conducted at 2,500 rpm. Emissions are collected by a tailpipe probe. The general characteristics of idle-mode testing include:

- Simplicity, requiring minimal training for inspectors
- Limited diagnosis of some engine maladjustments and malfunctions
- High probability that test conditions can be duplicated by private garages for repair diagnosis
- Brief test time and minimal equipment requirements
- Inability to detect some emission control system malfunctions that would occur when a vehicle is operating under road-load and higher speeds
- Inability to detect elevated emissions of nitrogen oxides (NO_x), a regulated pollutant
- Opportunity to perform minor carburetor adjustments during testing.

The results of any approvable short emissions test must correlate satisfactorily with results obtained from the Federal Test Procedure (FTP). FTP is EPA's baseline inspection cycle of over forty minutes' duration which requires a twelve-hour engine-off preconditioning period ("cold soak") for each vehicle tested. To date, EPA has not released a list of approved short cycle emissions tests. However, it is anticipated that the idle mode inspection procedure will be approved.

The loaded mode test may also be approved. This inspection procedure requires the use of a chassis dynamometer and, if specified, a gas analyzer for oxides of nitrogen (NO_x) in addition to the standard HC and CO analyzers. It has been determined from experimentally-derived data that most high contaminant emissions result from specific engine maladjustments or malfunctions that come to light under different engine speed and road-load conditions. Therefore, it is advisable that several different load conditions be applied to a vehicle during emissions inspection. One version of a loaded-mode test, called the transient-mode or Federal short-cycle inspection, analyzes emission samples from nine operating modes (simulated after vehicle positioning on the dynamometer) ranging from idle through acceleration to high cruise and deceleration over a time period of 125 seconds. The disadvantage of the Federal short-cycle test is that it is very equipment-intensive, requiring all equipment used in the FTP. By contrast, most loaded-mode testing conducted in ongoing I/M programs employs a limited selection of typical test speeds which usually include only high cruise (44 to 50 mph), low cruise (22 to 30 mph) and idle. Exact test speeds and loads would depend on vehicle weight. Different failure limits are established for the HC and CO (and NO_x) concentrations for each operational mode and vehicle model year. Better diagnostic information can usually be obtained from a loaded test because failures at non-idle modes generally point to a specific and identifiable malfunction referenced in a logic diagram or "truth chart." However, unless mechanics are extensively trained in the proper use of loaded test diagnostic information, the diagnostics do not result in emissions reduction greater than that which is obtainable from the idle mode test.

For the engine parameter/device inspection (EPDI), vehicles are subjected to a sequence of system component checks to determine the mechanical condition of various emissions-related systems. Components and/or operating parameters outside the accepted tolerance range are considered to have failed, and are required to be replaced or adjusted to manufacturer's specifications. This approach does not specifically include measurement of emissions levels, although in some cases, emission measurements would be taken to evaluate the state of vehicle systems such as oxidation and reduction catalysts. The diagnostic capabilities of the EPDI are probably the greatest of any of the short emissions tests discussed here.

The following sequence is generally applicable to any emissions testing procedure. Upon its arrival at an inspection facility, (1) the registration/license number of a vehicle and other pertinent information on vehicle characteristics are recorded. This is followed by (2) visual inspection of the exhaust system and emission control devices, (3) the exhaust emission test, (4) recording of test data, (5) notification of test results to the motorist, and (6) issuance of certificate (compliance, failure, or waiver). Figure 2 illustrates this sequence. For a drive-through facility with three positions per inspection lane, steps 1 and 2 above would occur at position one, steps 3 and 4 at position two, and

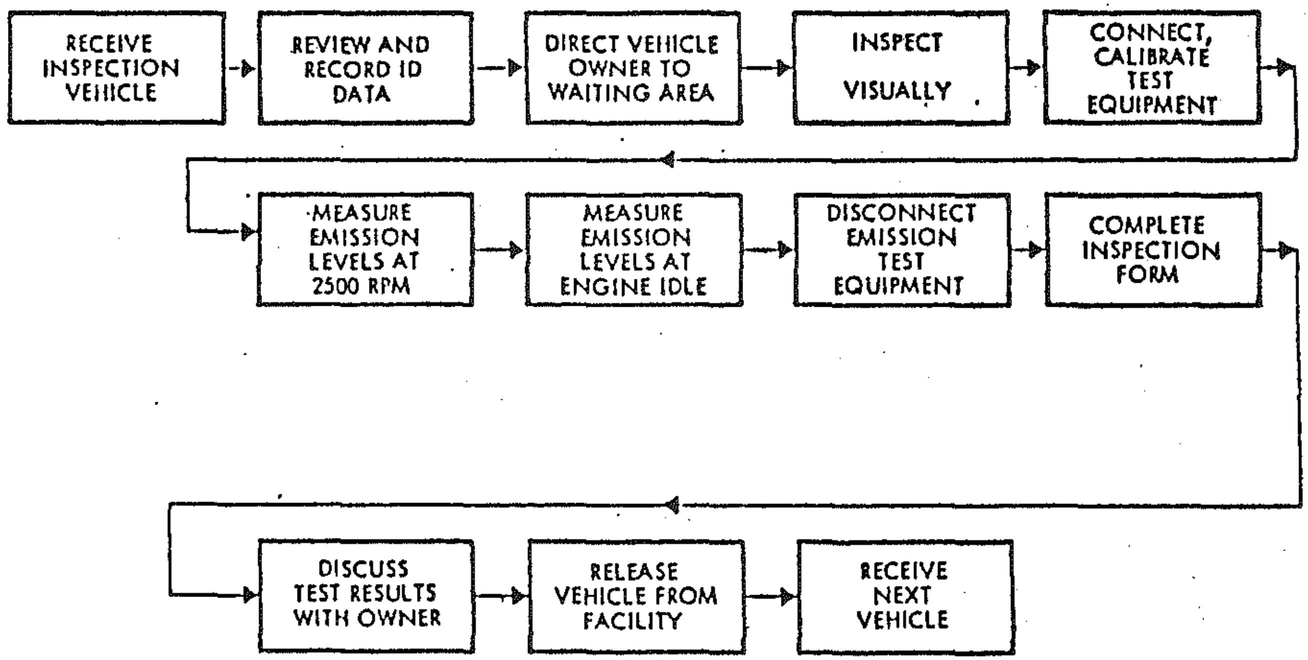


Figure 2. Typical Inspection Sequence

steps 5 and 6 at position three. These positions are respectively termed the receiving station, test station, and certification station. Data handling operations may be fully automated or manual, with automated data handling the rule at centralized inspection facilities. Based on the exhaust emission test data, a pass/fail decision is made and discussed with the vehicle owner. Passed vehicles are certified, but impending malfunctions are flagged. Failed vehicles are diagnosed as to the probable cause of failure, then released to the motorist for required repair. Certain vehicles may be granted a waiver from further testing but, in general, failed vehicles must return to an inspection station following repair for a retest.

The proposed inclusion of safety testing as part of an emissions inspection program was prompted in part by the Michigan Trial Substitute Vehicle Inspection Program, conducted during 1975 and 1976 at random check lanes in two Michigan counties. The following items were checked as part of this program.

- Vision defects (glass, wipers, washers, mirrors)
- Lighting defects
- Exhaust defects (noise and smoke)
- Control defects (steering, brake and tire condition)
- Miscellaneous deficiencies (horn, registration, and seatbelts)

Among the findings of this program, which is no longer in operation, was that the overall rate of inspection failure was relatively insensitive to sample size.

Vehicle-in-use standards and periodic motor vehicle inspection programs presently operating in other states emphasize safety-related components. There is a general belief that vehicles in good operating condition are less likely to be involved in accidents. The safety inspection envisioned for Michigan would involve quick visual checks of the parameters mentioned above and a brake test using the skid plate method which is described in Volume 2, Section 3.3.1 of the report.

The State of Michigan has already established procedures and standards for drive-by and stationary noise levels. However, the procedure is not compatible with indoor test facilities in which a large hard-surface testing site and low ambient noise levels cannot be assured. Simple stationary tests correlatable with federal pass-by procedures would be needed for integration into an I/M program. If such tests can be developed and specified, and their space requirements are not extensive, one or more may be performed at an emissions inspection facility.

1.3 EXPLORATION OF SPECIFIC PROGRAM OPTIONS

Volume 2 of the report is devoted to an in-depth examination of the characteristics of the specific I/M program options that may be considered for implementation in Michigan. The various benefits and economic effects attributable to I/M generally are discussed in a Michigan context. Also discussed are ancillary issues of program implementation and operation (including quality assurance of testing, consumer protection for repair, public information strategies and mechanic training programs) that must be addressed in any program regardless of administrative approach or method of test. Cost categories for the program are identified and explained; then, total life costs and annual consumer fees are developed for a comprehensive set of seven basic and seventeen additional program options. Based on a comparison of costs, the qualitative merits of each option and extensive consultation with State of Michigan Technical Advisory Committees for air quality and inspection/maintenance, the total number of candidate options is reduced to a set of two firm and one conditional program configurations for further study. These configurations are discussed in Section 1.5 of this Summary.

The primary purpose and principal benefit of an Inspection/Maintenance program is the reduction of vehicular emissions. However, there are associated benefits and positive effects of a successful I/M program in the realm of monetary savings and improved driveability for the individual and certain direct and indirect economic effects. Section 2.0 of Volume 2 introduces and expands upon the benefits of I/M applicable to Michigan.

Table 1 presents the total emission reductions that would result from an I/M program covering all light-duty vehicles (less than 8,500 pounds) in each of the State's five nonattainment metropolitan areas, under the assumption that 20 percent of vehicles tested would fail the emissions inspection and undergo repair. It is further assumed that trained mechanics perform these repairs. Values in the table were supplied by the Michigan Department of Transportation and the Southeastern Michigan Council of Governments, and were generated using EPA's MOBILE 1 computer program which computes vehicle emission factors under a wide variety of assumptions and incorporates the emission reduction credits attributed to an I/M program by EPA (based upon values presented in Appendix N of Part 51 of Volume 40, Code of Federal Regulations). Other program benefit issues discussed in Vol. 2, Section 2.0 are the likely increases in fuel economy, improved vehicle performance and vehicle life attributable to the identification and correction of out-of-tune and malfunctioning vehicles; the identification of warranty parts failures; employment generation and other economic growth effects attributable to the technical and material requirements of I/M; the "banking" of emission reduction credits through I/M in order to protect future industrial growth in Michigan; and miscellaneous difficult-to-quantify effects including reduced health-related costs and improved visual esthetics attributable to cleaner air. In general, assignable benefits are insensitive to program administration and method of test (with those test procedures for which EPA has acknowledged emission reduction benefits) but vary with geographical scope of coverage and by type and population of the vehicles subject to inspection.

Table 2 presents the matrix of 24 program options evaluated for Michigan. The "base options" incorporating all unique program features with repsect to administrative approach, method of test, and program objectives, are identified in the table by asterisks. For each base option output capabilities for an inspection lane were computed on the

Table 1. INSPECTION/MAINTENANCE PROGRAM RESULTS IN MAJOR URBAN AREAS IN THE DESIGNATED NONATTAINMENT REGION

		Detroit*	Flint	Lansing	Grand Rapids	Niles
CO						
1982:	No I/M	3,885,672	168,420	135,129	182,651	9,557
	I/M 1 year	3,512,449	146,679	117,530	158,860	8,305
	% Decrease	9.6	12.9	13.0	13.0	13.1
1987:	No I/M	2,346,511	92,333	78,492	101,874	5,514
	I/M 5 years	1,746,443	58,196	49,401	64,085	3,433
	% Decrease	25.6	37.0	37.0	37.0	37.7
HC						
1982:	No I/M	352,863	20,527	17,135	21,087	1,066
	I/M 1 year	340,469	19,680	16,449	20,166	1,017
	% Decrease	3.5	4.1	4.0	4.4	4.6
1987:	No I/M	204,066	10,868	9,424	11,648	622
	I/M 5 years	159,350	7,882	6,883	8,349	439
	% Decrease	21.9	27.5	27.0	28.3	29.4
Figures are kilograms per average-summer-day for 20 percent failure rate not including mechanics training						

*Values supplied by Southeastern Michigan Council of Governments. Hydrocarbon totals for Detroit include only reactive HC.

Note: I/M program presumed to include 20 percent failure rate (stringency factor) and repairs by trained mechanics.

Table 2. ALTERNATIVE APPROACH VERSUS METHOD OF TEST

ADMINISTRATIVE APPROACH	METHOD OF TEST		
	IDLE	LOADED	EPDI
State-Operated	1. without safety & noise*	9. without safety & noise*	17. without safety & noise*
	2. with safety & noise*	10. with safety & noise	18. with safety & noise
Contractor-Operated	3. without safety & noise*	11. without safety & noise	19. without safety & noise
	4. with safety & noise	12. with safety & noise	20 with safety & noise
Service Center (Private Garage)	5. without safety & noise*	13. without safety & noise	21. without safety & noise
	6. with safety & noise	14. with safety & noise	22. with safety & noise
Statistical Sampling	7. without safety & noise*	15. without safety & noise	23. without safety & noise
	8. with safety & noise	16. with safety & noise	24. with safety & noise

* base option

basis of time required to perform a single inspection (by test mode and scope) factored by an empirically-derived percentage multiplier of actual versus ideal efficiency. The output computation procedure for each mode of test is discussed in Section 3.6.2 of Volume 2. The following annual lane capacities were developed for a testing program involving light-duty vehicles (LDV).

Idle mode	23,000 LDV
Loaded mode	19,200 LDV
Engine Parameter/Device Inspection	4,500 LDV

Based on these values and the required staffing complement per inspection facility, total personnel and lane requirements were developed by county using projected vehicle registration for 1987. Given capacity and personnel requirements it became possible to identify specific values by program option for each of the cost elements shown in Table 3. We shall return to this table presently.

I/M program requirements that may result in public and private costs directly attributable to the program are introduced in Section 3.8 of Volume 2 and discussed in depth in appendices to the report. Individual states are responsible for obtaining the legal authority to implement vehicle Inspection/Maintenance programs. Michigan does not currently have enabling legislation. The legislation will be requested during the fall of 1979. Legislation may be very general, or may be very specific and assign all reponsibilities for the program, determine testing procedures, and even set emission standards. Preparation of this legislation will require considerable devotion of time and effort by elected officials and staff of the State of Michigan. Appendix B of Volume 2 presents a detailed discussion of the issues that should be considered for inclusion in I/M legislation.

While I/M legislation is debated and after its passage by the Legislature, the citizens of Michigan must be informed of all aspects of the impending program which will have an impact on their accustomed activities. The basic features of a public information effort and a suggested timeline for implementation of the various stages are presented in Appendix C.

Table 3. COST ELEMENTS

ITEM	COST ELEMENT
I.	INITIAL IMPLEMENTATION AND CAPITAL COSTS (NONRECURRING)
	A. Initial Implementation Costs
	1. Site Selection
	2. Bids Preparation and Evaluation
	3. Facilities Design
	4. Training Plan Development
	5. Personnel Selection
	6. Document Preparation
	7. Administrative Support
	8. System Integration, Checkout, and Certification
	9. Test Scheduling System Development
	B. Capital Costs (Construction)
	1. Land and Site Improvement Costs
	a. Land Cost
	b. Site Improvement Costs
	2. Facility Construction
	3. Instrumentation Cost
	4. Office Equipment
	5. Computer Costs
	a. Hardware
	b. Software
	C. Capital Costs (Other)
	1. Administrative Office Equipment
	2. Quality Control Equipment
	a. Mobil Unit
	b. Referee Station
	c. Correlation Car
	3. Consumer Complaint
II.	ANNUAL OPERATING COSTS
	A. Facility Operating Costs
	1. Personnel Costs
	2. Maintenance and Miscellaneous Item Costs
	a. Facility
	b. Equipment
	B. Support Costs
	1. Administrative
	2. Data Analysis
	3. Training
	C. Quality Control Operating Costs
	1. Personnel
	2. Supply
	3. Maintenance
III.	ANCILLARY PROGRAMS ANNUAL OPERATING COSTS
	A. Mechanic Training
	B. Public Information Program
	C. Consumer Complaint
	D. Vehicle Test Scheduling Costs

An I/M program will fully succeed with respect to its intended purpose and to the satisfaction of the public only if qualified mechanics perform the repairs necessary to bring polluting vehicles into compliance with standards. Michigan is fortunate to have a vehicle mechanic and repair facility certification and registration system already in place, which will greatly ease the problem of identifying qualified mechanics to perform vehicle repairs. However, additional mechanics must be trained and many mechanics retrained for perform the necessary repairs. Appendix D presents the elements of a mechanics program, discusses the two-phase training approach recommended by State of Michigan staff, and provides an appropriate program timeline. Costs developed for the training effort are incorporated in the detailed option cost analyses of Volume 2, Section 5.0.

Any vehicle owner subject to inspection/maintenance should expect that accurate, consistent inspections will be performed on his or her vehicle, and that there will be protection from improper and unnecessary repairs in the event of failing the test. Further, the owner should be assured that the motorist seeking to circumvent the system (and thus to neutralize the contribution the honest owner is making to clean air through proper vehicle maintenance) will be identified and that such cheating will be minimized. Mechanisms to assure accurate inspections at testing facilities include state-operated referee lanes or challenge garages (for complaint handling), mobile quality assurance vans equipped with instrument and gas calibration devices, correlation vehicles for comparative evaluation of test results from lane to lane, and a regular, internal, rigorously-observed schedule of instrument calibration and equipment maintenance. These mechanisms are all legitimate program costs directly assignable to the State and the operator(s) of the inspection facilities. For quality-assured repairs the present repair facility certification program in Michigan could be supported by periodic State inspections of garages and emission analyzers. Mechanics must also be instructed that they should tune a failed vehicle to manufacturer's specifications. Appendix E discusses these mechanisms in greater detail, reviews the most common means by which some motorists would attempt to cheat the system and identifies effective methods for their prevention. The costs of appropriate quality assurance elements have been included in the total program cost analysis for each program option.

1.4 PROGRAM COST ELEMENTS AND COSTING METHODOLOGY

Development of total program costs for each of the seven base options of Table 2 is based on a life cycle cost model which sums annual operating costs and amortized implementation and capital costs over the life of the program, and develops annualized program costs. The three principal cost categories are Initial Implementation Costs which are those expenditures required to bring a given I/M concept to the point of implementation and include design, development, documentation, training, and support personnel costs; Capital Costs which are those expenditures required for obtaining and improving land for facility sites, constructing the facilities, and procuring testing and support equipment; and Annual Operating Costs which are those expenditures necessary to administer, operate, and maintain inspection facilities and provide appropriate quality assurance, consumer protection and public information on an ongoing basis. The specific elements of each cost category are listed in Table 3 and explained in Sections 4.2.1 through 4.4.4 of Volume 2. The cost methodology is based on the following principal assumptions.

- Five-year life of program
- Amortization period of five years for equipment costs, twenty years for building costs, and perpetuity (constant value) for land
- All fringe costs to state and contractor are included
- Vehicle population growth rate of 2.8 percent per year
- Land cost estimates per square foot vary by density of land development
- Unit costs for facility construction are uniform for all options
- All costs are expressed in 1978 dollars

For the base options costing, costs were developed for a program that would cover the ozone nonattainment counties (Figure 1), which include the carbon monoxide nonattainment area of metropolitan Detroit. Only light-duty vehicles would be covered by inspection. For determining total capacity requirements, the vehicle failure rate is conservatively assumed to be 30 percent. Tests would be conducted at one or two-lane facilities using the three-position lanes described earlier. Options incorporating safety and noise testing use five position lanes. "Worst case" travel distance to a test facility (maximum) is 30 miles. An initial work schedule of 8 hours/day, 250 days/year (2,000 total hours) is assumed. The mandatory program would start January 1, 1983 utilizing implementation and construction funds made available by the end of 1982, and no additional facilities would be constructed during the life of the program; that is, vehicle population growth during 1983-87 would be accommodated by additional hours of operation.

The selected base options, and reasons for their selection, are described below. Option numbers reference Table 2.

a) State-operated, idle mode with automated testing and data processing but without safety and noise inspection (Option 1). This program is representative of any state-operated program that would involve all LDV's in the given study area.

b) State-operated, idle mode with automated testing and data processing and including safety and noise inspection (Option 2). This option develops the cost for incorporating safety and noise tests as part of the total testing procedure. This cost remains uniform (by geographic area) across all administrative or emissions test mode options.

c) Contractor-operated, idle mode with automated testing and data processing without safety and noise inspection (Option 3). This program is representative of any contractor-operated option but with cost requirements at the lowest level for any contracted system.

d) Private garage (decentralized), idle mode with manual testing and data processing without safety and noise inspection (Option 5). This was deemed the most feasible and probably lowest (total) cost representative of the range of private garage options.

e) <u>State-operated, statistical sampling program</u> with automated idle mode testing and data processing and no safety and noise check (Option 7). The State of Michigan has had experience with a program that statistically sampled vehicles for defects in safety-related equipment. The findings of this study indicated that the incidence of malfunction was relatively insensitive to the size of the sample. Therefore, statistical sampling for vehicle emission control malfunction could prove as effective as the safety testing program in identifying gross emitters. The selected option would be the least complicated of the statistical sample options, presuming the sampling rate to remain constant, across all possible configurations.

f) <u>State-operated, loaded-mode</u> with automated testing and data processing and without safety and noise testing (Option 9). This is the baseline representative of possible loaded mode configurations, selected specifically for cost comparison with Option 1.

g) <u>State-operated, EPDI inspection</u> without safety and noise check (Option 17). This option was selected specifically for cost comparison with Options 1 and 9.

Program cost development procedures are detailed in Appendix F to Volume 2, and program cost tables are presented in Section 5.0. The computed annual inspection fee per tested vehicle (1978 dollars) ranged from $5.32 for Option 1 to $21.85 for Option 17. For each option involving either a contracted or private garage testing program, a share of the fee is allocated for State costs and the remainder for the contractor or garage costs. Table 4 provides complete fee information for each of the options.

In order to develop program costs and fees for the entire set of program options, line-item sensitivity factors to estimate the costs for variation among key program elements were developed and are presented in tabular form in Volume 2, Section 6.0. An I/M program in Michigan will involve one of three inspection modes, any of six geographic areas, one of five program stringency factors (standards set such that 10, 20, 30, 40, or 50 percent of vehicles fail the inspection), one of three administrative approaches and any of six vehicle types. The values of Tables 6-2 through 6-5 of Section 6 express the sensitivities to cost (that is, the variation from the identified baseline of two-lane inspection stations for LDV testing throughout the O_3 nonattainment area) experienced as one moves along the range of possible combinations of each of the key program elements. Computations employing these factors generated a total program cost and fee breakdown for each of the remaining seventeen options of Table 2. These values are tabulated in Section 6, Table 6-1.

Table 4

	CONSUMER FEE IN 1978 DOLLARS		
OPTION NO.	STATE	CONTRACTOR OR GARAGE	TOTAL FEE
1	$ 5.32	$ .00	$ 5.32
2	7.04	.00	7.04
3	1.01	4.80	5.81
5	1.15	4.48	5.63
7	7.23	.00	7.23*
9	6.30	.00	6.30
17	21.85	.00	21.85

* This figure is reduced to $0.34 per owner if costs are equally allocated over the entire light-duty passenger vehicle population.

1.5 ELIMINATION OF UNSATISFACTORY OR INAPPROPRIATE OPTIONS

An objective of this study was to reduce the total number of candidate programs from twenty-four to a short list of three or fewer options to undergo further analysis in a later phase of the program. Although considerable information was derived from the alternatives costing analysis described above and from investigation of the relative advantages and disadvantages of the various options, it was desired to obtain additional comments and opinions on this issue from various groups representative of a larger constituency in the State of Michigan. Therefore, the decision on what options would comprise the short list was made only after extensive consultation with the Governor's Air Quality Review Committee, the Michigan Vehicles Inspection/Maintenance Advisory and

Technical Committees, the Legislative Advisory Committee, and guidance of U.S. EPA. It was also responsive to expressions of public opinion as obtained during the public hearings on the Michigan State Implementation Plan and through the medium of a public opinion poll conducted under auspices of the Michigan State Police, Office of Highway and Safety Planning.

The decision process resulted in the elimination of the following options. (Documentation of decisions is provided in Vol. 2, Section 7.0).

1. All inspection programs that include a safety and noise test.

   Key reasons were:

   - Mandatory safety and/or noise inspection programs are not currently operating in Michigan. While benefits may be realized from implementing these programs, neither will improve air quality, and both increase total program costs and costs to the consumer. The Michigan Legislature must decide if it is wise to go far beyond the intent of the Clean Air Act to include other programs within a program designed specifically to improve air quality.

   - States with safety programs currently operating question the effectiveness of safety inspections in reducing vehicle defect related accidents.

   - I/M programs that include safety and noise cost 30% more than programs testing emissions alone.

   - Experience from other safety and emissions testing programs indicates that over 50% of the tested vehicles fail the combined test. Costs for retesting failed vehicles will increase accordingly.

   - Average repair costs for vehicles needing repair will be higher.

   - Any I/M test mode is capable of identifying most of the vehicles that would fail a noise inspection, since most faulty mufflers or illegally modified exhaust systems are audible. In some cases faulty mufflers must be corrected prior to an emissions test, since exhaust leaks make it impossible to obtain accurate test results.

- Program implementation will take longer due to increased program complexity.

- It may be difficult to obtain legal authority for the combined program since the required legislation is much more complex and controversial than I/M legislation alone.

2. All options involving a statistical <u>sampling program with</u> participation not to exceed 25 percent of registered vehicles.

   Key reasons were:

   - It is not possible for the State of Michigan to demonstrate that the emission reduction from I/M required by EPA policy can be achieved by this program. This type of program may be able to demonstrate where overall emissions are, and what further reductions are possible through a vehicle I/M program.

   - Other control strategies either from stationary sources or from other transportation control strategies will be required to offset the shortfall in emission reductions obtained through this program.

   - This approach is not acceptable to the federal EPA, since it does fulfill the Clean Air Act Amendment requirement for I/M to be "mandatory and periodic".

3. All options involving a <u>State-operated network</u> of inspection stations.

   Key reasons were:

   - The initial costs to the State to implement the program are high.

   - There is uncertainty in obtaining required funds to implement the program.

   - Governmental employment will be greatly expanded as compared to other private sector administrative approaches.

   - There will be a loss of property tax revenues collected by local governments because taxes are not levied on State-owned facilities.

   - Flexibility to terminate the program is lacking.

   - Implementation time is likely to be greater due to the involvement of many state agencies, and because legal, financial, administrative, and hiring requirements are more complex in the public sector than in the private sector.

4. All options involving <u>both initial emissions testing and repair at private garages</u>.

   Key reasons were:

   - There is reluctance by the private sector and consumers to have private garages perform both the inspection and repair due to a potential and/or perceived conflict of interest.

   - A high turnover rate (10%/year) of garage ownership is experienced in Michigan. This makes it difficult to quantify program costs since the level of participation by garages is unknown.

   - Quality assurance costs are higher because instruments at many stations must be calibrated and checked for accuracy regularly. It is also necessary to check regularly for proper testing procedures and valid repairs.

   - More resources must be devoted to private garage licensing, quality control and complaint investigation than for the other administrative approaches.

   - So far, all of the states with private garage run I/M programs are states that had pre-existing safety inspection facilities. I/M was added onto their safety program. This substantially reduces planning time and capital required to implement the program. This is not the case in Michigan.

   - Most vehicles would have to be scheduled, by appointment, for inspection at a private garage, since most garages would be unable to achieve a high output rate. This increases the average workload at private garages and may increase average waiting times. In other inspection approaches, only the failed vehicles (20-30%) must schedule garage appointments. The overall effects of the added workload and its effect on program costs and consumer costs are not possible to predict at this time.

5. All options involving <u>loaded-mode inspections</u> (retaining the assumption that inspection stations could nevertheless be built to specifications that would accommodate such testing in the future.)

   Key reasons were:

   - The loaded mode test provides substantial diagnostic information. The benefit of the additional information is dependent on the mechanic's ability to use the diagnostics. So far there is no indication that mechanics effectively use this diagnostic information when repairing vehicles.

- A loaded test does not increase the amount of emission reductions obtained by the program.

- The repair industry may find it expensive and impractical to buy a dynamometer to duplicate loaded test results for repair purposes. If a repair garage cannot duplicate the test to see if repairs are correct there is a possibility of additional retests and additional consumer dissatisfaction.

- A loaded test costs 18% more than an idle test.

- If heavy duty vehicles are included in a loaded test I/M program, special double axle dynamometers will be necessary.. This substantially increases program costs.

6. All options involving <u>engine parameter/device inspection</u> (EPDI).

   Key reasons were:

   - The parameter inspection defined in this report is approximately four times as expensive as an idle test.

   - Very little information is available pertaining to the test time (and subsequently output rate at inspection stations) involved in parameter testing.

   - I/M facilities for another test mode may be designed to include flexibility to change to a parameter/device inspection test mode. If a cost effective parameter test is developed this option may be chosen.

   - EPA has not established a method for calculating emission reduction credits for this test type. Currently, the burden of proof of emission reductions from this type of program is on the individual states.

Therefore, the remaining candidate options will be carried forward for additional study.

a. Contractor-operated idle mode testing and retesting at centralized facilities.

b. Contractor-operated idle mode testing with retesting at private garages (New Jersey-type program).

c. Alternative parameter inspections (as information becomes available).

The comparative advantages of a centralized, contractor-operated program were found to be greatest for the following reasons.

- The direct costs to the State of Michigan are lowest.
- Implementation procedures are straightforward.
- This approach ranks second only to a state-operated program with respect to assured quality and consistency of test.
- Idle mode inspections were determined to be the most cost-effective testing procedure.
- Inspection facilities will remain on municipal and county tax rolls.
- The program can be more easily terminated at the end of the period of contract.
- The opportunity for conflict of interest between inspection and repair is minimal.
- The report has shown that total program costs are not significantly greater than for a similar state-operated system.

The other two options carried forward were not identified for analysis in this phase of the study.

EVALUATION OF MOTOR VEHICLE EMISSIONS INSPECTION/MAINTENANCE PROGRAMS FOR MICHIGAN

VOLUME I

Pacific Environmental Services, INC.

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VOLUME I

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Section 1

INTRODUCTION

Recent studies conducted by government agencies, independent laboratories, and the automotive industry have confirmed that pollutant emissions from automobiles can be reduced by proper vehicle maintenance and repair. These studies conclude that a vehicle emission inspection/maintenance (I/M) program that identifies those vehicles requiring maintenance/repair, and that requires the offending vehicles to be repaired, will reduce the amounts of carbon monoxide (CO) and oxidants in the ambient air.

The Clean Air Act Amendments (CAAA) of 1977 include specific provisions that require the establishment of I/M programs. According to the U.S. Environmental Protection Agency (EPA), by January 1979 each state must submit revisions to its State Implementation Plan (SIP) which specify methods to achieve the National Ambient Air Quality Standards (NAAQS). These methods include control of stationary sources of air pollution, and various transportation control measures, whose objective is to reduce vehicle miles traveled (VMT) thereby reducing pollution from mobile sources. If, in these revisions, the state cannot demonstrate that the NAAQS will be attained by 1982, an extension to 1987 must be requested, and several provisions must be met. One provision is the establishment of a specific schedule for the implementation of an I/M program. Since it is doubtful that the NAAQS can be attained in the State of Michigan through other measures, an I/M program will probably be required.

The objectives of this study are to define and evaluate alternative approaches for a vehicle I/M program for the State of Michigan. The Michigan Department of Transportation has outlined a study program to provide information on the technical and economic feasibility, and the benefits of a mandatory I/M program.

This study consists of six major tasks which are described as follows: 1) definition and review of alternative administrative I/M approaches and alternative test modes, 2) overall evaluation of alternative I/M programs, 3) detailed review of alternative I/M evaluation results, 4) identification of candidate I/M options for further study, 5) development of Task 2 program plan, and 6) final report preparation. These six tasks have been separated into two volumes.

This volume documents Task 1 wherein: (a) ownership/operation options, and (b) test modes for I/M programs are defined and reviewed:

(a) <u>Ownership/Operations</u>

- State-owned/operated centralized facilities
- Contractor-owned/operated centralized facilities
- Privately-owned/operated decentralized facilities
- Statistical sampling of vehicle population

(b) <u>Test Modes</u>

- Idle Mode - engine at idle, transmission in neutral, exhaust gas analyzed

- Loaded Mode - transmission in gear, engine loaded at one or more speeds, exhaust gas analyzed

- Engine Parameter/Device Inspection - the engine idle rpm and basic timing compared to manufacturer's specifications - positive crankcase ventilation valve (PCV), exhaust gas recirculation valve (EGR), etc., tested for proper performance - no exhaust gas analysis made

- Safety and noise inspections integrated with the above

This volume defines and reviews alternative administrative approaches and test mode options for an I/M program. It focuses on: 1) the administrative options; 2) U.S. EPA requirements for an I/M program; 3) the test mode configurations; and 4) special related topics in the Appendix.

Section 2 reviews the administrative options:

- State-owned/operated centralized facilities
- Contractor-owned/operated centralized facilities
- Privately-owned/operated decentralized facilities
- Statistical sampling of vehicle population

Section 3 presents benefit and cost information of an I/M program, and Appendix "N" (Appendix A of this report) requirements.

Section 4 discusses the test modes: 1) idle-mode, 2) loaded-mode, and 3) engine parameter/device inspection, and additional related modes, the Federal Test Procedure (FTP) and the Diagnostic Test Regime. This section also reviews the State of Michigan Safety and Noise Testing Program as it might be integrated with emission testing.

Section 5 is a glossary of technical terms used in discussing I/M programs. Section 6 contains the references, and the Appendices discussed:

- Appendix N credits (Ref. 3)
- Short-test emissions standards as related to the FTP
- Loaded-mode truth chart and diagnostic procedures
- Emissions-related parts list
- Noise testing

The information in this volume will serve as the foundation for the Task 2 evaluation.

Section 2

ADMINISTRATIVE OPTIONS

This section reviews the alternative I/M ownership/operation configurations for the State of Michigan, and provides information that will allow a comparison of the administrative options:

- State-owned/operated centralized facilities
- Contractor-owned/operated centralized facilities
- Privately-owned/operated decentralized facilities
- Statistical sampling of vehicle population

This information has been compiled from past and present I/M programs, and is organized into three subsections:

- Administrative options defined - provides working definitions for each administrative option
- Review of background information - provides an analysis of each option utilizing past and present I/M programs
- Functional comparisons between administrative options - provides a table of organization for each option by identifying ancillary organizations and their related support services.

2.1 ADMINISTRATIVE OPTIONS DEFINED

The four administrative options characterize the operational format of the inspection phase of I/M.* These administrative options are:

- State-owned/operated centralized facilities - A designated public authority assumes complete managerial and operational control of publicly-owned test facilities.

- Contractor-owned/operated centralized facilities - A corporation, selected through competitive bidding, assumes operational responsibility for inspection. The contractor and not the State assumes financial responsibility for constructing and operating test centers. Administrative control is still the responsibility of a public authority.

- Privately-owned/operated decentralized facilities - A public authority certifies and licenses qualified establishments (e.g., independent service garages and dealerships) to perform inspections. Managerial and operational authority is provided by each respective establishment. However, the State regulates and oversees the program to ensure that I/M requirements and provisions are met. This system provides a network of decentralized inspection and repair facilities which are certified and controlled by the State.

- Random sampling of vehicle population - Statistical sampling relating to an I/M program is the process of collecting I/M data (such as emission, costs, benefits, repair, etc.), to provide a basis for trend characteristics.

  The collection of such data on a certain number of vehicles from a specific vehicle population is called a sample of the data of the population, while the process (whereby the sample is selected) is called sampling. The nature of the sampling process is very likely

*Service garages, dealerships, and independents comprising the repair industry will provide the requisite maintenance for failed vehicles identified by the inspection phase.

to determine the success or failure of the deduction arrived at from the data.

It is necessary that the method of choosing the sample will ensure the sample will contain the same proportion of age/type/size/make/etc., characteristics of vehicles as contained in the total population. To achieve these objectives, a random sampling technique must be introduced. A "roulette wheel" selection of the area population could be programmed to provide for such a random selection.

A program to test a statistical sample of vehicles is an alternative to mandatory testing of all vehicles. It could be operated by either the State or a contractor, but is not an acceptable method to the EPA.

Conceptually, the selection of a specific administrative option would not have an impact on emission reduction, except in the case of a statistical sample operation, which would be less effective. However, the specific administrative option chosen will have a substantial affect on capital and operational expenditures, quality assurance, and enforcement. These issues are discussed using information from I/M programs presently operating in other states.

2.2 BACKGROUND INFORMATION OF PRESENT I/M PROGRAMS

Information on I/M programs operating in other states is summarized in Table 2-1. The programs are classified as State-operated, contractor-operated, or private-garage operated. For each program, detailed information such as responsible agency, number of vehicles tested, stringency factors, test mode used, facility site, and estimated cost data (i.e.; capital, operation, and inspection cost) is provided.

Government I/M programs can be divided into State-operated, county-operated, or municipality-operated programs. State-operated I/M programs exist in New

TABLE 2-1. EXISTING I/M PROGRAMS

PROGRAM TYPE	STATE	ADMINISTRATIVE AGENCY	VEHICLE POP (MILLIONS)	STRINGENCY OR FAILURE RATE L.D.V.	STRINGENCY OR FAILURE RATE H.D.V.*	STATIONS STATUS #Lanes	STATIONS STATUS #Sta.	STATIONS STATUS Mobile	MILLIONS OF DOLLARS Capital[a]	MILLIONS OF DOLLARS Operating[a]	INSPECTION FEE
I. GOVERNMENT											
A. State	New Jersey	DMV - EPA	3.9 LDVs	Idle 23%	NA	68	38	1	$2.50 (1972) +	1.33	$3.50 including safety
	Oregon[b] Portland	Dept. of Environ. Qual.	.550 LDVs (biennial)	Idle 40%	NA	14	7	1	$.38 Leased facil. (1975)	$2.22	$5
B. Municipal	Ohio, Cincinnati	Cincinnati APCD	.200 LDVs	Idle 30%	NA	4	1	None	$13k & safety facil.	.13 for 11 positions	$3.75 including safety
	Illinois, Chicago	Chicago Dept. Env. Control	1.0 LDVs	Idle 30-35%	NA	10	5	6	2.0 (1973)	1.45 (1977)	Program cost covered by a city sticker fee.
II. CONTRACTOR	Arizona,[c] Maricopa and Pima counties	Ariz. Dept. Health Ser.	1.1 cars, trucks, and motorcycles	Idle[d] 30%	EPA City	36	12	1	$10.5	$4.0	$5
III. PRIVATE GARAGE	Nevada (Clark Co. only)	Dept. Motor Vehicles and Dept. Human Resources	.500 LDVs	Idle	NA	218 Licensed Private Stations			0.17 (1974)	$.43 approx. (1974)	$10.00-$33.00 (including adjustments)
	Rhode Island	Dept. of Transportation	.500 LDVs	Idle 30%	NA	923 Private Garages + 1 State-Operated challenge lane			1.00 (1977)	Part of Capital cost 1st year	$4

[a] Cost data for a particular year. To update costs to present year multiply to appropriate inflation factor.

[b] State of Oregon, Oregon Environmental Quality Commission - "Report to the Oregon Legislature on the Motor Vehicle Emission Testing Program," January 14, 1977.

[c] State of Arizona, Bureau of Vehicular Emissions Inspections - "Tune-up for Less Emission,- It's Working, Arizona Vehicular Emissions Inspection Program Operations, 1977."

[d] Also test with loaded regimes.

*Definitions: DMV - Department of Motor Vehicles.
LDV - Light-Duty Vehicle (GVW <8501 lb.).
HDV - Heavy-Duty Vehicle (GVW >8500 lb.).

Jersey and Oregon. The New Jersey program, using an idle test, inspects 4 million light-duty vehicles per year, at 38 safety inspection stations. This requires a $2.5 million capital cost and $1.33 million annual operating cost. The Oregon program, which uses leased facilities, required a $0.38 million capital investment and $2.22 million yearly operating costs.

Municipally-operated programs are operating in Cincinnati, Ohio, and Chicago, Illinois. These programs inspect 0.2 to 1.0 million vehicles annually. Cincinnati has only one station (four-lane capacity) but intends to expand the program in the future. Chicago presently operates five test stations and six mobile test units. Capital and operating costs vary with the number of test stations, mobile units, and stringency factor (pass/fail emission parameters).

The only I/M program owned and operated by a contractor is located in Arizona (Maricopa and Pima Counties). The 12 test stations annually process an estimated 1.1 million vehicles using an idle-mode test with a 30 percent stringency factor. Capital costs are estimated at $10 million with annual operating costs approaching $4 million.

California conducted a 2-year pilot program (Ref. 4), operated by State personnel. At the completion of this program, California requested competitive bids from private contractors. A contractor will operate 17 test facilities. The capital costs are estimated to be $14 million, and the annual operating costs are estimated to be $22 million (Ref. 5).

Nevada and Rhode Island are the only states that have private-garage operated I/M programs at this time. Rhode Island has an extensive program testing 0.5 million vehicles at 923 certified garages. In Nevada, 218 garages are licensed. As expected, the capital cost expenditure for Rhode Island is quite large ($1 million) compared to Nevada ($170,000). The Rhode Island inspection fee is $2. The Nevada average-cost-per-vehicle ranges from $8.50 to $17, which includes the cost for vehicle adjustments when required.

Implementation problems, and their subsequent solutions, are shown in Table 2-2. The consensus is that inadequate enforcement, mechanics training, low efficiency, and adverse public reaction, are problem-areas that deserve

TABLE 2-2. TYPICAL I/M PROBLEMS, SOLUTIONS AND ACHIEVEMENTS

PROGRAM TYPE	LOCATION	PROBLEMS[a]	SOLUTIONS[a]	ACHIEVEMENTS
I. GOVERNMENT-OPERATED				
A. State-Operated	New Jersey	.2-Year Exemption for New Cars .Lack Operating Capital Capacity Improvements Cannot be Made .DMV Resistant to Increased Re-failure Rate Expected in Phase III .Refailure Rate is 25%	.Legislation Pending .Funding Has Increased $330,000 .No Position Change .Refailure Rate Now 11%	.Nation's Longest On-Going I/M Program .4,700 Garages Now Utilizing Exhaust Analyzers .Private Garage Reinspection Program
	Oregon (Portland)	.Biennial Inspection Lowers Program Effectiveness, Created Cash Flow and Personnel Problems .Tampering	.Inspection Period Will be Shortened .Trying to Implement An Annual Inspection Cycle, Requires Legislation action	.Estimates Reduction of HC is 14% and CO 7% .Private Garage Acceptance is Increasing
B. Municipal-Operated	Cincinnati, Ohio	.Low Throughput .Inadequate Enforcement .No Phase-In Period and No P.R. Program .Mechanics Inadequately Trained	.Improved Enforcement Led to Increased Throughput .P.R. Program Needed .Mechanic Training Program	.Demonstrated Short Lead Time in Adding I/M Program to Safety Program
	Chicago, Illinois	.Less Than 20% of Registered Vehicles Have Been Inspected	.Increased Enforecment Policies .Favor Mandatory Inspection with Three Conditions: 1. Fed. Govt. and Auto Manufacturer's Concurrence On Warrantee Program 2. Auto Manufacturer's Compliance With Existing Statutory Emission Standards 3. I/M Implementation Over Regional Area	.Communication Channels Established with Auto Manufacturers Regarding High Emission Levels of Late Model Vehicles .Nation's First Fully Automated Inspection Program

[a] Information provided by state personnel in each state.

(continued)

TABLE 2-2 (continued)

PROGRAM TYPE	LOCATION	PROBLEMS[a]	SOLUTIONS[a]	ACHIEVEMENTS
II. CONTRACTOR-OPERATED	Arizona Maricopa and Pima Counties	.Initial Adverse Public Reaction .Queuing Problems .Tampering .Inadequate Inspector Training	.Expected to Disappear With Increased Efficiency and Better Public Awareness .Increased Contractor Monitoring	.Nation's First Contractor-Operated Program
III. PRIVATE GARAGE-OPERATED	Nevada	.Minimal		.DMV Control of Licensing of Stations and Inspectors .Minimal Cost
	Rhode Island	.Inadequate Training of Garage Mechanics .Some Garages Violated Regulations	.On-Going Mechanic Training Program .Constant Monitoring Needed	.Program Initiated by Governor and Rhode Island DOT With Backing From Executive and Legislative Branches .State-Run Inspection Facility Used as Reference Station

[a]Information provided by state personnel in each state.

special attention. In most cases, when adequate mechanics training and public relations programs have been included in the program, the problems are minimized or resolved.

2.3 ORGANIZATION COMPARISONS

A functional block diagram shown in Figure 2-1, rather than a table of organization, identifies support services needed for an I/M program.

A State agency coordinates the efforts of all organizations involved in the program. Other responsibilities of the State agency include quality control and operational guidance of the inspection centers.

The three administrative approaches (State, contractor, and private garage) differ only in the operational format of the total I/M framework. For example, a contractor-owned/operated program (Figure 2-1a) could be responsible for its own in-house quality control program. The State would continue to provide independent quality control checks of each test station.

A decentralized (private garage) system would require State quality control checks and a State licensing and certification program for emission test facilities and mechanics.

In addition to the administrative quality control staff, the quality control section would require field personnel to operate the mobile quality audit unit and the correlation vehicle. Each test station would be periodically checked by these units. The mobile unit would check the instrumentation, and the correlation vehicle would test the total operating system of the inspection facilities.

Referee stations would be fixed facilities to provide the following services:

- Investigate consumer complaints
- Provide diagnostic capability for determining repair effectiveness
- Provide a waiver of further repair actions
- Information and direction to upgrade equipment and procedures.

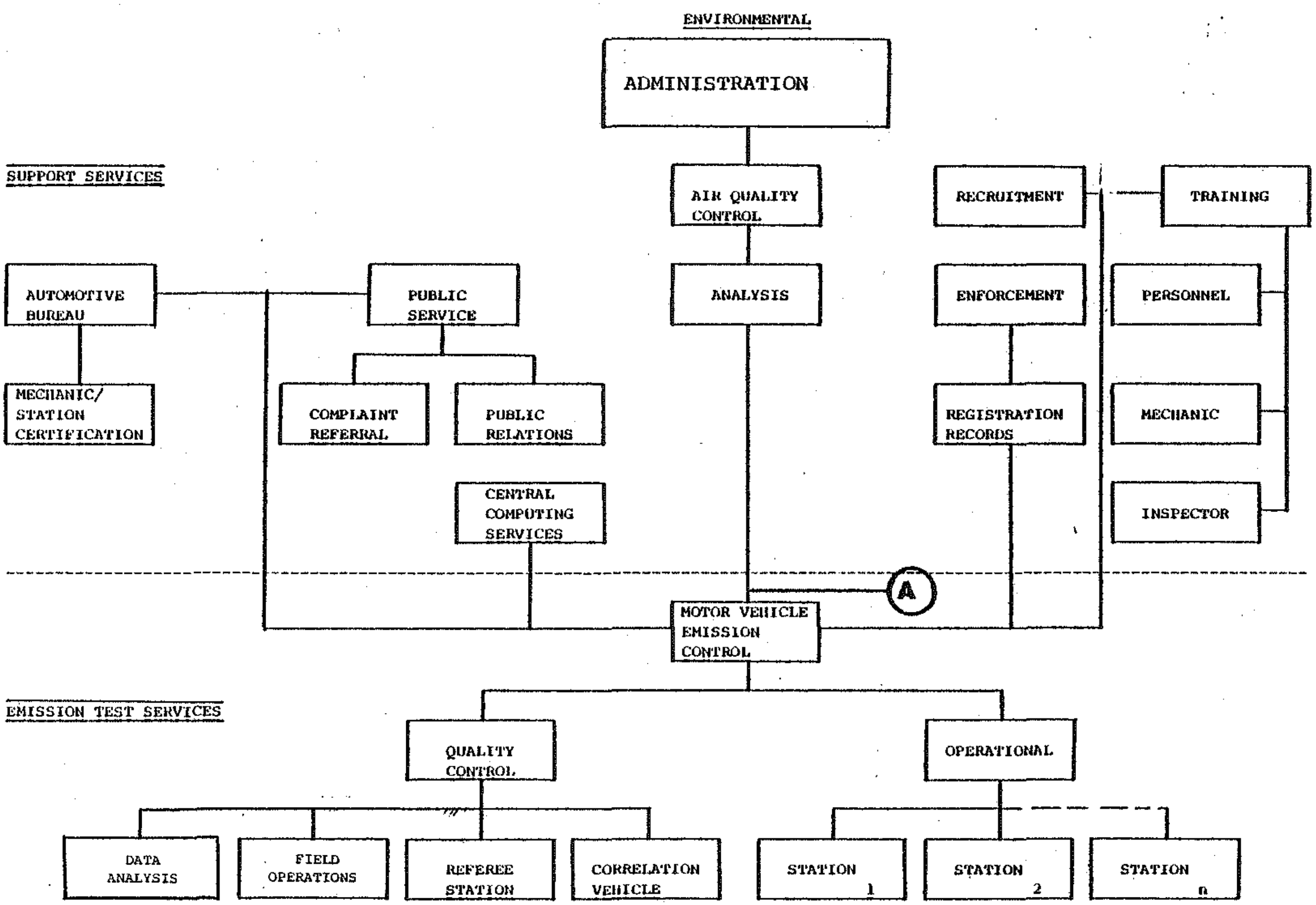

Figure 2-1. Functional administrative chart

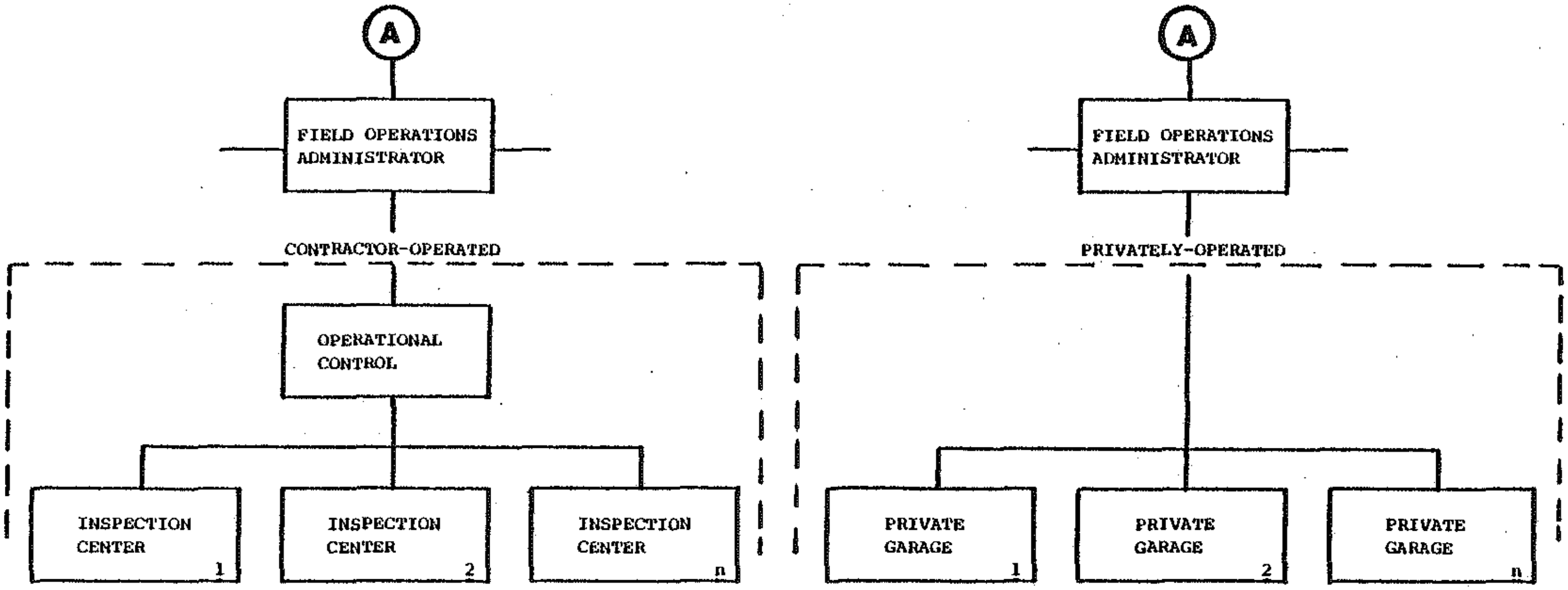

Figure 2-1a. County administered

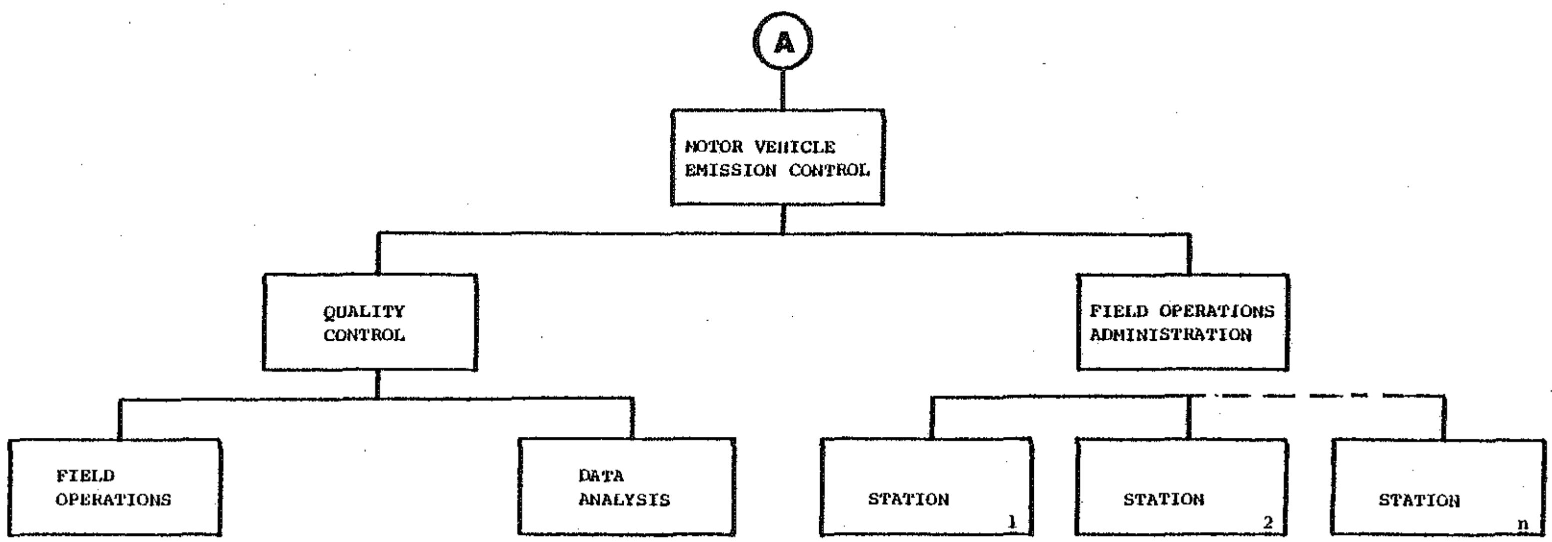

Figure 2-1b. Modifications to reflect contractor decentralized (private garage) system and county administered system

Section 3

BENEFIT AND COST OF I/M PROGRAM

I/M program benefits can include fuel savings, improved vehicle performance, increased vehicle life, and the primary objective of I/M programs, the reduction of pollutant emissions. Costs of an I/M program include capital costs of the test facilities, operating costs of the test facilities, program administration, and failed vehicle repair costs. Capital and operating costs are offset by an inspection fee paid by the vehicle owner. Repair costs are normally paid by the vehicle owner, but are shared by vehicle manufacturers when emission-related parts fail, and are replaced under warranty.

3.1 EMISSION REDUCTION BENEFITS

I/M programs will reduce pollutant emission from automotive vehicles by requiring repair of those vehicles which fail to meet the emission standards. The benefits are reduced atmospheric pollutants, and compliance with the Clean Air Act Amendments (CAAA).

Automobiles emit three major polluting gases: hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x). CO is a colorless, odorless gas produced by the incomplete burning of fossil fuels. When breathed, CO reduces the oxygen available to the brain and body cells and puts an extra burden on the heart and lungs.

HC and NO_x interact in the presence of sunlight to form photochemical oxidants (smog). Ozone (O_3), the main constituent of photochemical smog, causes irritation to the eyes and mucous membranes, and aggravates existing respiratory illnesses.

3.1.1 Appendix N - Emission Reductions Achievable Through Inspection and Maintenance of Light-Duty Vehicles, Motorcycles, and Light-Duty Trucks

Appendix N is part of the Federal Regulations, and is published in Part 51, Chapter 40, Code of Federal Regulations. A revision to Appendix N has been proposed by the U.S. EPA (Federal Register, May 2, 1977), and is expected to be promulgated in 1979. The revised Appendix N is included as Appendix A to this report.

Appendix N defines minimum requirements for an I/M program to be adopted by a State, and states that:

"Basic program requirements. There are two basic types of operation which may be utilized for an I/M program, namely a centralized inspection system (government or contractor-operated) and a decentralized inspection system (private commercial garages). In order to obtain full emission reduction benefits for either a centralized or decentralized inspection system, certain minimum requirements are established, which if not met, will result in assessed emission reduction lower that those listed in Tables 1 through 5 of this Appendix.

"a. Program requirements--Minimum for all programs.

   i. Provisions for regular periodic inspection (at least annually) of all vehicles for which emissions reductions are claimed.

   ii. Provisions to ensure that failed vehicles receive the maintenance necessary to achieve compliance with the inspection standards. The basic method is to require that failing vehicles pass a retest following maintenance.

   iii. Provisions for quality control. The reliability of the inspection system and equipment accuracy must be ensured. This will include routine maintenance, calibration and inspection of all I/M equipment, and routine auditing of inspection results.

"b. Minimum decentralized program requirements. In order to receive the basic emission reduction benefits for a decentralized I/M program, the following requirements must be included in addition to provisions listed in Section 5(a).

   i. Provisions for the licensing of inspection facilities which insure that the facility has obtained, prior to licensing, analytical instrumentation which has been approved for use by the appropriate governing agency. A representative of the facility must have received instructions in the proper use of the instruments and in vehicle testing methods. The facility must agree to maintain records, to collect signatures of operators whose vehicles have passed inspection, and to submit to inspection of the facility.

ii. Records required to be maintained should include the description (make, year, license number, etc.) of each vehicle inspected, and its emissions test results. Records must also be maintained on the calibration of testing equipment.

iii. Copies of these inspection records should be submitted on a periodic basis to the governing agency for auditing.

iv. The governing agency should inspect each facility at least once every 90 days to check the facilities' records, check the calibration of the testing equipment and observe that proper test procedures are followed.

v. The governing agency should have an effective program of unannounced/unscheduled inspections both as a routine measure and as a complaint investigation measure. It is also recommended that such inspections be used to check the correlation of instrument readings among inspection facilities."

Emission reductions attainable through in I/M program are documented in Appendix N. In the revised Appendix N, I/M effectiveness is given as a function of the levels of technology employed to: reduce pollutant emissions in vehicles; the stringency of the emissions standards; the number of years the program has been in force; and the adequacy of mechanic training. Other factors used to calculate program effectiveness are: the number of vehicles in each age group (model-year); and the average number of miles each age group is driven annually.

Credits are used to determine effectiveness. The units of credits are HC% and CO%, and represent the approximate amounts of HC and CO emission reductions accomplished by the program. The number of credits per program vary with: the stringency of the program; the age of the program; the adequacy of the mechanics training; and the number of Technology I and Technology II vehicles in the program.

Two levels of emission control technology are used to classify light-duty vehicles, and to determine credits. All light-duty vehicles built prior to model-year 1975 are Technology I vehicles. All 1975 and subsequent model-year light-duty vehicles are classified as Technology II vehicles. The general use of catalytic converters in 1975 and newer vehicles is a prime difference between Technology I and Technology II vehicles.

The stringency of an I/M program is measured by the stringency factor which is defined in Appendix N as follows:

> "Stringency factor is a measure of the rigor of a program based on the estimated fraction of the vehicle population whose emissions would exceed cutpoints for either or both carbon monoxide and hydrocarbons were no improvements in maintenance habits or quality of maintenance to take place as a result of the program."

The stringency of the emissions standards has a direct relationship with the effectiveness of an I/M program. High stringency factors provide more credits than lower stringency factors since more vehicles will fail the test because of lower cutpoints required by higher stringency factors. These lower cutpoints (lower percentages of CO and HC in the exhaust for pass/fail points) also require that the failed vehicles be adjusted and/or repaired to provide lower emissions to pass the retest. Since more vehicles will fail high stringency tests, and the failed vehicles must pass the retest at low emission levels, the emissions reduction is greater than provided by lower stringency factors.

Stringency factors greater than 0.50 are not used because they may be counterproductive. This is due to the poor correlation between the short-cycle tests used in I/M programs, and the FTP used to certify vehicles. The short-cycle tests with high cutpoints are effective in predicting high FTP emitters, but are not consistent predictors when stringency factors higher than 0.50 are used. If stringency factors greater than 0.50 are used, some of erroneously failed vehicles, could produce high levels of HC and CO after repair. An analysis of data presented in Appendix B supports this possibility.

The stringency factor and the fraction of inspected vehicles failed (failure rate) may be nearly the same the first year the I/M program is in force, but they may differ due to quality of maintenance provided to the vehicle population, and the validity of the cutpoints used. In subsequent years of testing, the fail rate can be lower than the stringency factor if vehicle maintenance and repair meet high standards.

For any inspection year, Appendix N provides first-year credits (CO and HC reduction in percent) for all model-year vehicles inspected as a function of stringency. The credits for Technology I vehicles and Technology II are different for every stringency factor except the HC% for stringency factor 0.30 as shown in Table 3-1. Those vehicle classes which have been inspected two or more times, gain additional credits up to the maximum for eight or more inspections, as shown in Table 3-2. Subsequent-year credits are the same for Technology I and Technology II vehicles.

When mechanics training is a part of the program, additional credits may be added. As with the basic credits, first-year credits are applied to all vehicles inspected, and subsequent-year inspection credits are additive. Different percentages are shown for Technology I and Technology II, and all mechanics training credits are a function of the stringency factor. The U.S. EPA determines what percentage of the maximum credits shown in Tables 3-3 and 3-4 can be used.

An example of the reductions in CO and HC emissions that could be achieved for calendar year 1987, as a function of I/M program starting date and stringency factor used, is shown in Table 3-5.

3.2 OTHER I/M BENEFITS

3.2.1 Fuel Savings

There are fuel savings for owners of vehicles that have been repaired to meet the emission levels mandated by an I/M program. The reduction of CO and HC in the exhaust emission is due (in part) to more complete combustion of the fuel by the engine (particularly in Technology I vehicles), resulting in improved mileage because more useful energy is extracted from a given amount of fuel. The fleet wide fuel savings are a function of many variable. The stringency factor, the number of miles traveled, the number of vehicles inspected, and the improvement in fuel consumption for failed vehicles after repair are particularly important. They are related to the fleet fuel saving in the following manner:

Table 3-1. FIRST YEAR OF PROGRAM CREDITS

STRINGENCY FACTOR	PERCENT HC Technology I	HC Technology II	CO Technology I	CO Technology II
0.10	1	1	3	8
0.20	5	3	8	20
0.30	7	9	13	28
0.40	10	16	19	33
0.50	11	24	22	37

Table 3-2. SUBSEQUENT YEARS PROGRAM CREDIT

NUMBER OF INSPECTIONS	ADDITIVE CREDIT HC (%)	ADDITIVE CREDIT CO (%)
2	7	8
3	14	15
4	20	19
5	25	23
6	30	27
7	33	30
8 or more	36	35

Table 3-3. MECHANIC TRAINING FIRST YEAR CREDITS

STRINGENCY FACTOR	TECHNOLOGY I HC (%)	TECHNOLOGY I CO (%)	TECHNOLOGY II HC (%)	TECHNOLOGY II CO (%)
0.10	1	5	3	7
0.20	3	7	5	10
0.30	4	9	4	10
0.40	6	8	1	7
0.50	7	7	1	5

Table 3-4. MECHANIC TRAINING SUBSEQUENT YEAR CREDITS

	TECHNOLOGY I			
	NUMBER OF INSPECTIONS			
	2		3 or more	
STRINGENCY FACTOR	HC (%)	CO (%)	HC (%)	CO (%)
0.10	3	3	15	18
0.20	4	8	10	15
0.30	6	5	9	9
0.40	5	5	5	5
0.50	3	2	3	2

	TECHNOLOGY II	
	NUMBER OF INSPECTIONS - 2 OR MORE	
STRINGENCY FACTOR	HC (%)	CO (%)
0.10	10	4
0.20	8	2
0.30	2	1
0.40	1	3
0.50	1	1

TABLE 3-5. LIGHT-DUTY VEHICLE EXHAUST EMISSION REDUCTIONS FROM INSPECTION/MAINTENANCE PROGRAMS AS OF DECEMBER 31, 1987

		BASIC PROGRAM		W/MECHANICS TRAINING[a,b]	
STRINGENCY FACTOR %	STARTING DATE[c]	CO (%)	HC (%)	CO (%)	HC (%)
10	07/01/80	22.7	26.0	46.8	42.5
	07/01/81	21.5	24.7	46.0	42.3
	07/01/82	19.6	22.6	43.2	39.0
	12/31/82	18.3	20.8	41.6	37.3
20	07/01/80	29.3	30.4	54.2	49.0
	07/01/81	27.9	28.7	52.0	47.2
	07/01/82	25.9	25.7	50.2	45.3
	12/31/82	24.5	23.9	48.8	43.6
30	07/01/80	34.0	33.6	57.7	52.1
	07/01/81	32.3	32.6	56.3	50.9
	07/01/82	30.4	30.0	54.5	49.3
	12/31/82	28.6	27.5	53.2	47.6
40	07/01/80	38.2	35.7	61.1	57.7
	07/01/81	36.6	34.2	59.8	54.3
	07/01/82	34.3	31.8	57.9	53.1
	12/31/82	32.8	30.0	56.5	51.2
50	07/01/80	41.4	36.8	62.5	57.2
	07/01/81	40.0	35.5	61.1	56.1
	07/01/82	37.9	32.9	59.3	54.3
	12/31/82	35.5	31.0	57.9	52.8

NOTE: Policy guidance regarding the utilization of of I/M credits is due in November 1978.

[a] Assumptions:

1. All model years are included in the program.
2. Nationwide averages of vehicle mix by model year plus distribution of vehicle miles traveled by model year are assumed.

[b] Utilization of all or part of this credit can be made with USEPA approval.

[c] Mandatory repair for failed vehicles is initiated on this date.

Ref: "Motor Vehucle Emission Inspection/ Maintenance Information Kit," EPA-460/3-78-013

$$F_s \alpha \quad V_m \times T_v \times F_s \ (F_{ca} - F_{cb})$$

where:

F_s = Fuel saved per year (gallons)

V_m = Average miles per vehicle year $(\frac{\text{Miles}}{\text{Vehicle Year}})$

T_v = Total number of vehicles inspected (Vehicles)

S_f = Stringency factor (No Units)

F_{ca} = Average fuel consumption after repair $(\frac{\text{Gallons}}{\text{Miles}})$

F_{cb} = Average fuel consumption before repair $(\frac{\text{Gallons}}{\text{Miles}})$

Results of preliminary studies indicate that fuel economy can be increased from 3.0 to 3.8 percent (Ref. 5). Other reports indicate fuel savings from 0 to 12 percent. The amount of fuel savings depends on the nature of the vehicle population and the I/M program (Ref. 6,7,8). The methodology for calculating fleet wide fuel savings is expanded and applied in Volume II, Section 2.

3.2.2 Performance and Increased Vehicle Life

Although studies to date have not been conclusive, it seems reasonable to assume that a properly maintained vehicle will experience less wear than if it is not maintained to manufacturer's specifications. If this relationship is true, an I/M program will have a positive effect on vehicle life, and emissions will be reduced to its minimum pollution capability after it is repaired to the manufacturer's specifications.

3.2.3 Warranty Benefits

The emission control system performance warranty, contained in Section 207 of the Clean Air Act, may provide possible benefit to motor vehicle owners under an I/M program. Section 207 of the Clean Air Act mandates a new vehicle and engine emission warranty that includes a general defects warranty in 207(a), a performance warranty in 207(b)*, and an enforcement and recall provision in 207(c). Section 207(a) has generally been interpreted to require manufacturers to warrant vehicles or engines to be free from defects in materials and workmanship that will cause them to violate applicable regulations, including applicable emissions standards.

An applicable list of emissions control items is presented in Appendix D. It is assumed that failure of these items would degrade the emissions performance of a vehicle. Section 207(b), which specifies a performance warranty generally provided for in 207(a), cannot be implemented at the Federal level until the administrator promulgates a correlatable short emissions test on which the performance warranty can be based. When the EPA determines that a short test is available which is "reasonably capable of being correlated" with the official certification test, manufacturers will be liable to correct vehicles which fail such a test regardless of whether any specific part defects have been identified.

Manufacturers argue that the Clean Air Act Amendments of 1977 showed that Congress intended to limit the 207(b) performance warranty to "hang-on" components only (e.g.; air pump, catalyst, EGR valve). Congress has diminished the scope of the 207(b) warranty to some extent and its interpretation needs clarification.

It is assumed that the 207(b) warranty presently applies only to "hang-on" components after 24,000 vehicle miles. Before the 24,000-mile point has been reached, however, 207(b) applies to a broader range of emissions-related components. This range is, as yet, undefined, since the EPA has failed to promulgate a specific list.

Congress did not amend the scope of the 207(a) defects warranty. It still applies to a broader range of emissions-related components (as yet undefined on a Federal level) for the full useful life period of 50,000 miles. The warranty, however, has limits with respect to abuse, neglect or improper maintenance.

*Performance warranty means a warranty that a vehicle's emission will not exceed the certification emission standards for its useful life, as evidenced by a correlatable short test.

In 1977, the State of California completed a surveillance test program on 1975 and 1976 model-year vehicles (Ref. 7). These vehicles were testing using:

- FTP 75 test used in new car certification
- Federal Highway Fuel Economy Test (HFET)
- Loaded-mode test
- Acceleration/deceleration driving sequence EPA modal test
- Sealed housing evaporative determination (SHED) test

Only 9 percent of the failed vehicles were failed due to defective components. These defective components may not have been covered by warranty because of:

- Lack of maintenance
- Abuse of vehicle
- Other noncovered reason

It is obvious that the subject of warranty repair work performed requires further study.

3.3 COSTS OF AN I/M PROGRAM

I/M program costs vary substantially depending on the type of administration, the type of test, the stringency factor, and the local economic conditions (e.g.; labor rates, land cost, etc.). The costs of an I/M program include implementation, capital, and operating costs. To the vehicle owner, there are inspection fees and repair costs. This subsection presents information on costs of existing I/M programs.

3.3.1 Implementation, Capital and Operating Costs

Capital costs for an I/M program include all the costs accrued to provide the test facilities. These include; construction costs; land costs; test equipment costs; other equipment costs (tools, desks, chairs, etc.).

Implementation cost includes all cost to develop the operational details of the program, such as procedures and training plans to make the inspection facilities ready for operation.

Operating costs include: costs of hiring and training personnel; salary costs (wages and benefits); utility costs (gas, electricity, water, telephone); taxes (property, payroll, supplies, etc.); costs of consumable supplies (paper, calibration gases, etc.); cost to repair and maintain facilities and equipment; travel and transportation costs; demurage costs for calibration gas bottles; cost of mechanic training program; and interest costs on money borrowed for capital expenditures. Operating costs include all costs of those items required to provide continuing operation of the facilities.

Costs of existing I/M programs were presented in Table 2-1. In the New Jersey State-operated program, the capital cost per inspection lane was $36,800; the average operating cost was $19,600 per lane per year. The New Jersey program also includes safety inspection. The State of Oregon had a lower capital cost by leasing the test facilities. Total capital costs for the test equipment and mobile vans was $380,000. The operating cost was $2.22 million for biannual inspection of approximately 0.5 million vehicles.

3.3.2 Consumer Inspection Fee

Vehicle owners pay an inspection fee in most states. This fee offsets the capital and operating costs of the program. The inspection fees for existing I/M programs range from $3.50 to $12. (In Nevada, the fee includes the cost of vehicle adjustments (when required) and varies from $10 to $33.)

3.3.3 Repair Costs

In addition to the emission inspection fee, the consumer absorbs the cost of repair if the vehicle fails the emission test. Several studies have dealt with the vehicle repair costs that result from failure of an exhaust emission inspection. Repair costs depend primarily on the scope of engine adjustments and/or tune-up required to pass the retest, level of mechanics training, the usefulness of the repair instructions given to mechanics, the general condition of the vehicle, and the technology employed in the vehicle (Technology I or Technology II). Detailed maintenance procedures have been prepared to aid mechanics to diagnose engine malfunctions. Unnecessary repairs can be drastically reduced when mechanics are instructed in proper engine diagnostics.

Major report conclusions relating to repair costs for vehicles failing emission inspection criteria are:

1. Olson Laboratories, The Short-Cycle Project; Effectiveness of Short Emission Inspection Tests in Reducing Emissions Through Maintenance (1973) (Ref. 10)

   The average repair cost for servicing vehicles that failed an idle test was $29.13 when diagnostic information was provided for the mechanics diagnostic routine. In contrast, the average repair cost for servicing vehicles that failed the loaded test without diagnostic information provided to the mechanic was $35.20.

   An approximate average unnecessary cost of $10 was incurred in repairing failed vehicles based upon a review of actual repairs accomplished versus the repairs indicated by the diagnostic information.

   An approximate average unnecessary cost of $4 was incurred in repairing failed vehicles after a more thorough training of repair shop mechanics was completed.

2. Elston and Cooperthwait, New Jersey's Auto Emission Inspection Program: An Assessment of One Year's Mandatory Operation (June 1975) Ref. 11)

   During the first year of mandoatory I/M 80 percent of all failed vehicles in New Jersey required only idle adjustments or minor tune-ups. The average repair cost for all failed vehicles was less than $40. Repair cost ranges were idle adjustment, $0 to $10; minor tune-up, $13 to $40; major tune-up, $30 to $100; engine overhaul, over $100.

3. Scott Research Laboratories, Inc., Exhaust Emission and Test Evaluation of the State of California Roadside Idle Emission Inspection Program and State of California Evaluation of Mandatory Vehicle Inspection and Maintenance Programs (Ref. 12)

In this study, approximately 100 vehicles failed to pass inspection requirements; subsequently, they were directed to 34 different Class A repair stations located in the San Bernardino and Riverside areas of California. The average repair costs by model-year are shown in Table 3-6.

TABLE 3-6. AVERAGE REPAIR COST BY VEHICLE MODEL-YEAR

Model-Year	Vehicles Repaired	Repair Cost
1966	10	$29.39
1967	13	37.89
1968	13	42.10
1969	14	37.72
1970	24	21.23
1971	16	32.49
1972	8	33.47
1973	2	26.10
1975[a]	33	53.00

[a]Riverside data - range $8 to $175 (Ref. 2).

Technology I vehicles manufactured in 1967 through 1969 had comparatively high average repair bills. In contrast, late-model Technology I vehicles (1970 to 1973) were slightly lower. Technology II vehicles (1974 model-year only) had a higher average cost than any Technology I vehicles.

4. State of Arizone, Arizona Vehicular Emissions Inspection Program Operation 1977

In this report, repair costs were listed by type of repair facility and by two vehicle categories--vehicles manufactured without any exhaust emissions controls (model-years 1964-1967) and vehicles with exhaust emissions controls (1968-1977 model-years). No distinction between Technology I and Technology II for the second category vehicles was made. The costs are shown in Table 3-7.

TABLE 3-7. ARIZONA - DECEMBER 1977 REPORT (Ref. 13)

Type Facility	1964-1967	1968-1977	1964-1977
Franchised Dealers	$41.25	$26.82	$27.97
Service Stations	23.06	19.81	21.14
Merchandisers	15.53	20.29	19.43
Tune-up Specialists	36.19	22.86	24.72
Independent Garages	21.33	27.46	26.79
"Do-It-Yourselfers"	14.27	20.61	19.08

Dealerships, as indicated in this survey, have the highest average repair costs.

5. Clean Air Research Company, An Evaluation of the Effectiveness of Automobile Engine Adjustments to Reduce Exhaust Emissions (Ref. 14)

The average cost to repair 300 vehicles was $27.47 per vehicle for both controlled (Technology I), and uncontrolled vehicles, representing the 1957 to 1970 California vehicle population.

6. Additional Repair Cost Studies - Additional repair cost studies are presented in Table 3-8.

TABLE 3-8. AVERAGE REPAIR COST FOR FAILED VEHICLES

	Idle	Loaded	Stringency Factor
California Study (Ref. 5)	$21	$23	35%
Northrop (Ref. 9)	34	30	50
EPA (Ref. 15)	26	28	50
Olson (Ref. 16)	26	-	50

Both the idle and loaded emission inspection programs can be performed on a cost/benefit basis if the cost of I/M is measured against the amount of emission reduction and fuel savings achieved. For most owners of failed vehicles, the cost of repair is well within acceptable limits. For the very small percentage of vehicles that would require a major tune-up or an engine overhaul to meet established emission criteria, states can set a ceiling on the maximum dollar amount that would be required to be paid for emissions-related adjustments.

Repair Cost Ceilings, from a California study (Ref. 5), examines the effect on I/M program benefits (improved fuel economy, reduced CO and HC emissions), when the failed vehicles with the highest costs-to-repair are exempted from repair. This table indicates that some failed vehicles can be exempt from repair without producing a mathematical significant reduction in program benefits. For example, when idle tests were used, there was no significant increase in benefits derived from repairing those vehicles with repair costs over $100. When a loaded test was used, the cost was $120. This data indicates that exceptional economic hardships on vehicle owners can be eliminated by exempting those vehicles from repair when repair costs exceed the established maximum without significantly reducing the program benefits. The increase in public acceptance of an I/M program that provides for exemption based on repair cost ceilings should be weighted against any decrease in program benefits that would result from exemptions.

Section 4

TEST MODES DEFINITION

In reviewing the emission test modes, safety and noise will be integrated into each. The short test modes are:

- Idle
- Loaded
- Functional

4.1 FEDERAL TEST PROCEDURE

The Federal Test Procedure (FTP) is used to ensure that all vehicles meet the emission requirements promulgated for their model-year as defined in Table 4-1. The FTP provides the most reliable measure of exhaust gas emissions, and is used by the Federal government as a baseline emission test. The FTP requires a preconditioning period called a cold soak, that requires the vehicle to remain inoperative for at least 12 hours prior to the emission test. The test is performed on a chassis dynamometer which provides road-load and inertia simulation. The dynamometer must also measure the distance traveled during the test. The vehicle is operated over a driving schedule (simulating a typical urban route) requires approximately 41 minutes to complete. The driving schedule has three distinct phases: cold transient; cold stabilized; and hot transient. Exhaust gas samples are collected in bags for each phase of the driving schedule by a constant volume sampler (CVS).

Each sample is analyzed for hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2) and oxides of nitrogen (NO_x).

TABLE 4-1. VEHICLE EXHAUST EMISSION STANDARDS
(LOW-ALTITUDE, NONCALIFORNIA EMISSION STANDARDS)

1. LIGHT-DUTY VEHICLES

Model Year	Hydrocarbons	Carbon Monoxide	Oxides of Nitrogen
Pre-1968	no standard	no standard	no standard
1968-1969	*410 ppm mole volume	*2.3% mole volume	no standard
	*350 ppm mole volume	*2.0% mole volume	no standard
	*275 ppm mole volume	*1.5% mole volume	no standard
1970-1971	1/ 2.2 gm/mi	23 gm/mi	no standard
1972	2/ 3.4 gm/mi	39 gm/mi	no standard
1973-1974	3.4 gm/mi	39 gm/mi	3 gm/mi
1975-1973	3/ 1.5 gm/mi	15 gm/mi	3 gm/mi
1977-1979	1.5 gm/mi	15 gm/mi	2.0 gm/mi
1980	0.41 gm/mi	7.0 gm/mi	2.0 gm/mi
1981+	0.41 gm/mi	3.4 gm/mi	1.0 gm/mi

*Emission standard varied with vehicle's engine displacement; using 7-mode driving cycle test

1/ Using 7-mode test
2/ Using 1972 FTP
3/ Using 1975 FTP

2. LIGHT-DUTY TRUCKS (LDT)

a. LDTs less than 6,000 pounds curb weight:

Model Year	Hydrocarbons gm/mi	Carbon Monoxide gm/mi	Oxides of Nitrogen gm/mi
Pre-1975	SAME STANDARDS AS LDVs (AUTOMOBILES)		
1975-1978	2.0	20	3.1
1979-1982	1.7	17.9	2.3
1983-1984**	0.99	9.4	2.3
1985+**	0.99	9.4	1.5

b. LDTs between 6,001 and 8,500 pounds:

Model Year	Hydrocarbons gm/mi	Carbon Monoxide gm/mi	Oxides of Nitrogen gm/mi
Pre-1979	SAME STANDARDS AS HEAVY-DUTY GAS VEHICLES		
1979-1982	1.7	17.9	2.3
1983-1984**	0.99	9.4	2.3
1985+**	0.99	9.4	1.4

**Predicted standards

(continued)

TABLE 4-1. (continued)

3. HEAVY-DUTY GASOLINE VEHICLES

Model Year	Standards
Pre-1970	no standards
1970-1973	CO = 1.5% mole volume
	HC = 275 ppm mole volume
	NO_x = no standard
1974-1978	1/ CO = 40 grams per bhp-hr
	2/ HC plus NO_x = 16 grams per bhp-hr
	3/ CO = 25 gm/bhp-hr
	4/ HC = 1.5 gm/bhp-hr
	5/ HC + NO_x = 10 gm/bhp-hr
1983-1984	CO = 29.7 gm/mi*
	HC = 2.85 gm/mi*
1985+	NO_x = 5.35 gm/mi

1/ g/mi equivalent standard is 159 gm/mi Co
2/ g/mi equivalent standard is 12.4 gm/mi HC and 15.3 g/mi NO_x
3/ g/mi equivalent standard is 140 gm/mi CO
4/ g/mi equivalent standard is 3.2 gm/mi HC
5/ g/mi equivalent standard is 13.3 gm/mi NO_x

4. HEAVY-DUTY DIESEL VEHICLES

Model Year	Carbon Monoxide	Hydrocarbons plux Oxides of Nitrogen
Pre-1973	no standard	no standard
1973	1.5%	no standard
1974-1978	40 g/bhp-hr	16 g/bhp-hr
1979-1982	25 g/bhp-hr	1.5 gm /bhp HC and 10g NO_x or: 5g HC + NO_x
1983+*	SAME AS GASOLINE HDV's	

5. MOTORCYCLES

Model Year	Hydrocarbons	Carbon Monoxide	Oxides of Nitrogen
Pre-1978	no standard	no standard	no standard
1980-1982	5-15 gm/km	17 gm/km	no standard
1980	5 gm/km	12 gm/km	no standard
1983*	0.97 gm/km	12 gm/km	no standard
1985*	0.97 gm/km	12 gm/km	0.14 g/km

*Predicted standards

Alternative test procedures should be evaluated on their ability to correlate with the FTP. ^ppendix B contains data that correlates the idle- and load-mode test procedures for light-duty vehicles (LDV). While the FTP reads in grams-per-mile, the idle- and loaded-mode short tests used in I/M programs provide readings in parts-per-million (ppm) mode volume.

4.2 DIAGNOSTIC INSPECTION TEST MODE

The most sophisticated inspection and test concept involves a chassis dynamometer, an oscilloscope, and other engine analysis equipment operated by a skilled diagnostician, following a well-developed procedure, who can analyze faulty engine operation and specify the necessary repair(s) (Ref. 17). A chassis dynamometer is used to simulate road-load at idle, full throttle, cruise, and a transient deceleration mode. During each of the operating modes, the exhaust is analyzed for HC. CO is measured in all modes except deceleration. Vehicles exceeding the established limits are diagnosed using the oscilloscope. The patterns displayed for common malfunctions are illustrated, and serve as a diagnostic aid.

The test procedure includes engine-load modes that stress certain emission-critical components. Components that fail during the stress conditions may be marginal under normal operating conditions. Replacement of these marginal components may preclude subsequent failure and resultant high exhaust emissions.

The diagnostic test identify specific component failures and direct the vehicle owner to accomplish specific repairs. This technique could reduce the owner's repair costs. A sample of a typical diagnostic analysis report is shown in Table 4-2.

4.3 IDLE INSPECTION TEST MODE

Although various emissions studies indicate very low correlation between the idle-mode test and the FTP, the idle-mode test does identify FTP high emitters.

TABLE 4-2. DIAGNOSTIC ANALYSIS REPORT
(REF. 3)

S	U	Function
		Air Cleaner
		Heat Riser
		Carb. Choke Action
		Rhythm Test
		PCV Valve Action
		Air Injection Pump
		Air Injection Check Valves
		Gulp Valve
		Emission System Hose Cond.
		Polarity
		Cap
		Rotor
		Condenser
		Coil
		Idle Speed Spec ______ Actual ______
		Dwell Spec ______ Actual ______
		Timing (Vac Hose Off) Spec ______ Actual ______
		Mechanical Advance (Vac Hose Off) Spec ______ Actual ______
		Total Advance (Vac Hose On) Spec ______ Actual ______
		Vacuum Advance (Total-Mech Advance) Spec ______ Actual ______
		Firing Order __ __ __ __ __ __ __ __ Power Drop Test (5 Sec per Cycle) __ __ __ __ __ __ __ __
		Plug Condition-Idle
		Carb - Idle AFR ______ CO ______
		Plug Condition - Loaded
		Carb - Power AFR ______ CO ______
		Plug Wires
		Points
		Detonation
		Carb - Cruise AFR ______ CO ______
		Carb Surges
		Blow - By
		Valve Action
		Knocks
		Head Gasket (On decel - use Bloc Chek) NOTE: Remove & replace radiator cap above 2000 RPM

Car Number ______
License Number ______
Date ______
Test Start Time ______

S	U	Visual Check
		Battery Appearance
		Cables
		Belts
		Hoses
		Radiator
		Oil Leaks
		Fuel Leaks

REPAIR INSTRUCTIONS

Test Completion Time ______

REMARKS -

Recent studies by some automobile clubs, the California Air Resources Board (ARB) and the State of New Jersey, indicate that the emission measurement at idle engine speed is capable of identifying high emitters of HC and CO (Ref. 18). However, NO_x cannot be successfully measured at idle, since it occurs under loaded conditions (low and/or high cruise-open-throttle operation).

In the idle inspection test, the engine is run until proper operating temperature is reached. While the engine is operating at idle, a sample of the exhaust is analyzed for HC and CO concentrations, and the results recorded. If the vehicle does not pass the established emission limits, it will be required to be repaired.

The term "two-speed idle" is frequently used to describe this test since the vehicle is also operated at higher rpm (2,500) as part of the inspection test cycle. Vehicle system malfunctions which result in high emissions at idle rpm, frequently contribute to high emissions over a typical load/speed range as measured by the standard Federal test. However, the sensitivity of idle testing can be improved by performing additional testing at higher engine speeds. The loads during higher rpm operations, provide an opportunity to measure effectiveness of off-idle carburetor circuits and to detect additional malfunctions that can contribute to high emissions. During the idle test procedure, engine operations and emission measurements are accomplished at 2,500 rpm, prior to performing idle measurements. This sequence provides the opportunity for engine temperature stabilization.

A description of a typical idle test sequence, and diagnostic information when the vehicle fails is:

A. <u>Pre-Test</u>

Prepare vehicle and equipment for test:

1. <u>Test Equipment</u> - Service, warm up, and calibrate HC/CO test equipment per manufacturer's specifications

2. Test Vehicle - Verify engine is at normal operating temperature (warm up as required)

3. Hook-Up - Insert probe in exhaust pipe (driver's side, if dual exhaust), hook up tachometer per manufacturer's instructions

B. Test

Perform HC/CO and rpm measurements and compare to idle test standards:

1. High-Idle - Operate engine in neutral at 2,500 rpm and record HC/CO measurements.

2. Low-Idle rpm - Operate engine at low idle rpm and record HC/CO measurements. If the vehicle is equipped with an automatic transmission, it is placed in drive during the low-idle portion of the test to duplicate its use during normal driving.

C. Diagnostic Information

High HC - High HC is caused by misfires due to ignition misfires, advanced ignition timing, exhaust valve leakage, and/or over-lean mixtures.

High CO - High CO is caused by overrich air/fuel ratios which are caused by abnormally restricted air cleaner, stuck or partially-closed choke or carburetor idle circuit failure,

Rough or erratic idle can be caused by PCV valve malfunction,

Idle HC/CO failure/malfunction truth table (Table 4-3) can be used as a guide to identifying failures.

TABLE 4-3. MALFUNCTION TRUTH TABLE

Malfunction	HC High	HC Very High	CO High	CO Very High	Rough Idle
PCV Valve Dirty/Restricted			X		X
Air Cleaner Dirty/Restricted			X	X	
Choke Stuck Partially Closed				X	
Carburetor Idle Circuit Malfunction	X		X		X
Intake Manifold Leak	X	X			X
Ignition Timing Advanced	X				
Leaky Exhaust Valves	X	X			X
Ignition System Misfire	X	X			X

Source: Northrop Study (Ref. 19)

4.4 LOADED TEST

The loaded test is performed on a chassis dynamometer at vehicle speeds and road load that are calculated to expose engine faults. The operational speeds are idle, low-cruise, and high-cruise. After vehicle pretest activities are performed, the vehicle is positioned on the dynamometer and emission test equipment attached. The initial test is at high-cruise conditions. The driver accelerates to a speed and load range of 44 to 50 mph and 21 to 30 horsepower (hp), depending upon vehicle weight. The load is applied to simulate actual road-load conditions. During this period, the engine temperature is stabilized. High-cruise emission measurements are performed, and the vehicle speed and load is reduced to 22 to 30 mph and 6 to 12 hp depending again upon vehicle weight. After measurement, the vehicle is returned to idle for final measurements prior to post-test operations.

Those operating modes that expose these engine faults are high-cruise, low-cruise, and idle (Ref. 20). For each of these modes, different failure limits are established for HC, CO, and NO_x concentrations. By referring to a logic diagram called a "truth" chart, corresponding probable engine malfunctions and adjustments are denoted as an aid to the repair technician.

A description of a typical loaded test sequence with diagnostic information derived from testing when the vehicle fails is:

A. Pre-Test

Prepare vehicle and equipment for test:

1. Test Equipment - Calibrate HC/CO/NO_x test equipment per manufacturer's specification

2. Test Vehicle - Verify engine is at normal operating temperature

3. Hook-Up - Position vehicle on dynamometer, adjust controls for proper dynamometer load setting, and insert probe in exhaust tail pipe

B. Test

Perform HC/CO/NO_x measurements and compare to test standards:

1. High-Cruise - Operate vehicle at speed and load appropriate for test vehicle weight. Record HC/CO/NO_x measurement

2. Low-Cruise - Operate vehicle at speed and load appropriate for test vehicle weight. Record HC/CO/NO_x measurements

3. Idle - Operate engine with transmission in neutral in manual shift vehicle; drive in automatic transmission vehicles at idle rpm and record HC/CO/NO_x measurements

C. Diagnostic Information

Diagnostic information is derived from a diagnostic truth chart. An example of a truth chart and it's use is included in Appendix C.

4.5 TRANSIENT-MODE INSPECTION AND TEST (ALTERNATIVE LOADED-MODE)

A transient-mode driving pattern, frequently used for emission testing, consists of a nine-mode cycle called the Federal short-cycle test. This short cycle consists of specific changes in vehicle speed, and acceleration/deceleration rates, over a time period of 125 seconds. The vehicle is positioned on the dynamometer and driven through this cycle. The dynamometer must be calibrated to apply top road-load and inertial-load specified for the weight of the vehicle. This cycle is more representative of emission levels produced on the road, and requires all the equipment used in the FTP.

4.6 ENGINE PARAMETER/DEVICE INSPECTION

For this approach, vehicles are subjected to a sequence of inspections that determine the mechanical functional condition of various emissions-related vehicle systems. Components and/or operating parameters with measurements outside of accepted tolerances, are required to be replaced or adjusted to specification. Table 4-4 presents test parameters and their emission relationships. This approach does not actually measure emission levels, although emission measurememts may be made to evaluate the state of certain vehicle systems (e.g., measurement of idle CO concentration to evaluate proper idle air/fuel ratio adjustment).

Table 4-4. ENGINE PARAMETER/DEVICE TEST AND EMISSION RELATIONSHIPS

EMISSION CONTROL SYSTEM	INDICATION OF MALFUNCTION	POLLUTANT EMISSION RELATION HC	CO	NO_x
1. Carburetor System				
a. Choke	Adjustment	x	x	
b. Metering rod	Adjustment		x	
c. Power valve	For ruptured diaphragm	x	x	
d. Idle adjustment	Fuel mixture	x	x	
e. Float and valve	Float level		x	
f. Vacuum break valve	Ruptured diaphragm or loose vacuum hose		x	
2. Ignition System				
a. Spark plugs	Electrode deterioration	x	x	
b. Wires	Cable deterioration	x	x	
c. Cap	Terminal corrosion or erosion	x		
d. Rotor	Terminal corrosion or erosion	x		
e. Vacuum advanced	Ruptured diaphragm or loose vacuum		x	x
f. EI Mag trigger	Deterioration		x	
g. Timing	Adjustment			x
3. Thermal Air Inlet	Ruptured diaphragm or loose vacuum hose	x	x	
4. Heat Riser	Stuck	x	x	
5. PCV Components	Clogged	x	x	
6. EGR Components	Stuck			x
7. EVAP Components	Clogged	x		
8. Air Injection System	Broken hose or fault air pump	x	x	
9. Spark Delay Valves	Stuck			x
10. Three-Way Catalyst	High ppm HC	x	x	x
11. Reduction Catalyst	O_2 emissions status[a]			x
12. Oxidation Catalyst	O_2 emissions status[a]	x	x	

[a]In lieu of O_2 emissions status, a gas sample would have to be checked before and after the catalyst. Visual inspection could be made for a general status; discoloration of the stainless steel case is indicative of higher temperature effects and possible malfunction.

4.7 ASSOCIATED PROGRAMS

There are several associated programs that may be efficiently integrated with I/M. These programs are categorized as follows: Safety Inspection, Noise Inspection, Safety and Noise Integrated with I/M. The Safety and Noise Inspection paragraphs discuss the benefits derived from these inspections and the current developments in inspection techniques.

4.7.1 Safety Inspection

The vehicle-in-use (VIU) standards and periodic motor vehicle inspection programs presently operating emphasize safety-related components. There is a general belief that vehicles in good operating condition are less likely to be involved in accidents. Periodic motor vehicle inspection is recognized as a factor in reducing automobile accidents. Organizations that have a significant role in developing safety-related VIU inspection standards include:

- For Vehicles Under 10,000 Pounds -- The National Highway Traffic Safety Administration (NHTSA), the Motor Vehicle Manufacturers Association (MVMA), and the American National Standards Institute (ANSI).

- For Motorcycles -- The ANSI and the Motorcycle Industry Council.

In addition to these organizations, state and local governments with periodic motor vehicle inspection programs also have a limited role in developing safety-related inspection standards. States that have adopted standards and methods have chosen those initially promulgated by the NHTSA and/or the cognizant industry associations in most cases.

A comparison of the Federal VIU Standards (Part 570) developed by the NHTSA with those developed by MVMA, ANSI, and Michigan for vehicles under 10,000 pounds, is presented in Table 4-5 (Ref. 20,21,22,23, and communications from the State of Michigan).

Table 4-5. SUMMARY OF NHTSA, MVMA, ANSI AND MICHIGAN SAFETY STANDARDS FOR VEHICLES UNDER 10,000 POUNDS

AUTOMOTIVE SYSTEM	ORGANIZATION			
	NHTSA (Part 570)	MVMA	ANSI (D7.1-1973)	Michigan[a]
Service Brake	X	X	X	X
Power Brake	X	X	X	X
Steering	X	X	X	X
Suspension	X	X	X	
Tires	X	X	X	X
Wheel Assembly	X	X	X	
Lighting		X	X	X[b]
Electrical		X	X	
Horn			X	X
Glazing		X	X	
Mirrors		X	X	X
Windshield		X	X	X[c]
Wipers			X	X
Washers			X	X
Body/Sheet Metal		X	X	
Exhaust		X	X	X
Fuel		X	X	
Emissions		X		X[d]

[a]Source: 1. J.D. Flora, R.F. Corn, R.C. Copp, Highway Safety Research Institute, The University of Michigan, Report UM-HSRl-76-9-2. Evaluation of the Michigan trial substitute vehicle inspection program, ASG 1976.

2. J.D. Flora, R.F. Corn, R.C. Copp, Highway Safety Research Institute, May 1976 (Report UN-HSRl-76-9-1.

3. J.D. Flora et al, UM-HSRl-77-57 Ltd-August 1977.

4. U.S. Department of Transportation, Evaluation of Diagnostic Analysis and Test Equipment for Small Automotive Repair Establishments, July 1978.

[b]All lights.

[c]Safety and vision impaired.

[d]Smoke testing only.

The State of Michigan conducted a 2-year study to evaluate the effects of the Michigan check lane inspection system as defined in References 21, 22, 23. The Michigan trial substitute vehicle inspection program required that a 6 to 15 percent statistical sample receive the safety inspection as noted in Table 4-5. The safety inspection was performed as follows:

- Vision Defects - Visual inspection for glass (safety glass, windows cracked or chipped, operating windshield wipers and washers, and condition of mirrors.

- Lighting Defects - Headlight aiming and output, high-beam indicator lights, tail lights, stop lights, and license plate lights.

- Exhaust Defects - Noise and excessive smoke.

- Control Defects - Steering, the foot and parking brake by the wheel-pull method, and by the moving/stopping test method. Tread depth, tire condition, and tire pressure.

- Miscellaneous Defects - Horns, licenses and registrations, and seat belts.

The conclusions and recommendations are:

- The primary purpose of the vehicle safety study was to estimate the effect of a 15-percent check-lane inspection program and to compare this with the estimated effect of a periodic (annual) motor vehicle inspection program. It was concluded that the increase in the rate of inspection from a level of about 5 percent (Statewide) to a level of 15 percent did not change the overall rate of failure of the inspection.

- The sampling check to simulate a periodic motor vehicle inspection indicated that the simulated periodic motor vehicle inspection group did not experience a significant improvement rate from one year to the next. It was concluded that operating the check lanes with an inspector to select vehicles for test was successful due to his ability to visually select vehicles that appeared to have defects. Thus, it was not a random sample, but a select sample check.

- The comparison of the moving/stopping test with the wheel-pull brake inspection indicated that the moving/stopping test more accurately determined the car's braking capability. It is also quicker and easier to perform and was recommended for adoption as the inspection procedure for checking brakes.

- Drivers in Jackson County showed a greater knowledge and awareness of the check lane inspection than did those in Monroe County. This coincided with a more intensive information campaign in Jackson County. It was recommended that the public information campaign be continued.

As shown in Table 4-5, the standards developed by NHTSA, MVMA, and ANSI are similar to those in Michigan. The greatest difference is that the NHTSA VIU standards prescribe tests for only those systems which have been shown to be major causal or contributing factors to accidents (i.e.; brakes, steering and alignment, suspension, tires, and wheel assemblies), while ANSI, MVMA, and Michigan also include standards for automotive systems that have less direct causal relationships to accidents (e.g., glazing and lighting).

4.7.2 Noise Inspection

4.7.2.1 Contribution of Surface Transportation to Urban Noise

A variety of noise studies have shown that surface transportation composed of automobiles, trucks, motorcycles, etc., is the major component of general urban noise. Automobiles and trucks contribute about equally to the total amount of noise in urban and rural areas, particularly near major highways. Individual trucks generate more sound than automobiles, but automobiles tend to make up the difference by outnumbering trucks.

The basic noise sources for automobiles and trucks are the same, but they do not have the same relative importance for these two vehicle types under the same driving conditions. The noise sources are:

<u>Engine</u>

exhaust noise

inlet noise

radiation from engine casing

-due to combustion

-due to valves

-fan and other ancillary equipment

<u>Running Gear and Accessories</u>

drive train

tires

<u>Aerodynamics</u>

air flow over wheel wells and other surfaces

irregularities

SHED vorticity from the vehicle

boundary layer turbulence

Considering all of these sources, the most definitive work on noise levels has been done on the engine itself. However, it is known that other individual sources (such as the fan and tires) can be strong contributors to the radiated noise. In most cases, tire noise and aerodynamic noise become important in the same speed range. It may not always be possible to separate these two sources from each other.

4.7.2.2 Passenger Car Noise Sources

For passenger cars, the evidence shows that a rank order of noise sources would be as follows:

LOW-SPEED (URBAN)	HIGH-SPEED (FREEWAY)
engine exhaust	tires
cooling fan	aerodynamic noise
engine casing radiation	engine noise

4.7.2.3 Truck Noise

Existing data indicates that motorcycles and trucks generally are noisier than passenger cars. A well-muffled truck is only about 10 dB noisier than a passenger car, where trucks with straight exhaust can be as much as 20 to 25 dB noisier. In general, noise of motorcycles is also due to inadequate muffling on some models. These sources can be reduced to acceptable levels with adequate muffling.

4.7.2.4 Promulgated Noise Regulation

Medium and Heavy-Duty Trucks - On October 30, 1974, notice was published in the Federal Register (39 FR 38338) that the EPA was proposing noise emission standards for new medium and heavy trucks. The purpose of this notice was to establish final noise emission standards for new medium and heavy trucks by establishing a new Part 205 of Title 40 of the Code of Federal Regulations. This final rule-making is promulgated pursuant to Sections 6, 10, 11, and 13, of the Noise Control Act of 1972; 86 Stat. 1234; Public Law 92-574 (the Noise Control Act).

Standard and Effective Date - The regulation establishes standards and enforcement procedures for noise emissions resulting from the operation of newly manufactured medium and heavy trucks over 10,000 pounds gross vehicle weight rating (GVWR). The standard (specified A-weighted) sound pressure level is measured at a distance of 50 feet (15.24 meters) from the longitudinal centerline of the truck, using fast meter responses. The standard measurement procedure used to obtain the data is presented in more detail in S205.54 of the Code of Federal Regulations.

The standard and effective dates are:

Sound Level Decibel A-weighted (dBA)	Effective Date
83	January 1, 1978
80	January 1, 1982
(Reserved)	January 1, 1985

The enforcement procedures include production verification, selective enforcement auditing procedures, warranty, compliance labeling and anti-tampering provisions.

Motorcycles - On May 28, 1975, the EPA identified motorcycles as a major source of noise. In accordance with the requrement of the Noise Control Act, this notice proposes to add two new subparts to Part 205 of Title 40 of the Code of Federal Regulations establishing noise emission regulations for new motorcycles and new motorcycle replacement exhaust systems. Compliance with the proposed standards is expected to cause an average 5 db reduction in new street motorcycle sound levels by 1985, and a 2-to-9 db reduction in sound levels of new off-road motorcycles. Proposed noise standards for motorcycle replacement exhaust systems are anticipated to cause significant reductions in motorcycle noise impact by eliminating the availability of ineffective motorcycle replacement exhaust systems. Under the provisions of the Noise Control Act, regulation of motorcycle operation after the time of sale is reserved for State and local authorities.

Standards - The proposed noise emission standards and effective dates for street and off-road motorcycles are presented in Table 4-6.

Table 4-6. PROPOSED NOISE EMISSION STANDARDS

EFFECTIVE DATE	Sound Level (dBA)
Street motorcycles:	
January 1, 1980	83
January 1, 1982	80
January 1, 1985	78
Moped-type street motorcycles:	
January 1, 1980	70
Off-road motorcycles, engine displacement 170 cc and below:	
January 1, 1980	83
January 1, 1982	80
January 1, 1985	78
Off-road motorcycles, engine displacement more than 170 cc:	
January 1, 1980	86
January 1, 1983	82

It was proposed that all motorcycles manufactured after the effective dates would be required to meet the above values. To assure compliance with "not-to-exceed" standards, it is expected that manufacturers will produce motorcycles that will be several decibels below the specified limits for noise.

There are no promulgated or proposed regulations on light-duty vehicles by the Federal government. However, the EPA is studying the feasibility of such promulgation. These noise standards promulgated by the EPA will preempt all state noise standards for new vehicles.

The State of Michigan has established the following drive-by and stationary noise levels (Ref. 24).

"Sec. 707c. (1) After April 1, 1978, a motor vehicle shall not be operated or driven on a highway or street if the motor vehicle produces total noise exceeding 1 of the following limits at a distance of 50 feet except as provided in subdivisions (b)(iii) and (c)(iii):

(a) A motor vehicle with a registered weight of 8,500 pounds or more, singly or towing a semitrailer, pole trailer, or trailer or a combination of those trailers:

(i) Ninety DBA if the maximum lawful speed on the highway or street is treater than 35 miles per hour.

(ii) Eight-six DBA if the maximum lawful speed on the highway or street is not more than 35 miles per hour.

(iii) Eighty-eight DBA under stationary run-up test.

(b) A motorcycle or a moped as defined by section 32b:

(i) Eighty-six DBA if the maximum lawful speed on the highway or street is greater than 35 miles per hour.

(ii) Eighty-two DBA if the maximum lawful speed on the highway or street is not more than 35 miles per hour.

(iii) Ninety-five DBA under stationary run-up test at 75 inches.

(c) A motor vehicle or a combination of vehicles towed by a motor vehicle not covered in subdivision (a) or (b):

(i) Eighty-two DBA if the maximum lawful speed on the highway or street is greater than 35 miles per hour.

(ii) Seventy-six DBA if the maximum lawful speed on the highway or street is not more than 35 miles per hour.

(iii) Ninety-five DBA under stationary run-up test 20 inches from the end of the tailpipe."

4.7.2.5 Stationary Vehicle Noise Acceleration Test (Ref. 25)

Common vehicle pass-by noise test procedures specify a measurement distance of 15m (50 feet) which necessitates a large hard testing site and low ambient noise levels. For inclusion into the I/M program, it is desirable to test vehicle noise at a shorter distance, and in a stationary mode, to have the results closely correlated with the pass-by test at 15m (50 feet).

Previous studies have shown weak correlation among noise measurements made at various microphone distances ranging from 5m (15 feet) to 30m (100 feet) when the microphone is at a fixed height aboveground. There are methods to improve the correlation by preserving the acoustic interference pattern at various measurement distances through adjusting the microphone height. Then the noise levels follow closely the spherical spreading law, and correlation is improved. Noise testing at shorter distance, therefore, is possible. Simple stationary tests correlatable with the Federal pass-by procedures are required in order to be integrated into an I/M program. Reference 25 notes that stationary tests can be devised without using external loading; e.g., dynamometers, because the instantaneous vehicle noise is dependent mostly on the engine power (throttle setting) and the engine speed. An example is given in Reference 26 where a 15m (50 feet) pass-by motorcycle test is transformed into a 3m (10 feet) stationary test. Experiments performed at Sandusky, Ohio and in California showed good correlation between the two procedures.

The stationary noise test could be integrated in the inspection process as a screening for noise enforcement of in-use vehicles. Appendix E reviews noise testing.

4.7.3 <u>Safety and Noise Integrated with Exhaust Emission Testing</u>

A description of an idle-mode emission test, integrated with the vehicle stationary engine acceleration noise test, and the Michigan safety inspection as described previously, is as follows:

A. <u>Pretest</u>

Prepare the vehicle and equipment for emission testing, perform visual safety checks and vehicle noise acceleration test.

1. Vehicle Identification/External Visual Safety Checks - Record vehicle ID, check windshield, mirrors, and tires (bulge, breaks, and tread).

2. Test Equipment/Internal Visual Safety Checks - Service, warm up, and calibrate HC/CO/NO_x test equipment per manufacturer's specifications. Perform safety check of wipers, washers, horn, steering and lights (e.g.; headlights, tail lights, directional signals, etc.).

3. Test Vehicle/Exhaust System Check - Verify engine is at normal operating temperature and check exhaust system for smoke.

4. Hook-Up/Noise Test - Hook up tachometer per manufacturer's instructions and perform vehicle noise acceleration test. Insert probe in exhaust pipe (driver's side, if dual exhaust).

B. Test

Perform HC/CO and rpm measurements and compare to idle test standards.

1. 2,500 rpm - Operate engine in neutral at 2,500 rpm, record HC/CO measurements.

2. Idle rpm - Operate engine at idle rpm (in drive if automatic transmission), record HC/CO measurements.

C. Post-Test

Remove emission test equipment, perform brake safety checks, and prepare diagnostic information.

1. Test Equipment - Post calibration check of HC/CO on test equipment, and remove exhaust pipe probe.

2. Brake Check - Perform Michigan moving foot brake and parking brake safety checks.

3. Diagnostic Information - Derive diagnostic information from malfunction truth table (see Appendix C).

4. Vehicle Checkout - Certify passed vehicles, supply diagnostic report to failed vehicle operator.

The following is a description of a loaded-mode emission test integrated with the vehicle noise acceleration test and the Michigan safety inspection.

A. Pretest

Prepare the vehicle and equipment for emission testing, perform visual safety checks and vehicle noise acceleration test.

1. Vehicle Identification/Exhaust Visual Safety Checks - Record vehicle ID, check windshield, mirrors, and tires (bulge, breaks and tread).

2. Test Equipment/Internal Visual Safety Checks - Service, warm up and calibrate HC/CO/NO_x test equipment per manufacturer's specification. Perform safety check of wipers, washers, horn, steering and lights (e.g.; headlights, tail lights, directional signals, etc.).

3. Test Vehicle/Exhaust System Check - Verify engine is at normal operating temperature and check exhaust system for smoke.

4. Hook-Up/Noise Test - Position vehicle on dynamometer, identify proper load settings, and hook up tachometer per manufacturer's instructions. Perform loaded vehicle noise acceleration test. Insert probe in exhaust pipe (driver's side if dual exhaust).

B. Test

Perform HC/CO/NO_x measurements and compare to test standards.

1. High Cruise - Operate vehicle to a speed and load range of 44 to 50 mph and 21 to 30 hp, depending on vehicle weight. Record HC/CO measurement.

2. Low Cruise - Operate vehicle at 22 to 30 mph and 6 to 12 hp, depending upon vehicle weight. Record HC/CO/NO_x measurements.

3. Idle - Operate engine at idle rpm and record HC/CO/NO_x measurements.

C. Post Test

Remove test equipment, perform brake safety check and prepare diagnostic information.

1. Test Equipment - Post calibrate check of HC/CO/NO_x on test equipment. Remove exhaust pipe probe.

2. Brake Check - Remove vehicle from dynamometer and perform moving/stoping foot brake safety test and parking brake safety check.

3. Diagnostic Information - Derive diagnostic information from a malfunction truth table (see Appendix C).

4. Vehicle Checkout - Certify passed vehicles or supply diagnostic report to owners of failed vehicles.

Section 5

GENERAL DEFINITIONS

These definitions are commonly used in inspection and emissions testing procedures and I/M programs.

accuracy: The degree by which an instrument is able to determine the true concentration of a pollutant in the exhaust gas sampled.

air contaminants: Any fumes, smoke, particulate matter, vapor gas, or any combination, but excluding water vapor or steam condensate.

air-fuel ratio: The expression of the proportional mixture by weight of air to gasoline created by the carburetor. Usually expressed as a numerical relationship such as 14:1, 13:1, etc.

ambient air: The surrounding or outside air.

analyzer: An instrument which samples and determines the concentration of a particular gas of interest.

calibration gases: A blend of hydrocarbon and carbon monoxide gases at known concentrations using nitrogen as the inert carrier gas.

carbon monoxide: A nonirritating, colorless, odorless, but nonetheless toxic gas which has the molecular form of CO.

catalytic converter: Device to reduce automobile emissions by converting CO and HC emissions to harmless carbon dioxide and water.

certificate of compliance: A document which is issued upon completion of inspection which records the results and serves as proof for vehicle owner.

certified mechanic: An individual certified by the State or I/M program office, to install, repair and adjust motor vehicle engine emissions-related components and pollution control devices so that the motor vehicle meets emissions standards.

certified station: A private facility certified by the State or I/M program office, to install, repair and adjust motor vehicle engine emissions-related components and pollution control devices so that the vehicle meets applicable emissions standards.

chassis dynamometer: A test instrument equipped with two parallel rollers that support the rear wheels of a motor vehicle. When positioned on the dynamometer the vehicle may be "driven" to simulate the road operation. A power absorption unit is connected to the rollers to simulate the loading from the various sources of fluid and mechanical friction present during road operation. Weights can also be coupled to the rollers to simulate the inertial effects of vehicle mass during acceleration and deceleration.

crankcase emissions: The products of combustion emitted into the ambient air from the engine crankcase ventilation system.

cut point: A threshold value of measured tail pipe pollutant emission concentration above which a vehicle will fail an emissions inspection.

degradation: An increase in emissions due to normal wear of engine system.

deterioration: A synonym for degradation indicating an increase in emission levels due to wear.

drift: The amount of analyzer meter reading change over a period of time. Zero drift refers to change of zero reading when a zero gas is flowing through the analyzer. Span drift refers to a change in reading of an analyzer meter when a calibration gas of known concentration is flowing through the analyzer.

emission inspection program: An inspection and maintenance program in which each vehicle is subjected to a test of its emissions under specified conditions. The emission levels are compared with a standard established for the vehicle class. If the emissions are higher than the standard, the vehicle fails and must be adjusted or repaired to bring its emissions to within the standards.

engine family: The basic classification unit of a manufacturer's product line used for the purpose of test-fleet selection.

engine-system combination: Both an engine family-exhaust emission control system and a fuel evaporative emission control system.

exhaust emissions: The gases emitted into the ambient air from any opening downstream of the exhaust ports of an engine.

exhaust gas analyzers: Instruments that can determine the amounts of one or more gas(es) in the exhaust of a motor vehicle.

failure rate: The percentage of vehicles tested that fails inspection.

fleet operator: The owner of a fleet of a designated number of vehicles.

fleet owner authorized stations: Stations operated by a fleet owner under certified authority to perform vehicle emissions inspection and limited to his fleet only.

fuel system: Combination of fuel tank, feeder lines, fuel pump, and evaporative emissions control system.

gross vehicle weight: The manufacturer's gross weight rating for the individual vehicle.

hang-up: HC which clings to the surface of the sampling and analyzer system in contract with the gas sample stream which causes an erroneous indication of HC in the measured value.

heavy-duty vehicle: Any motor vehicle designed for highway use having a gross vehicle weight of more than 8,500 pounds.

hydrocarbons: An organic compound whose molecular composition consists of atoms of hydrogen and carbon only. Gasoline is composed of various hydrocarbons.

idle test: An emission inspection program which measures the exhaust emission from a motor vehicle operating at idle. (No motion of the rear wheels.) A vehicle whereby the automatic transmission may be in "drive" with brakes applied or in neutral gear.

independent contractor: Any person, business firm, partnership, or corporation with whom the State may enter into an agreement providing for the construction, equipment, maintenance, personnel, management and/or operation of official inspection stations.

inspection and maintenance program: A program to reduce emissions from in-use vehicles through identifying vehicles that need emissions control-related maintenance and requiring that maintenance be performed. Abbreviated as I/M program.

inspection station: A facility used for inspecting or testing motor vehicles and pollution control devices for compliance with applicable regulations.

inspector: An individual who inspects motor vehicles and pollution control devices for compliance with applicable regulations.

light-duty vehicle: A motor vehicle designed for highway use and less than 6,001 pounds gross vehicle weight. Further distinctions are sometimes made between light-duty automobiles and light-duty trucks such as pickup trucks.

loaded mode test: An emission inspection program which measures the exhaust emissions from a motor vehicle operating under simulated road load on a chassis dynamometer.

medium-duty vehicle: A motor vehicle designed for highway use with a gross vehicle weight between 6,000 and 8,500 pounds.

model-year of vehicle: The production period of new vehicle designated by the calendar year in which such period ends.

motor vehicle: Any self-propelled vehicle which is designed primarily for travel on public right-of-way streets and is used to transport persons and/or property.

output rate: The number of vehicles that can be processed at a test lane per unit time. The longest work station test time defines the output rate.

oxides of nitrogen: Any molecule containing nitrogen and oxygen only. For air pollution purposes, only nitric oxide (NO) and nitrogen dioxide (NO_2).

pollution control device: Equipment designed for installation on a motor vehicle to reduce pollutants emitted from the vehicle, or an engine modification resulting in pollutant reduction.

positive crankcase ventilation: A system designed to return blowby gases from the crankcase of the engine to the intake manifold to burn them in the engine. Blowby gas is unburned fuel/air mixture that leaks past the piston rings into the crankcase during the compression and ignition cycles of the engine. Without positive crankcase ventilation, these gases which are rich in hydrocarbons escape to the atmosphere.

prescribed inspection procedure: Approved procedure for identifying vehicles that need emissions control-related maintenance.

quality: The results of engineering and manufacturing that determine the degree to which the product meets design specifications.

registered owner: An individual, firm, corporation, or association whose name appears in the files of the Department of State as the owner of the vehicle.

repeatability: The instrument's capability to provide the same value for successive measures of the same sample.

response time: The period of time required by an instrument to provide a read-out after a step-change in gas concentration level initiated at the tail pipe sample probe.

smoke: Small gasborne and airborne particles, exclusive of water vapor, resulting from insufficient combustion in sufficient number to be visible.

stringency factor: A design or theoretical failure rate.

tampering: The alteration, modification, or disconnection of emission control devices.

vehicle dealer: An individual, firm, corporation or association who is licensed to sell motor vehicles.

vehicle emissions standard: A specific emission limit allowed for a class of vehicles. The standard is normally expressed in terms of maximum allowable concentrations of pollutants (e.g., parts per million). However, a standard could also be expressed in terms of mass emissions per unit of time or distance traveled (e.g., grams per mile).

Section 6

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Appendix A

EMISSION CREDITS GIVEN IN THE CODE OF FEDERAL REGULATIONS

Proposed Appendix N - Emission Reductions Achievable Through Inspection and Maintenance of Light-Duty Vehicles, Motorcycles and Ligh- and Heavy-Duty Trucks.

ENVIRONMENTAL PROTECTION AGENCY

[40 CFR Part 51]

[FRL 703-4]

APPENDIX N—EMISSION REDUCTIONS ACHIEVABLE THROUGH INSPECTION AND MAINTENANCE OF LIGHT DUTY VEHICLES, MOTORCYCLES, AND LIGHT AND HEAVY DUTY TRUCKS

AGENCY: Environmental Protection Agency.

ACTION: Proposed rule.

SUMMARY: This Appendix presents estimates of potential emissions reduction benefits which, in the judgment of the Administrator, are likely to be achievable through the application of a properly structured and managed inspection/maintenance (I/M) program. Estimates of emission reductions available through retrofit programs, formerly contained in Appendix N, have been deleted. Inspection/Maintenance program effectiveness is given as a function of the level of technology, the stringency of emission standards, the length of program operation, and the adequacy of mechanic training. Basic program requirements are outlined for both the centralized and decentralized program concept. Attachment 1 provides a discussion of the modeling techniques utilized to generate the emission reduction estimates, while Attachment 2 provides computational examples illustrating the usage of Appendix N.

FOR FURTHER INFORMATION CONTACT:

John O. Hidinger, Director, Office of Transportation and Land Use Policy (AW-445) U.S. Environmental Protection Agency, 401 M Street SW., Washington, D.C. 20460 (202-755-0480).

ADDRESS: Submittal of Comments: Comments upon Appendix N are requested. Such comments should be directed to the individual below and postmarked no later than August 1, 1977.

Dated: April 19, 1977.

DOUGLAS M. COSTLE,
Administrator.

In Part 51, of Title 40, Code of Federal Regulations, Appendix N is revised to read as follows:

APPENDIX N—EMISSION REDUCTIONS AND ACHIEVABLE THROUGH. INSPECTION AND MAINTENANCE OF LIGHT DUTY VEHICLES, MOTORCYCLES, AND LIGHT AND HEAVY DUTY TRUCKS

AUTHORITY: Section 301(a) of the Clean Air Act as amended by section 15(c)(2) of Pub. L. 91-604, 84 Stat. 1713; 81 Stat. 504 (42 U.S.C. 1857g(a)).

1. *Introduction.* This Appendix presents estimates of the potential emissions reduction benefits which, in the judgment of the Administrator, are likely to be achievable through the application of a properly structured and managed inspection/maintenance (I/M) program. Since the publication of the original Appendix N, new data obtained and experience gained from operating programs have shown the necessity for a revision to certain portions of this document. In addition, estimates of emission reductions available through retrofit programs, formerly contained in Appendix N, have been deleted. Retrofit guidance will be placed in a separate appendix consistent with a format to be followed for other strategies.

To the extent possible, estimates in this Appendix are based on empirical data. However, lack of data in several areas has necessitated extrapolation of empirical data using modeling techniques based on sound engineering judgment. A description of these modeling techniques is contained in Attachment 1. As new data become available, or as predicted extrapolations change, this Appendix will be revised and amended accordingly.

Several definitions have been modified to reflect their intended meaning. Most important, "initial failure rate" has been redefined as a "stringency factor." Hopefully, this new definition will dispel past misapprehension concerning the "initial failure rate" concept. In addition, the idle test has been slightly redefined to reflect actual idle emission testing currently being used.

The minimum requirements of an I/M program are defined. Those programs which are contemplating the use of a private garage I/M program should note the special requirements necessary to obtain the basic emission reduction credits.

Emission reductions for light duty vehicles are estimated not only for the first year of an I/M program but also for subsequent years since modeling has shown that the reduction benefits can increase with time. Additional emission reductions are estimated for those programs which include twice-a-year inspection and special mechanic training. Estimates of emission reductions resulting from I/M programs for light-duty trucks, heavy-duty trucks, and motorcycles are also given.

Certification data and recent surveillance data indicate that I/M effectiveness may be greater (especially for carbon monoxide) for catalyst equipped in-use vehicles than for pre-catalyst vehicles. By the time many I/M programs are fully implemented, catalyst-equipped vehicles will dominate the vehicle mix. Estimates are therefore given for the effectiveness of I/M on such vehicles, despite the limited data base at the present time.

Tables 1 through 5 summarize the emission reductions obtainable from I/M programs. The actual benefit obtained by any state or region implementing a well-designed program may exceed the emissions reductions listed. Such higher reductions, however, would have to be shown through an adequate source surveillance study.

2. *Definitions.* a. "Cutpoint" means the level of emissions which discriminates between those vehicles requiring emission-related maintenance and those that do not.

b. "Federal Test Procedure" (FTP)—A sequence of testing utilized by the Agency to measure vehicle exhaust emissions over a typical urban driving cycle.

c. "Heavy-duty vehicle" means for the purpose of this Appendix, a gasoline fueled motor vehicle whose GVW is greater than 8,500 pounds.

d. "Idle emissions test" or "idle test" means a test procedure for sampling exhaust emissions which requires operation of the engine in the idle mode only. At a minimum, the idle test should consist of the following procedure carried out on a fully warmed-up engine: a measurement of the exhaust emission concentrations for a period of time of at least 15 seconds, shortly after the engine was run at 2,000 to 2,500 rpm with no load for approximately 30 seconds.

e. "Inspection/maintenance" means a strategy to reduce emissions from in-use vehicles by identifying vehicles that need emissions-related maintenance and requiring that such maintenance be performed.

f. "Light-duty vehicle" means a passenger car or passenger car derivative capable of seating 12 persons or less.

g. "Light-duty truck" means, for the purpose of this Appendix, a motor vehicle designed primarily for the transportation of property, or the derivation of such a vehicle, whose GVW is 8500 pounds or less.

h. "Load emissions test" or "loaded test" means a test procedure for sampling exhaust emissions which exercises the engine under loading by use of a chassis dynamometer to stimulate actual driving conditions. As a minimum requirement, the loaded test must include running the vehicle and measuring exhaust emissions at two speeds and loads other than idle.

i. "Motorcycle" means for the purpose of this Appendix, a two-wheeled motorized vehicle designed to transport persons or property on a street or highway.

j. "Stringency factor" is a measure of the rigor of a program based on the estimated fraction of the vehicle population whose emissions would exceed cutpoints for either or both carbon monoxide and hydrocarbons were no improvements in maintenance habits or quality of maintenance to take place as a result of the program.

k. "Tampering" means, for the purpose of this Appendix, rendering inoperative, or intentional misadjustment of any motor vehicle device or element of design intended to control exhaust emissions.

l. "Technology I" means the general type of exhaust emission control technology utilized on all light-duty vehicles subject to pre-1975 Federal emission standards.

m. "Technology II" means the general type of exhaust emission control technology utilized on light-duty vehicles subject to 1975 and later model year federal exhaust emission standards.

3. *Emission reductions for light-duty vehicles.* Tables 1 through 4 list emission reductions for light-duty vehicles that can be achieved through properly structured and managed programs of inspection/maintenance and accompanying mechanic training. See Attachment 1 and 2 for a description of the derivation of these credits and for computational examples of the use of the tables.

a. *First year program credits.* The following first year credits are applicable to both idle and loaded tests.

TABLE 1.—*First year of program credits*

Stringency factor	HC (percent)		CO (percent)	
	Technology I	Technology II	Technology I	Technology II
0.10	1	1	2	6
.20	5	3	8	20
.30	7	9	13	28
.40	10	16	19	33
.50	11	26	23	37

b. *Subsequent years program credit.* The following additional (to Table 1) credits are applicable to vehicles which have undergone more than one inspection by the beginning of the calendar year of interest. These credits are not applicable to programs having inspection intervals of longer than one year. For a model year group of vehicles, the appropriate credit is selected on the basis of the specific number of inspections that the group has incurred by the beginning of the calendar year of interest. The credit is then added to the appropriate first year credit above. Credits are applicable to both technology level cases, to the idle and loaded tests, and to all stringency factor programs.

TABLE 2.—*Subsequent years program credit*

Number of inspections	Additive credit	
	HC (percent)	CO (percent)
2	7	8
3	14	15
4	20	19
5	25	22
6	30	27
7	33	30
8 or more	38	35

c. *Semi-annual I/M program credit.* A credit of 0.2 percent per subsequent semi-annual inspection may be added, up to 15 times, to the first year (Table 1) credits for those programs requiring semi-annual inspection. This credit is applicable at all stringency factors for both HC and CO, idle and loaded tests, and both technology levels.

d. *Mechanic training program credit.* The following additional credits may be taken for the presence of an adequate program of mechanic training.[1] Table 3 provides the basic credits for mechanic training, while Table 4 lists the appropriate credits to be added to Table 3 credits for subsequent years of program operation. The sum of Table 3 and 4 credits is then to be added to the basic credit computed from Tables 1 and 2.

TABLE 3.—*Mechanic training first year credits*

Stringency factor	Technology I		Technology II	
	HC (percent)	CO (percent)	HC (percent)	CO (percent)
0.10	1	5	3	7
.20	3	7	5	10
.30	4	9	4	10
.40	6	8	1	7
.50	7	7	1	5

[1] The "adequacy" of a mechanic training program will, for the present, be determined on a case-by-case basis. Guidelines will be issued in the future if found to be feasible.

TABLE 4.—*Mechanic training subsequent year credits*

Technology I

Stringency factor	Number of inspections			
	2		3 or more	
	HC (percent)	CO (percent)	HC (percent)	CO (percent)
0.10	3	3	13	13
.20	4	6	10	15
.30	4	5	9	9
.40	5	5	5	5
.50	3	3	5	3

Technology II

Stringency factor	Number of inspections—2 or more	
	HC (percent)	CO (percent)
0.10	10	4
.20	5	2
.30	3	1
.40	1	2
.50	1	1

The above Table 4 credits are applicable to vehicles which have undergone more than one inspection by the beginning of the calendar year of interest. For a model year group of vehicles, the appropriate credit is selected on the basis of the technology level of the vehicles, the number of inspections the vehicles have incurred by the beginning of the calendar year of interest, and the stringency factor of the I/M program. The credit is then added to the appropriate first year mechanic training credit (Table 3) and the result is added to the basic credit calculated from Tables 1 and 2. Credits are applicable to both the idle and the loaded test.

Inspection/maintenance approaches are expected to be applicable to heavy duty gasoline fueled trucks and motorcycles, as well as light duty vehicles.

a. *Emission reductions for motorcycles and light duty trucks.* The estimated emission reductions for this group of vehicles are the same as those given in Tables 1 through 4 for Technology I light-duty vehicles.

b. *Emission reductions for heavy duty trucks.* Estimated emission reductions due to I/M for gasoline fueled heavy duty vehicles, using either an idle or loaded emissions test are as follows:

TABLE 5.—*Heavy duty vehicle I/M credit*

Stringency factor	HC (percent)	CO (percent)
0.20	11.4	8.3
.30	12.1	9.3
.40	15.6	10.5
.50	17.1	12.0

Analysis of data (generated by the City of New York under EPA grant) on 65 trucks indicate that I/M is a potentially viable emission reducing strategy. The estimated emission reductions given above are based on these limited data. No data on the deterioration of trucks with or without I/M are available. The assumption utilized to develop Table 5 is that the average yearly effectiveness is one-half of the initial benefit achieved as a result of a tune-up.

5. *Basic program requirements.* There are two basic types of operation which may be utilized for an I/M program, namely a centralized inspection system (government or contractor operated) and a decentralized inspection system (private commercial garages). In order to obtain full emission reduction benefits for either a centralized or decentralized inspection system, certain minimum requirements are established, which if not met, will result in assessed emission reductions lower than those listed in Tables 1 through 5 of this Appendix.

a. *Program requirements—Minimum* for all programs.

i. Provisions for regular periodic inspection (at least annually) of all vehicles for which emissions reductions are claimed.

ii. Provisions to ensure that failed vehicles receive the maintenance necessary to achieve compliance with the inspection standards. The basic method is to require that failing vehicles pass a retest following maintenance.

iii. Provisions for quality control. The reliability of the inspection system and equipment accuracy must be ensured. This will include routine maintenance, calibration and inspection of all I/M equipment, and routine auditing of inspection results.

b. *Minimum decentralized program requirements.* In order to receive the basic emission reduction benefits for a decentralized I/M program, the following requirements must be included in addition to provisions listed in Section 5(a).

i. Provisions for the licensing of inspection facilities which insure that the facility has obtained, prior to licensing, analytical instrumentation which has been approved for use by the appropriate governing agency. A representative of the facility must have received instructions in the proper use of the instruments and in vehicle testing methods. The facility must agree to maintain records, to collect signatures of operators whose vehicles have passed inspection, and to submit to inspection of the facility.

ii. Records required to be maintained should include the description (make, year, license number, etc.) of each vehicle inspected, and its emissions test results. Records must also be maintained on the calibration of testing equipment.

iii. Copies of these inspection records should be submitted on a periodic basis to the governing agency for auditing.

iv. The governing agency should inspect each facility at least once every 90 days to check the facilities' records, check the calibration of the testing equipment and observe that proper test procedures are followed.

v. The governing agency should have an effective program of unannounced/unscheduled inspections both as a routine measure and as a complaint investigation measure. It is also recommended that such inspections be used to check the correlation of instrument readings among inspection facilities.

c. *Motorcycle and heavy duty truck program requirements.* An acceptable I/M program for motorcycles and trucks must include the same provision specified in Section 5 for light duty vehicles. In addition, a source surveillance program, such as discussed in Section 6(c) is strongly recommended for any emission reduction estimates for motorcycles and heavy duty vehicles. The test procedures and program design for the evaluation of emission reductions should be reviewed in advance by EPA. The source surveillance program can include an assessment of emission deterioration at the option of a state. Without such an assessment, the assumption will be made that average yearly effectiveness is half of the initial benefit found.

6. *Additional Topics—Emission reductions.*

a. *Idle vs. loaded testing.* Although idle and loaded testing do not necessarily fail a mutally inclusive set of vehicles, latest available data indicate no overall difference in HC and CO emission reductions between the two tests. The available data do indicate that the loaded test can be more effective in reducing emissions than the idle test, but only if mechanics are extensively trained in the proper use of loaded test diagnostic information. For this reason, no additional credit is given for loaded mode testing. The loaded emission test does, however, have the potential to measure oxides of nitrogen from automobile emissions and can therefore be a valuable strategy in areas where there is a defined NOx problem.

b. *Tampering inspection.* Additional annual reductions in emissions can be achieved from a program of tampering inspection, in conjunction with emissions inspection. The amount of reduction credited will be a function of the sophistication and complexity of the tampering inspection and the training of the inspectors. To obtain these reductions there must be inspection and maintenance for tampering along with emission I/M. Any plans for tampering inspection should be reviewed with EPA in advance in order to estimate the potential benefits.

c. *Added benefits—source surveillance program.* It is possible that well designed and managed I/M programs will achieve greater reductions than those estimated in this Appendix. This can occur because deterioration rates and other factors may be different for specific geographic areas or because the service industry is doing a better job than estimated or because public maintenance habits improve significantly in response to the program.

To overcome the uncertainty associated with the above it is recommended that a source surveillance program be performed. The results of such a program would allow states and areas to update the emission reduction benefit for I/M as data become available. Such source surveillance studies can determine three key pieces of information: the initial reduction which vehicles can achieve in the first year of a program as a result of inspection and repair, the change in lifetime vehicle emission deterioration which can be credited to yearly inspections, and an accurate location specific emission inventory prior to I/M implementation.

An I/M program has the potential to change both the first year emission rate and the lifetime deterioration curve. Since a source surveillance program needs to be carefully designed to adequately evaluate benefits attributable to I/M, states are encouraged to review source surveillance study designs with regional EPA offices before beginning such programs. Technical guidance for program design and sizing of test samples will be available from EPA.

In the absence of a source surveillance program, states required to submit transportation control plans must use the estimates contained in this Appendix in the determination of emission reductions from inspection/maintenance programs. In addition, current and projected emission factors supplied by EPA must be used in these determinations, unless substantiating justification for other factors is provided.

At the present time, EPA is looking at the possibility of using short inspection tests to determine both percent emission reduction due to inspection and maintenance, and emission deterioration of vehicles over time. The ability to use short tests to determine percent emission reductions due to maintenance will depend upon the correlation of the short test with the Federal Test Procedure. Additional source surveillance implementation information will become available as current analyses are completed.

d. *Alternative approaches.* Maintenance-oriented programs that employ approaches other than emission testing may be capable of achieving emission reductions for in-use motor vehicles. Such approaches, including mandatory maintenance procedures and engine parameter inspection, will be acceptable only if sufficient data are provided to justify the emission reductions estimated.

e. *Program alterations.* Alternations to program design during the course of an I/M program will be evaluated on a case-by-case basis. Such alternations might include: change from an idle test, after several years of use, to a loaded test; change from annual inspection, after several years of use, to a semiannual inspection.

f. *Cutpoint variations.* For a given stringency factor (which is based on both hydrocarbons and carbon monoxide), individual cutpoints for hydrocarbons and carbon monoxide can be varied in a theoretically infinite number of ways. The reductions given in this Appendix assume that there is a particular relationship between hydrocarbon and carbon monoxide cutpoints. This relationship, though considerably more complex than mentioned here, can be generally stated as, for Technology I vehicles, two carbon monoxide failures for each hydrocarbon failure, and for Technology II vehicles, three carbon monoxide failures for each hydrocarbon failure. It is possible that an area's particular pollution problem may call for I/M cutpoints that result in substantial deviations from the HC/CO relationships implicit in this Appendix. At the State's or local area's request, EPA will review the program's cutpoint structure, and make adjustments to emissions reduction credit as necessary.

g. *High altitudes, California.* All emission reductions estimated in this section are also applicable to high altitude areas and for vehicles equipped for use in California.

h. *Oxides of nitrogen.* It has not been shown that maintenance directed at reducing HC and CO emissions has a significant impact on oxide of nitrogen (NOx) emissions. All available data show very minor increases or decreases in NOx levels. It has already been cited (Section 6(a)) that a loaded test is capable of detecting high NOx emitters. Maintenance procedures and an ensuing control strategy to reduce NOx emissions, based on I/M, are therefore conceivable. To the extent that tampering is directed toward NOx emission controls, a good anti-tampering program can reduce NOx emissions.

ATTACHMENT 1

DESCRIPTION OF THE SIMULATION MODEL

Introduction. Empirical data from ongoing inspection/maintenance (I/M) programs has shown that mandatory inspection and maintenance will result in significant air quality benefits. Increased future benefits are to be expected as such programs become stabilized, i.e., the vehicle population has been subject to I/M requirements during its full lifetime. Currently available data, however, is somewhat limited in its ability to estimate these future benefits quantitatively. For this reason, a mathematical model of the I/M process has been developed, in which available empirical data is utilized to make the model as realistic as possible. This approach was used to derive the estimates of benefit presented in Appendix N. Two groups of vehicles were considered, and these groups of vehicles are designated as Technology I and Technology II. Technology I vehicles include all light-duty vehicles manufactured prior to the 1975 model year that were designed to meet pre-1975 exhaust emission standards. Technology II vehicles include all post-1974 light-duty vehicles that were designed to meet the more stringent 1975 and later emission standards. Samples of vehicles of the two technology levels were input to the model, and were taken as representative of Technology I and Technology II vehicles on a nationwide basis. Please note: all computations in Attachments 1 and 2 are based upon the metric system.

I. Description of the simulation model of the inspection/maintenance process. The I/M process as currently conceived in the model consists of the following events:

1. Emission deterioration from existing levels,

2. Inspection lane testing of HC and CO levels using the idle test to detect high FTP emitters (NOx emissions are insignificant at idle, and therefore are not considered in the model),

3. Maintenance or repair (resulting in lower emission levels), if a vehicle fails the inspection.

Each vehicle undergoes this sequence of events throughout its useful life, which is assumed to be nine years, or approximately 160,000 kilometers.

The model compares average FTP emissions in the case where an I/M program is operational, with emissions in the case where no I/M program exists. Benefit is calculated as the percent reduction in FTP emissions from the average level in the no I/M case. FTP emission levels are used to measure benefit since the FTP driving cycle is assumed to be representative of vehicle operation in urban areas. Two types of benefit can be computed: (1) the average benefit over a vehicle's life, and (2) the benefit in a particular year of a vehicle's life. Both types of benefit are dependent upon the vehicle's level of emission control technology and the number of times the vehicle has been subjected to a mandatory inspection program. The average benefit for a population of vehicles in a given calendar year is computed from the individual technology level vehicle benefits given in Appendix N, which are of the second type. The calculation methodology is discussed in a later section of this Appendix.

Issues affecting estimated I/M benefit. Benefit due to I/M depends upon the assumptions used to implement the simulation of the I/M process; that is, the assumptions surrounding the three events identified above. Because the currently available data are limited, assumptions were made regarding some of the issues that logically affect benefit. The model reflects these assumptions, which were based on engineering judgment. The issues and assumptions are discussed below.

Issue 1. Emission levels of vehicles at first inspection.

Concept. Benefit in the first and subsequent inspection years is expected to depend on the emission levels of vehicles at their first inspection. There are two ways in which differences in the first year emission levels could produce significant differences in benefit. First, it is possible that for vehicles of a given age there will be differences in the distribution of emission levels at first inspection from one technology level to another; for example, it might be the case that for one technology level vehicles have either very low or very high emissions at first inspection, whereas for another technology level vehicles have emissions which are clumped closely together around some average value. This situation could possibly result in more benefit for the first technology level case, even if the same percentage of vehicles of each technology level were to fail an inspection, since failures in the first technology level case could result in bigger drops in emissions percentagewise. Second, within a technology level, different emission levels at the time of I/M implementation will naturally exist for different model year vehicles, and it is possible that these absolute numerical differences will result in benefit (or percentage) differences as well.

Assumptions. The first year Appendix N benefits, and indirectly the benefits for each subsequent inspection year, were determined by analyzing the emissions performance of one-year-old cars with and without I/M. Separate benefits were calculated for the Technology I and Technology II cases. Technology I first year benefits were based on emissions data on 180 1973–74 models tested in the FY '73 Emission Factor Program. Technology II first year benefits were based on emissions data on 587 1975 models tested in the FY '74 Emission Factor Program. These vehicles were taken to be representative of the nationwide mix of low altitude non-California one-year-old Technology I and Technology II vehicles, respectively, in terms of mileage and maintenance characteristics. As Appendix N benefit numbers indicate, I/M benefits differ by technology level, at least for CO.

With regard to different first year emission levels that all model year vehicles, regardless of age, obtain the same first year benefits. This assumption is based upon the premise that, for public acceptance reasons, the first year pass/fail cutpoints would differ with age or model year so that all vehicles would experience similar failure rates. Limited data indicate that under this premise, benefits (on a percentage-wise basis) are similar.

Issue 2. Emission deterioration.

Concept. Emission deterioration is the process whereby vehicle emission rates increase over time from the levels at which the vehicles were intended to emit when new. Emission deterioration includes changes in emissions due to normal wear of engine/emission control components as well as changes in emissions due to tampering or poor maintenance.

Assumptions. The deterioration rates used in the model are expressed as a percentage of low mileage average FTP values per year. These percentage rates are assumed to be equal for all vehicles of a given technology level, and are constant over time. Specifically, the rates were taken to be 13 percent per year for HC and 15 percent per year for CO for Technology I vehicles; 21 percent per year for HC and 14 percent per year for CO for technology II vehicles. These rates are based on data from EPA's FY '71 through FY '74 Emission Factor Programs and represent vehicle deterioration under typical owner maintenance practices. For a given pollutant and vehicle, the model considers the FTP rate of deterioration per year (grams/kilometer/year) to be constant over time. Thus, deterioration is modeled as a linear phenomenon. The grams/kilometer/year value is calculated as the overall deterioration rate, (in percent) multiplied by the individual vehicle's first-year emission level. Thus, each vehicle is considered to be an inherently low or high emitter with respect to each pollutant; vehicles which have low emissions when new will continue to have relatively low emissions as they accumulate mileage. Emissions of vehicles in the no I/M case are assumed to deteriorate throughout their useful life until they reach the average levels of pre-controlled cars at 161,000 kilometers (100,000 miles).

Significant percentages of catalytic converter failure may occur with increasing vehicle age and if such a situation does occur, the emission rates will increase sharply in later years; that is, a constant deterioration rate assumption will not be valid. However, the surveillance data currently available to EPA do not cover mileage ranges extensive enough to estimate the frequency and effect of such failures.

The FTP deterioration rate (grams kilometer/year) is assumed not to be affected by the existence of an I/M program. However, if an I/M program is operational, the deterioration process is not continuous because deterioration is interrupted by annual idle test emissions inspections. If a vehicle fails the idle test, its emissions are assumed to be reduced via maintenance or repair to meet the pre-determined idle test standards. The FTP emissions are assumed to be reduced correspondingly, as determined by regression relationships. Following an I/M repair, the deterioration process continues under the assumption that a vehicle's yearly rate of deterioration (gm/km) is unaffected by the repair that occurred. The implication is that the inherent emissions characteristics of a vehicle cannot be improved via repair. If a vehicle passes the idle test, its emissions are left unchanged for the calculation of the average emission levels (gm/km) following the round of I/M. The deterioration process then continues until the next annual inspection occurs.

The idle test deterioration rate per year (percent CO or ppm HC) is also assumed to be constant over time for each vehicle. Idle test deterioration rates are determined from FTP deterioration rates using the following rationale: The effectiveness of I/M in reducing in-use vehicle emissions as measured over the FTP requires that the short test used in the inspection lane be an accurate predictor of FTP passage or failure. One way to ensure this is to define the idle deterioration rate in terms of the FTP deterioration rate. Currently in the model the assumption is made that FTP emissions can be quantitatively predicted from idle test emissions, and vice versa. The idle deterioration rate for a given vehicle is determined from the FTP deterioration rate and a regression relationship. Based on data over a limited mileage range, the relationships are assumed to be independent of milage and maintenance state.

Issue 3. Short test pass/fail cutpoints.

Concept. The purpose of an inspection/maintenance program is to reduce the emissions of in-use vehicles as measured over the FTP. A short emissions test procedure is intended to provide a practical method (i.e., quick and inexpensive) for identifying high FTP emitting vehicles. The benefit associated with an I/M program is dependent on the methodology used to determine the short test pass/fail cutpoint for each pollutant from year to year. The method of determining initial short test cutpoints has varied in practice from assigning cutpoints that are make/model specific to assigning one set of cutpoints for all light duty vehicles with similar emission control technology. The possibility of changing short test cutpoints to reflect vehicle age is also an important consideration.

Assumptions. The HC and CO cutpoints on which the Appendix N benefits are based are technology level specific. Thus, all vehicles of a given emission control technology (for example, catalyst-equipped cars) are assumed to have the same cutpoints. Cutpoints for the first year of the simulated I/M program were set by first specifying a stringency factor and then analyzing appropriate EPA emission factor data on one-year-old vehicles which were assumed to be representative of the nationwide mix of one-year-old vehicles. The analysis resulted in the determination of idle test pass/fail cutpoints for HC and O which corresponded to the specified stringency factor (ranging from 10 percent to 50 percent). For example, if a 30 percent stringency factor was specified, then HC and CO idle test cutpoints were determined so that approximately 30 percent of all vehicles would fail the idle test at the first inspection assuming that owners did not change their maintenance habits from those typically in effect prior to the implementation of I/M.

The relative stringency factors for HC and CO were determined by assuming that a car emitting at twice the HC FTP standard is equally likely to be failed as a car which is emitting at twice the CO FTP standard. This assumption is only one of an infinite number of ways that relative HC and CO stringency factors could be weighted to achieve the specified overall stringency factor. For example, since more AQCRs exceed ambient oxidant emission standards than exceed ambient CO standards, a car at twice the HC FTP emission standard could be considered equally likely to fail as a car which is at four times the CO FTP standard. The result of the weighting criterion which was applied is that at stringency levels below 30 percent, the large majority of vehicle failures can be attributed to high CO emission levels; even though significant percentages of HC failure are detected at stringency levels of 40 percent and above, HC failure is never as high as CO failure, percentagewise.

One of the model's critical assumptions with regard to cutpoint specification is that the first year cutpoints continue to be used year after year to determine which vehicles will pass or fail the idle test. One implication of the assumption of maintaining constant cutpoints over time is that vehicles can continue to be repaired to meet the same standards year after year, regardless of vehicle age or mileage. In support of th'- assumption, data from the 1973 and 197 EPA In-use Compliance Program (IUCP) programs indicate that vehicles can continue to be repaired to FTP levels well below short test levels which represent 50 percent stringency levels.

If service industry repair capability is assumed to be minimal (as in the base case Appendix N credits, where failed vehicles are repaired just to meet the idle test cutpoints), another implication is that the percentage of failed vehicles increases over time to about twice the initial stringency factor if, as the model assumes, significant voluntary owner maintenance does not occur. Data from I/M programs in New Jersey and Chicago indicate that the failure rates of a given model year of vehicles do not increase significantly as vehicles age, even though the same cutpoint is applied. Thus, either considerable voluntary maintenance is occurring or mechanics are repairing vehicles to levels significantly better than the minimum required repair levels.

Issue 4. Service industry repair capability.

Concept. Air quality benefit derived from an I/M program is dependent on the ability of the service industry to perform the repair work necessary to lower emissions. Depending on the level of service industry training, idle emissions could be reduced just to the cutpoints, or well below the cutpoints, potentially resulting in different benefits to air quality.

Assumptions. The base case benefits given in Table 1 of Appendix N assume that the service industry is capable of repairing all failed vehicles exactly to the idle test cutpoints. Then the equivalent FTP levels are computed so that the average urban benefits can be calculated. The model assumes that a vehicle which is failed incorrectly on the idle test does not have its FTP emissions either raised or lowered by the repair process. The model also assumes that a vehicle which fails for one pollutant only will have the other pollutant emissions lowered to the FTP equivalent idle standard in cases where errors of emission occurred.

Additional benefit is predicted if mechanic training is in effect. The model assumes that mechanic training would result in the reduction of emissions of failed vehicles to the FTP standards. As in the base case, the model assumes that if a vehicle fails for one pollutant only, the other pollutant will also be reduced to the FTP standard if an error of emission occurred. The first year credits indicate a dependency on stringency factor. For catalyst vehicles, the tendency is for mechanic training to have the largest effect on programs with stringency factors of 20 and 30 percent. This is reasonable because the effect of mechanic training is jointly dependent on the percent of cars failed and the degree of improvement in the FTP levels of repaired vehicles resulting from the mechanic training program: If only 10 percent of all cars are failed initially, then only 10 percent of all cars are repaired so that even an apparently significant increased reduction due to mechanic training will be somewhat dampened by the fact that a good percentage of the remaining cars are undoubtedly high FTP emitters which simply were not caught. If, on the other hand, 50 percent are failed and the FTP standards in gm/km are approximately equal to the FTP levels corresponding to the more stringent idle test cutpoints, additional benefit due to mechanic training would be insignificant. For precatalyst CO, the tendency described above, although less apparent, still seems to be present. However, precatalyst HC exhibits a tendency for mechanic training to have an increasing effect with increasing stringency factor. The tendency is explained by the fact that for the data which were input to the computer program, the HC FTP standards in gm/km was significantly lower than the FTP level corresponding to the idle test HC cutpoint, even at stringencies of 40 to 50 percent. As a result, an increased percentage of failed vehicles continued to produce increased benefit due to mechanic training.

The model assumes that owner tampering following the sequence of events: failure of the idle test, vehicle repair, and subsequent passage of the idle test, does not occur. Since motorists frequently attribute driveability problems to properly-functioning emission control devices, this assumption may be somewhat unrealistic unless mechanics become more knowledgeable about the tradeoffs between performance and emission rates. However, a good estimate of the frequency and effect of owner tampering (either with or without IM) is not available at the present time. Moreover, the benefit credits given in Appendix N require the existence of an effective anti-tampering program.

Issue 5. Frequency of inspection.

Concept. Since emission deterioration is modeled to occur continuously over time, the frequency of inspection determines the extent of vehicle deterioration between inspections. The more frequent the inspection, the less the vehicles deteriorate and thus the greater the I/M benefit.

Assumptions. For the base case benefits given in Appendix N, inspections are modeled to take place annually. Additional benefits result from semi-annual inspections. The difference in benefits from the annual to the semi-annual case is presented in section 3(c) of Appendix N.

Issue 6. Short test procedure used in the inspection lane.

Concept. Since the intent of an I/M program is to reduce the emissions of in-use vehicles as measured over the FTP, one would ideally be able to design a short emissions test procedure whose results could be used to accurately predict FTP emission levels. From a practical standpoint, the short test procedure must be quick, inexpensive, and applicable to vehicles in a warmed-up condition.

Assumptions. Benefits presented in Appendix N are based on the assumption that the idle test is used in the inspection lane. Limited analysis using the simulation model indicates that ~~benefits~~ using the idle test and a loaded test are comparable since the two tests are equally able to identify high FTP emitters.

ATTACHMENT 3

METHODOLOGY FOR APPLYING APPENDIX N BENEFIT NUMBERS

Tables 1 and 2 of Appendix N provide the I/M benefit numbers necessary to calculate the estimated calendar year percent reduction in HC and CO emissions from emission levels expected in the absence of I/M. To determine the percent reduction in HC and CO emissions for a given calendar year, the Appendix N numbers must be applied to the scenario in question. The scenario is specified in determining the following for the calendar year i of interest:

1. The calendar year, y, in which an I/M program was implemented.

2. The number or percentage of vehicles of each model year ($i-12$ through i) contributing to the total vehicle population (vehicles of model years earlier than $i-12$ should be considered as model year $i-12$),

3. Average vehicle kilometers traveled by each model year group of vehicles,

4. HC and CO emission factors (grams/kilometer) for each model year group of vehicles, assuming I/M has never been in effect.

The calculation of emission reduction in kilograms for a given pollutant (HC or CO) in calender year i is performed as follows:

$$D_i = \sum_{t=i-12}^{i} b_{ti} c_{ti} m_{ti} n_{ti},$$

where

b_{ti} = percent reduction in emissions for vehicles of model year t in calendar year i,[1]

c_{ti} = emission factor (grams/kilometer) for vehicles of model year t in calendar year i, assuming I/M has never been in effect,

m_{ti} = average kilometers traveled by vehicles of model year t in calendar year i,

n_{ti} = number of vehicles of model year t in calendar year i,

[1] The benefit numbers in Tables 1 through 4 of Appendix N (which represent both the base case of I/M and the case where mechanic training and/or a semi-annual program is in effect), can be used to determine b_{ti} by identifying the technology level represented by vehicles of model year t and the number of inspections which vehicles of model year t have undergone by the beginning of calendar year i. The number of inspections can be calculated formally as the minimum of $(i-y)$ and $(i-t)$ for an annual I/M program, where i is the calendar year of interest, y is the year in which I/M was implemented, and t is the model year. It is assumed that the maximum number of annual inspections for vehicles of all model years will be eight. For purposes of calculating benefit, model year vehicles which have undergone more than eight inspections should be treated as if only eight have been undergone.

The calculation of benefits in percent, B_i, in calendar year i requires one further step:

$$B_i = 100\, D_i \Big/ \left(\sum_{t=i-12}^{i} c_{ti} m_{ti} n_{ti} \right),$$

where the definitions of m, n, and c are as above.

If only the percent reduction is of interest, rather than the kilograms, the following alternative calculation of B_i can be used:

$$B_i = 100 \frac{\sum_{t=i-12}^{i} b_{ti} c_{ti} m_{ti} p_{ti}}{\sum_{t=i-12}^{i} c_{ti} m_{ti} p_{ti}},$$

where b, c, and m, are defined as above, and p is the fraction of vehicles on the road in calendar year i which are of model year t.

The calculation of the scenario's reduced emission factor (grams/kilometer) in calendar year i as a result of I/M, is performed as follows:

$$(BF)_i = \frac{(100-B_i)}{100} \cdot \left(\sum_{i=j-12}^{j} e_{ij} m_{ij} n_{ij}\right) \Big/ \left(\sum_{i=j-12}^{j} m_{ij} n_{ij}\right),$$

where B_i, e_{ij}, m_{ij}, and n_{ij} are as defined above. (Replacement of n_{ij} with p_{ij} will yield the same numerical results).

Appendix N can also be used to compute the average percentage benefit of I/M for a given vehicle over its useful life, which is assumed to be nine years or approximately 160,000 kilometers and represents eight annual I/M inspections. If the vehicle is of model year i and I/M began in calendar year y, this percent reduction in emissions for a specific pollutant is computed as follows:

$$U_i = 100 \cdot \left(\sum_{k=i}^{i+8} b_{k,i} c_{k,i} m_{k,i}\right) \Big/ \left(\sum_{k=i}^{i+8} c_{k,i} m_{k,i}\right),$$

where

k = calendar years covering the useful life of a vehicle of model year i; $k=i, i+1, \cdots, i+8$,

$b_{k,i}$ = percent reduction in emissions for vehicles of model year i in calendar year k,[4]

$c_{k,i}$ = emission factor (grams/kilometer) for vehicles of model year i in calendar year k, assuming I/M has never been in effect.

$m_{k,i}$ = average kilometers traveled by vehicles of model year i in calendar year k.

[4] The benefit numbers in Tables 1 through 4 of Appendix N (which represent both the base case of I/M and the case where mechanic training and/or a semi-annual program is in effect), can be used to determine $b_{k,i}$ by identifying the technology level represented by vehicles of model year i and the number of inspections which vehicles of model year i have undergone by the beginning of calendar year k. The number of inspections (for calendar years after calendar year y) can be calculated formally as the minimum of $(k-y)$ and $(k-i)$ for an annual I/M program, where y is the year in which I/M was implemented, i is the model year, and k is the calendar year. Note that $b_{k,i}=0$ for k less than or equal to y.

Nationwide estimates of the number of vehicles of each model year in the calendar year of interest, and average kilometers traveled by each model year vehicle for the calendar year of interest can be obtained by referring Table 1 which provides nationwide estimates of number of vehicles by vehicle age, and average kilometers traveled by vehicle age. Nationwide estimates of emission factors by calendar year are available in AP-42. Tables 2 and 3 provide, for illustrative purposes only, sample emission factors for calendar years 1977-1980 in format to be utilized in the upcoming revision of AP-42, Supplement 5.

Examples of the application of the methodology for calculating benefit.

Specification of scenario for problem examples 1 and 2. The nationwide mix of vehicles by age and average VKTs, as given in AP-42, applies. An I/M program with a 40 percent stringency factor was implemented in 1973, and vehicles one-year-old or older were tested by the end of calendar year 1973.

Problem 1. Determine the present reduction in emissions for HC and CO in CY 1977, assuming that the I/M inspections are annual, and that no mechanic training program is in effect.

Solution. The percent reduction, B_{77}, can be calculated from the formula:

$$B_{77} = \frac{\sum_{i=77-12}^{77} b_{77,i} e_{77,i} m_{77,i} p_{77,i}}{\sum_{i=77-12}^{77} e_{77,i} m_{77,i} p_{77,i}} \times 100,$$

where

$b_{77,i}$ = percent reduction in emissions for vehicles of model year i in calendar year 1977 (obtained from Appendix N),

$e_{77,i}$ = emission factor (gm/km) for vehicles of model year i in calendar year 1977, assuming I/M has never been in effect (obtained from AP-42),

$m_{77,i}$ = average kilometers traveled by vehicles of model year i in calendar year 1977 (obtained from AP-42)

$p_{77,i}$ = fraction of total vehicles on the the road in calendar year 1977 which are of model year i (obtained from AP-42).

Note that the denominator of B_{77} is the usual AP-42 type calculation of emission factors.

The following tables detail the calculation of both the numerator and denominator of B_{77} for HC and CO:

i	$b_{77,i}$ (percent)	$a_{77,i}$	$m_{77,i}$	$p_{77,i}$	Numerator product	Denominator product
1977	0	0.9	25.6	0.081	0	1.86
1976	16	1.1	24.2	.110	.47	2.93
1975	28	1.2	22.5	.107	.86	2.89
1974	24	2.8	21.1	.108	1.56	6.46
1973	30	2.4	19.6	.102	2.04	6.80
HC 1972	30	2.7	18.2	.096	1.94	6.46
1971	30	4.1	16.6	.088	1.80	5.99
1970	30	4.5	15.1	.077	1.57	5.23
1969	30	4.9	13.7	.064	1.29	4.30
1968	30	5.3	12.2	.049	.95	3.17
Pre-1968	30	6.1	10.8	.120	2.37	7.98
					14.66	54.67

HC: $B_{77}=(14.7/54.1)\times1.00=.27$.

i	$b_{77,i}$ (percent)	$a_{77,i}$	$m_{77,i}$	$p_{77,i}$	Numerator product	Denominator product
1977	0	14.7	25.6	0.081	0	30.5
1976	33	16.6	24.2	.110	14.6	44.2
1975	41	18.6	22.5	.107	18.4	44.8
1974	34	25.3	21.1	.108	25.8	73.9
1973	38	29.5	19.6	.102	30.0	79.0
CO 1972	38	42.7	18.2	.096	32.0	76.3
1971	38	47.9	16.6	.088	26.6	70.0
1970	38	52.1	15.1	.077	23.0	60.6
1969	38	54.3	13.7	.064	18.3	48.4
1968	38	60.5	12.2	.049	13.7	36.2
Pre-1968	38	77.5	10.8	.120	38.2	100.4
					228.1	670.3

CO: $B_{77}=(228.1/670.3)\times1.00=.34$.

Problem 2. Determine the percent reduction in emissions, B_{77}, for HC and CO in CY 1977, assuming that the inspections are annual and that an adequate mechanic training program is in effect.

Solution. The method used for Problem 1 applies. Only the $b_{77,i}$ numbers will differ to reflect the presence of an adequate program of mechanic training. The following tables detail the calculation of both numerator and denominator of B_{77} for HC and CO:

i	$b_{77,i}$ (percent)	$a_{77,i}$	$m_{77,i}$	$p_{77,i}$	Numerator product	Denominator product
1977	0	0.9	25.6	0.081	0	1.87
1976	17	1.1	24.2	.110	.50	2.93
1975	25	1.2	22.5	.107	.72	2.89
1974	36	2.9	21.1	.108	2.37	6.49
1973	41	2.4	19.6	.102	1.79	4.80
HC 1972	41	4.7	18.2	.096	2.85	6.48
1971	41	4.1	16.6	.088	2.46	5.99
1970	41	4.5	15.1	.077	2.15	5.25
1969	41	4.9	13.7	.064	1.76	4.30
1968	41	5.3	12.2	.049	1.30	3.17
Pre-1968	41	6.1	10.8	.120	3.24	7.98
					19.84	54.04

HC: $B_{77}=(19.8/54.0)\times1.00=.37$.

i	$b_{77,i}$ (percent)	$a_{77,i}$	$m_{77,i}$	$p_{77,i}$	Numerator product	Denominator product
1977	0	14.7	25.6	0.081	0	30.5
1976	40	16.6	24.2	.110	17.7	44.2
1975	51	18.6	22.5	.107	22.8	44.8
1974	47	25.3	21.1	.108	27.1	73.9
1973	51	29.5	19.6	.102	40.3	79
CO 1972	51	42.7	18.2	.096	38.9	76.3
1971	51	47.9	16.6	.088	35.7	70
1970	51	52.1	15.1	.077	30.9	60.6
1969	51	54.3	13.7	.064	25.2	48.4
1968	51	60.5	12.2	.049	18.5	36.2
Pre-1968	51	77.5	10.8	.120	51.2	100.4
					318.2	670.3

CO: $B_{77}=(318.2/670.3)\times1.00=.48$.

Specification of scenario for problem example 3. The nationwide mix of vehicles by age and average VKT, as given in AP-42, applies. An I/M program with a 30% stringency factor was implemented in calendar year 1980, and vehicles one year old or older were tested by the end of calendar year 1980. The program is annual and no mechanic training program is in effect. Since the emissions characteristics of 1978 and later model year cars are unknown, it will be assumed that the initial year emissions from these vehicles will be the same as that determined for 1975 model year vehicles by the Agency's Emission Factor Program; namely, .87 gm./km. HC and 14.7 gm./km. CO. Also, it will be assumed that 1978 and later model year vehicles deteriorate at the same rate as 1975-77 models; namely, .17 gm/km./yr. HC and 1.96 gm./km./yr. CO.

Problem 3. Determine the percent reduction in emissions, B_{90} for HC and CO in calendar year 1990, and the resulting reduced emission factors for HC and CO for calendar year 1990.

Solution. To calculate B_{90} the method used in the solutions to Problems 1 and 2 applies. The following tables detail the numerical calculation of both numerator and denominator of B_{90} for HC and CO.

i	$b_{90,i}$ (percent)	$a_{90,i}$	$m_{90,i}$	$p_{90,i}$	Numerator product	Denominator product
1990	0	0.9	25.6	0.081	0	1.87
1989	9	1.1	24.2	.110	.25	2.93
1988	16	1.2	22.5	.107	.46	2.89
1987	25	1.4	21.1	.108	.73	3.12
1986	29	1.6	19.6	.102	.93	3.20
1985	34	1.7	18.3	.096	1.01	2.97
HC 1984	39	1.9	16.6	.088	1.08	2.78
1983	42	2.0	15.1	.077	.98	2.33
1982	45	2.2	12.7	.064	.81	1.98
1981	45	2.4	12.2	.049	.65	1.44
1980	45	2.4	10.8	.033	.38	.86
Pre-1980	45	2.4	10.8	.087	1.01	2.26
					8.28	28.38

HC: $B_{90}=(8.3/28.4)\times1.00=.29$.

i	$b_{90,i}$ (percent)	$a_{90,i}$	$m_{90,i}$	$p_{90,i}$	Numerator product	Denominator product
1990	0	14.7	25.6	0.081	0	30.5
1989	25	16.6	24.2	.120	12.4	44.2
1988	29	18.6	22.5	.107	14.1	44.8
1987	42	20.6	21.1	.108	19.3	46.1
1986	47	22.5	19.6	.102	21.1	45.0
1985	51	24.5	18.3	.096	21.8	42.8
CO 1984	55	26.6	16.6	.088	21.3	38.8
1983	58	28.4	15.1	.077	19.2	33.0
1982	63	30.3	13.7	.064	14.7	26.6
1981	68	32.3	12.2	.049	12.3	19.3
1980	68	32.3	10.8	.033	7.8	11.5
Pre-1980	68	33.3	10.8	.087	18.1	28.3
					186.9	412.7

CO: $B_{90}=(186.9/412.7)\times1.00=.45$.

To calculate the reduced emission factors for HC and CO, the following formula can be used:

$$(EF)_{90} = \frac{100 - B_{90}}{100} \times \frac{\sum_{i=90-12}^{90} e_{90,i}\, m_{90,i}\, p_{90,i}}{\sum_{i=90-12}^{90} m_{90,i}\, p_{90,i}}$$

The following tables detail the calculation of the numerator and denominator:

	$e_{90,i}$	$m_{90,i}$	$p_{90,i}$	Numerator product	Denominator product
1990	0.9	25.6	0.081	2.07	1.87
1989	1.1	24.2	.110	2.93	2.66
1988	1.2	22.5	.107	2.89	2.41
1987	1.4	21.1	.106	3.13	2.24
1986	1.6	19.6	.102	3.20	2.00
1985	1.7	18.2	.096	2.97	1.75
HC 1984	1.9	16.6	.088	2.78	1.46
1983	2.0	15.1	.077	2.32	1.16
1982	2.2	13.7	.064	1.93	.88
1981	2.4	12.2	.049	1.43	.60
1980	2.4	10.8	.033	.86	.36
Pre-1980	2.4	10.8	.087	2.25	.94
				28.78	18.33

HC: $(EF)_{90} = .71 \times \frac{28.8}{18.3} = 1.12$ g/km.

i	$e_{90,i}$	$m_{90,i}$	$p_{90,i}$	Numerator product	Denominator product
1990	14.7	25.6	0.081	30.5	2.07
1989	16.6	24.2	.110	44.2	2.66
1988	18.6	22.5	.107	44.8	2.41
1987	20.6	21.1	.106	46.1	2.24
1986	22.5	19.6	.102	45.0	2.00
1985	24.5	18.2	.096	42.8	1.46
CO 1984	26.4	16.6	.088	38.6	1.46
1983	28.4	15.1	.077	33.0	1.16
1982	30.3	13.7	.064	26.6	.88
1981	32.3	12.2	.049	19.3	.60
1980	32.3	10.8	.033	11.6	.36
Pre-1980	32.3	10.8	.087	30.3	.94
				412.7	18.24

CO: $(EF)_{90} = .55 \times \frac{412.7}{18.3} = 12.5$ g/km.

TABLE 1.—*Estimated fraction of vehicles in use nationwide and average annual kilometers driven nationwide, by vehicle age*

Vehicle age, in years	Fraction of vehicles	Average annual kilometers driven, in thousands
1	0.081	25.6
2	.110	24.2
3	.107	22.5
4	.106	21.1
5	.102	19.6
6	.096	18.2
7	.088	16.6
8	.077	15.1
9	.064	13.7
10	.049	12.2
11	.033	10.8
12+	.087	10.8

Source: AP-42.

TABLE 2.—*Emission factors for light-duty, gasoline-powered vehicles (automobiles) (low altitude, non-California)*

Model year	Carbon monoxide, grams/kilometer; calendar year—			
	1977	1978	1979	1980
Pre-1968	77.5	77.5	77.5	77.5
1968	60.5	60.5	60.5	60.5
1969	56.3	60.5	60.5	60.5
1970	52.1	56.5	60.5	60.5
1971	47.9	52.1	56.5	56.5
1972	43.7	47.9	52.1	56.5
1973	39.5	43.7	47.9	52.1
1974	35.3	39.5	43.7	47.9
1975	18.6	20.6	22.5	24.5
1976	16.6	18.6	20.6	22.5
1977	14.7	16.6	18.6	20.6

TABLE 3.—*Emission factors for light-duty, gasoline-powered vehicles (automobiles) (low altitude, non-California)*

Model year	Hydrocarbons, grams per kilometer; calendar year			
	1977	1978	1979	1980
Pre-1968	6.1	6.1	6.1	6.1
1968	5.3	5.3	5.3	5.3
1969	4.9	5.3	5.3	5.3
1970	4.5	4.9	5.3	5.3
1971	4.1	4.5	4.9	5.3
1972	3.7	4.1	4.5	4.9
1973	3.4	3.7	4.1	4.5
1974	2.9	3.4	3.7	4.1
1975	1.2	1.4	1.6	1.8
1976	1.1	1.2	1.4	1.6
1977	.9	1.1	1.2	1.4

Appendix B

SHORT TEST EMISSIONS STANDARDS AS RELATED TO

THE FEDERAL TEST PROCEDURES (FTP)

Appendix B

SHORT TEST EMISSIONS STANDARDS AS RELATED TO THE FEDERAL TEST PROCEDURE (FTP)

B.1 SHORT TEST CORRELATION

The correlation attributes between short test programs and FTP tests for noted gaseous emissions for model year 1975 are presented in Figures B-1, B-2, B-3, B-4, B-5, and B-6. In setting pass/fail limits in a mandatory inspection program using modal testing, it is required to set concentration standards that relate in a logical manner to the Federal Constant Volume Sampling (CVS) test procedure.

U.S. Environmental Protection Agency (EPA) report "Evaluation of Restorative Maintenance on 1975 and 1976 Light-duty Vehicles in Detroit, Michigan" (Ref. 27) presented emission test results for individual vehicles for test types noted in Table B-1. This data is plotted in the graphs as noted above for idle and loaded mode. The data, along with its statistical analysis, indicates a low level of correlation. Superimposed on the graph is a Federal Test Procedure to short test procedure regression relationship established by the EPA (Ref. 28). To establish a starting point for any one level of gr/mile as required by the Federal registration, read the FTP Reading and project this to regression line. Proceed to read the corresponding ppm reading. This is a starting point to establish the promulgated regulation ppm reading under Michigan law for a short-test operation. It is evident that this is a very rough approximation because of the lack of correlation of data points as plotted with respect to FTP test requirements.

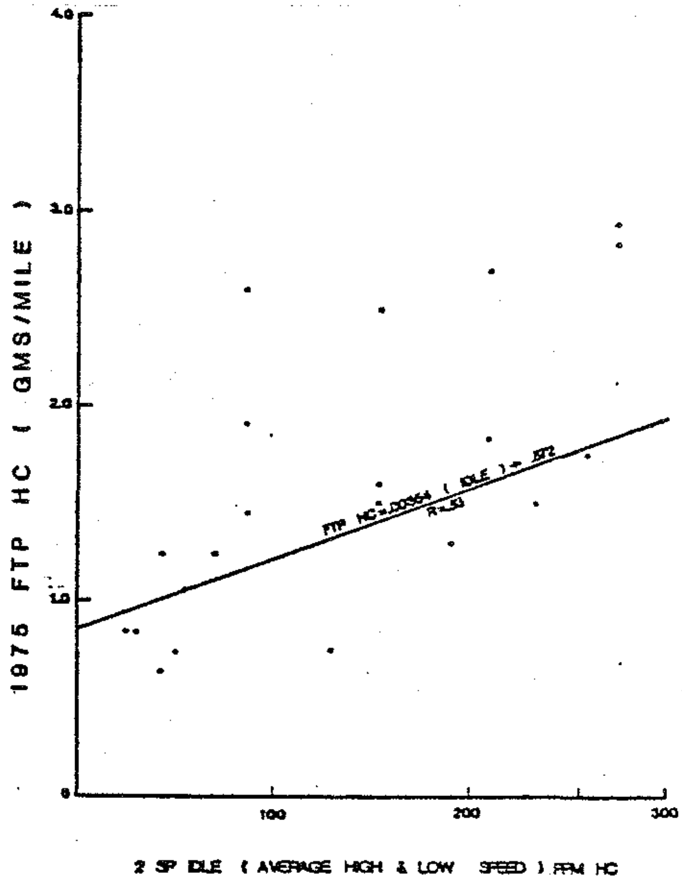

Fig. B-1
HC Emissions
Idle Mode

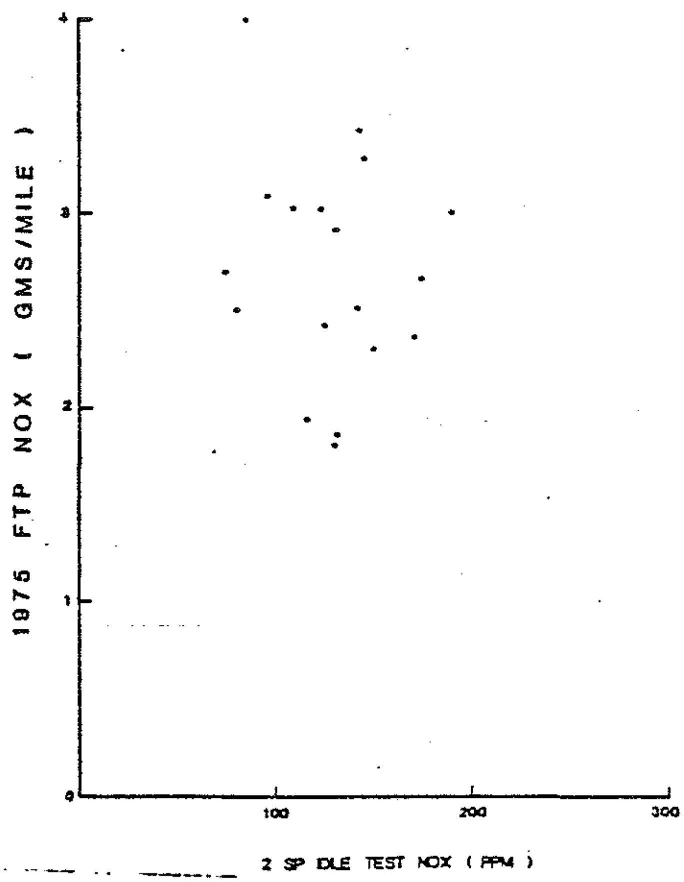

Fig. B-2
NO_x Emissions
Idle Mode

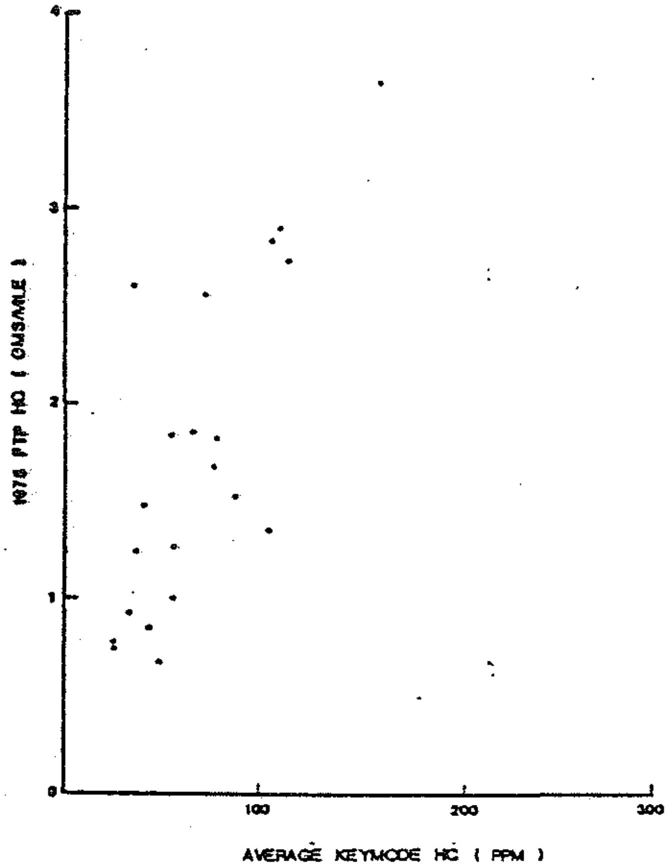

Fig. B-3
HC Emissions
Key Mode

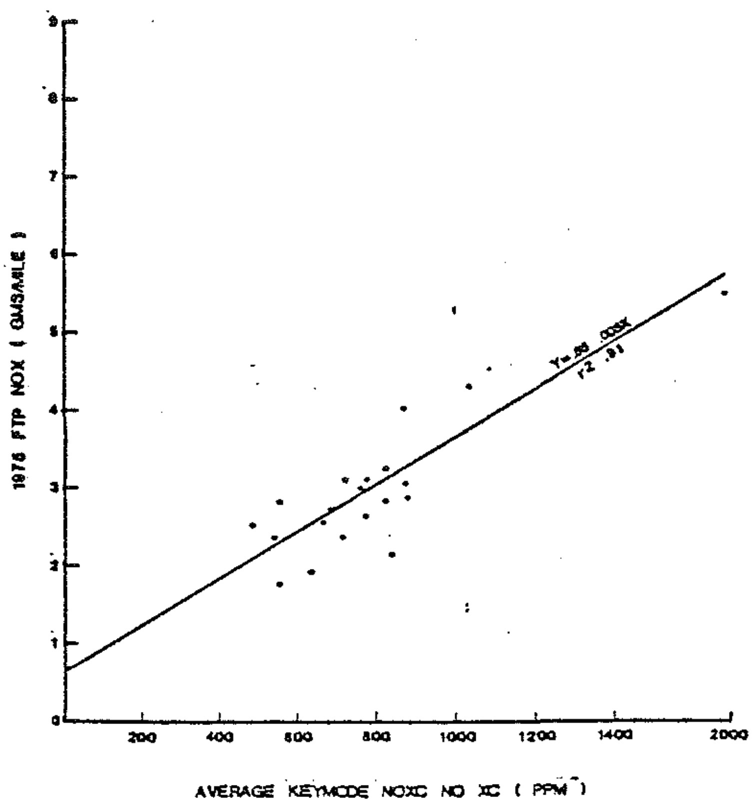

Fig. B-4
NO_x Emissions
Key Mode

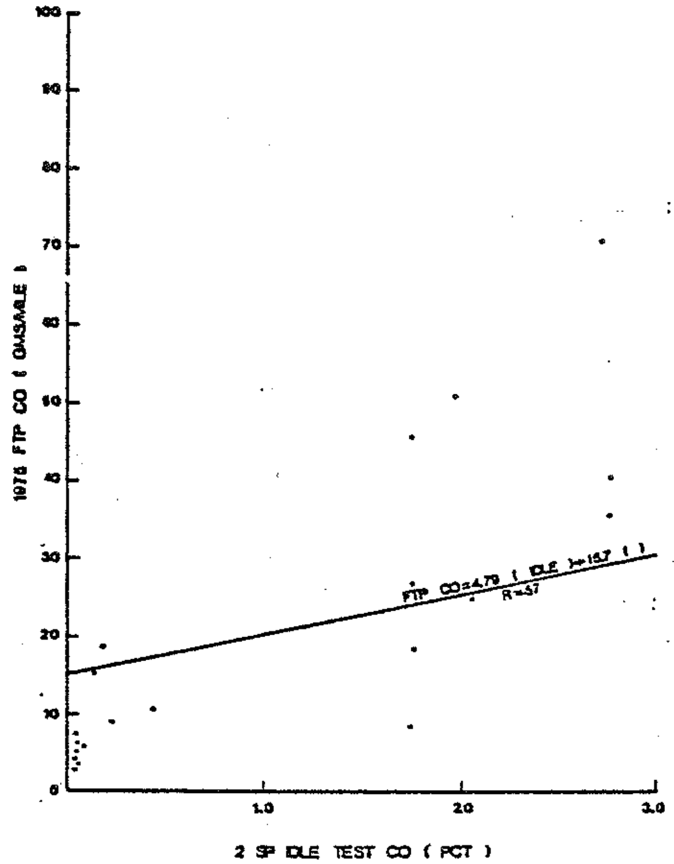

Fig. B-5
CO Emissions
Idle Mode

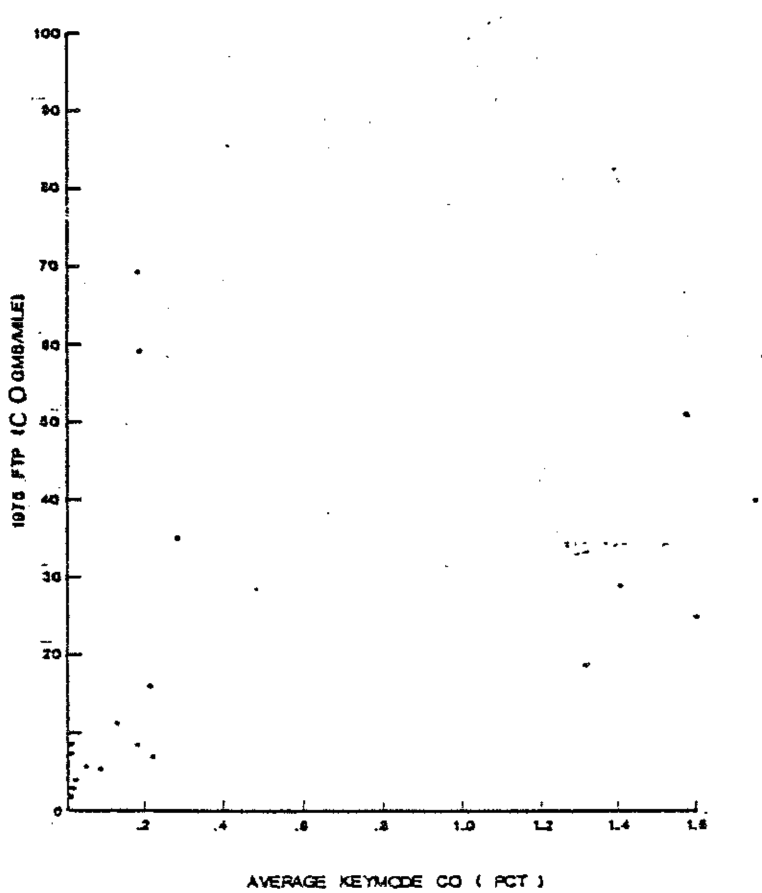

Fig. B-6
CO Emissions
Key Mode

Table B-1. TEST TYPES

TEST	EMISSIONS READINGS	TEST PROCEDURE CHARACTERISTICS
1975 FTP	GMS/Mile	Defined in sections 85.076-14 through 85.075.24 of Federal Register Vol. 37, No. 221
HWY FET	GMS/Mile	Defined driving cycle of 10.2 miles and 765 second duration
FED SCY	GMS/Mile	Driving cycle of 125 second duration and .7536 miles in length and 9 modes
NY/NJ	GMS/Mile	Driving cycle of 75 seconds duration and .2792 miles in length consisting of 7 mode
KEY MODE	Concentration ppm/pct	3 Steady-state operating conditions high-speed, low speed and idle plus presoak
TWO-SPEED IDLE TEST	Concentration ppm/pct	Nonloaded test having two speeds: idle and 2,250 rpm
FED THREE-MODE	Concentration ppm/pct	Similar to Key Mode with dynamometer loads simulating the average power as required on the FTP under NADA weight class

Table B-2 presents correlation coefficient for short-test emission measurement procedures on a California 1972 Idle Inspection Fleet Test Program.

B.2 IDLE TEST CORRELATION AND COMMISSION ERRORS

Until there is a sufficient data base that describes the operational characteristics of emission control systems, it is not possible to determine with certainty the adequacy of various emission test procedures in identifying malfunctions of those systems. The relative importance of identifying various types of malfunctions cannot be determined until operating experience with substantial numbers of new and future emission control systems has been gained. However, some conclusions can be drawn, based on the general characteristics of various test procedures.

The Federal Certification Test Procedure (FTP) is considered the standard for measuring vehicle emissions because it is representative of vehicle operation in urban areas. The idle-mode emission test, as compared with the FTP, provides for testing a limited number of operating conditions.

The idle-mode test for emission testing is unable to diagnose malfunctions of exhaust gas recirculation (EGR) systems which are currently used by most automobile manufacturers to ensure compliance with the 1973 Federal NO_x emission standards. When the EGR valve is functioning properly, there is no recirculation of the exhaust gas during idle operation so the system provides no reduction of idle NO_x emissions. A malfunction of the EGR system causing an increase in NO_x emission during loaded operating modes would not result in a concurrent increase in idle-mode emissions. The malfunction would remain undetected by an idle test measurement.

A loaded-emission test includes a wide range of operating conditions and would be generally useful in testing future vehicles. However, all current short emission tests are hampered by their inability to measure cold-start emissions, which is important for vehicles equippped with a catalytic or thermal reactor emission control systems.

Table B-2

CORRELATION COEFFICIENTS FOR SHORT TEST EMISSION MEASUREMENT PROCEDURES

1972 FTP REGRESSION BEFORE SERVICE

CALIFORNIA IDLE INSPECTION FLEET DATA

Test Procedure	Emission Measurement	Correlation Coefficient			Standard Error of Estimate Grams Per Mile		
		HC	CO	NOx	HC	CO	NOx
Federal Short Cycle	Mass	0.94	0.81	0.74	2.5	32	1.1
Seven Mode Cycle	Mass	0.91	0.70	0.70	3.1	38	1.1
Key Mode (multiple regression)	Mass	0.96	0.81	0.66	2.2	32	1.2
Steady State Modes (mult. regression)	Mass	0.96	0.82	0.71	2.2	32	1.2
Idle Mode	Mass	0.80	0.62	0.15	4.4	42	1.6
Seven Mode Cycle	Volumetric	0.57	0.77	0.43	6.0	34	1.4
Key Mode (multiple regression)	Volumetric	0.79	0.68	0.61	4.5	40	1.3
Steady State Modes (mult. regression)	Volumetric	0.81	0.68	0.63	4.4	40	1.3
Idle Mode	Volumetric	0.35	0.50	0.02	6.8	46	1.6

The evaluation of alternative inspection procedures must also consider their relationship to enforcing the warranty provisions set forth in Section 207 of the Clean Air Act. That section authorizes the EPA to establish regulations requiring automobile manufacturers to warrant the emission control performance of every new motor vehicle for the vehicle's useful life. To implement this provision, Section 207 requires that there be available short-test procedures which aciieve adequate correlation with the FTP. While the definition of adequate correlation is yet to be established, it is clear that those short tests which achieve the highest degree of correlation will most likely satisfy the requirements for adequate correlation. Correlation analyses have consistently shown that for current vehicles, the dynamic (loaded) tests, as a general category, achieve significantly higher correlation with the FTP than do the idle-mode tests. States are not required to consider the feasibility of enforcing the warrantly provisions in the design of their transportation control plans.

The selection of an individual inspection test requires the development of criteria for determining what degree of correlation is adequate to satisfy the warranty provisions. The following analysis provides a qualitative means of making such a determination.

For illustrative purposes, it is assumed that the points marked"a" in Figure B-7 represent the Federal emission standard for all the vehicles in a sample fleet. The points marked "b," "c," "d," and "e," represent hypothetical cut points for a state inspection program. A higher cut point results in a lower rejection rate and, thereby, reduces the fleet emission reduction potential of the program. Any vehicle which is above the inspection cut point, and is to the left of point "a," is defined as an error of commission. There vehicles are erroneously identified as excessive emitters. Any vehicle which fails the inspection criteria and is to the right of point"a" is a valid failure.

The feasibility of enforcing the warranty will be determined by the frequency of commission errors among the vehicles which fail the short test. The probability of a commission error can be reduced by raising the inspection

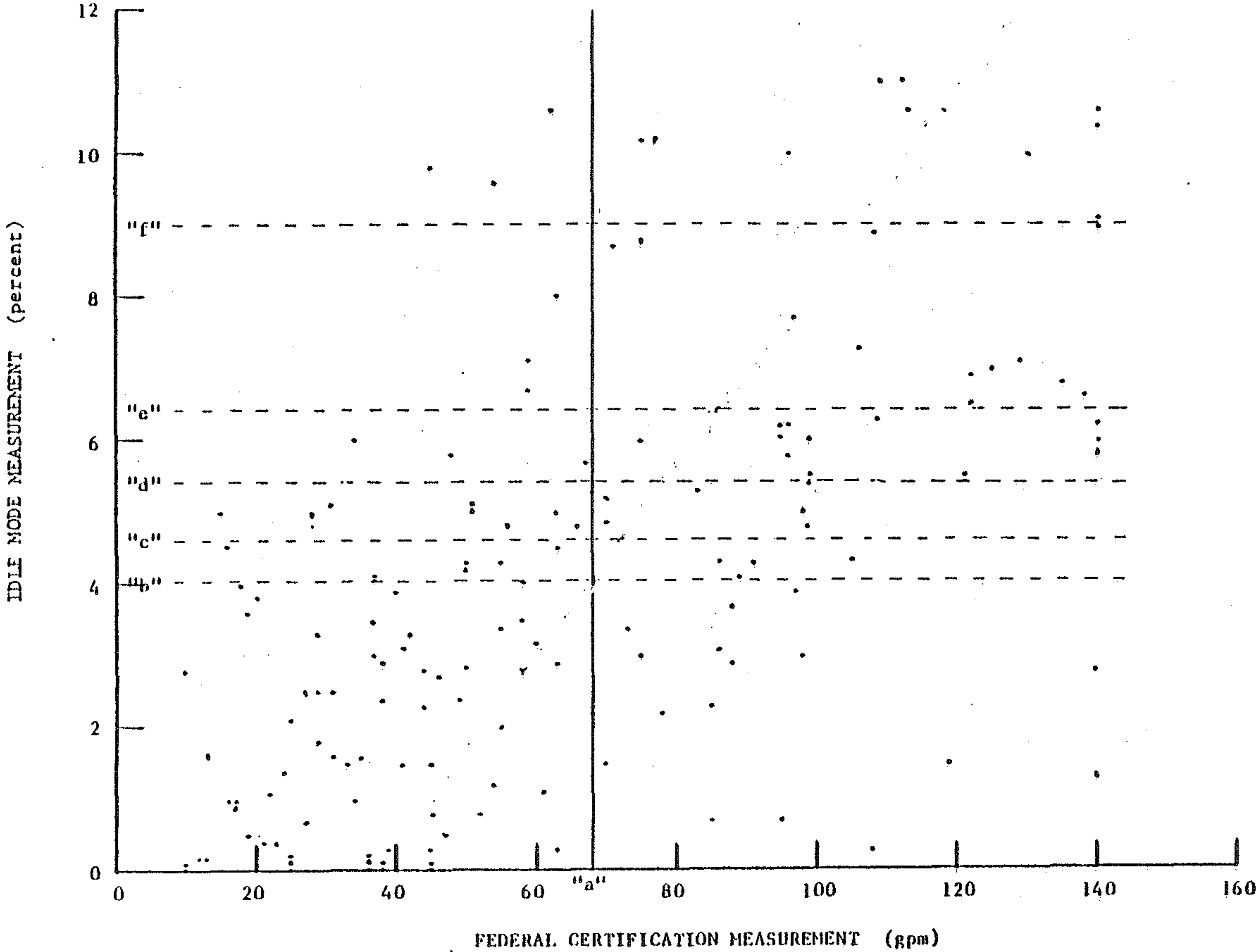

Figure B-7. CARBON MONOXIDE EMISSIONS IDLE MODE TEST CYCLE VERSUS FTP

Correlation Coefficient = .375

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ENVIRONMENTAL ENGINEERING DIVISION

test failure criteria. At any cut point, a commission error is still defined as any failed vehicle to the left of point "a." A trade-off exists between the feasibility of enforcing the warranty and the fleet emission reduction achieved by the inspection strategy. The degree of correlation between the two test procedures is a measure of the extent to which the short-test failure criteria must be raised to reduce the errors of commission to an acceptable level.

Table B-3 presents the results of applying this type of analysis for the idle-mode test procedure. The rejection rate, the frequency of commission errors, and the fleet emission reductions are shown for selected short test cut points.

Table B-3. ERRORS OF COMMISSION FOR IDLE-MODE SHORT-TEST PROCEDURES

TEST TYPE	REJECTION RATE %	FREQUENCY OF COMMISSION ERRORS % OF FAILED VEHICLES	FLEET EMISSION REDUCTION AFTER MAINTENANCE (CO Emissions) %
Idle Mode Test	50	43	17
(Corr. Coef. = 0.375)	40	40	15
	30	30	10
	20	30	12
	10	27	8
	5	14	4

Source: Ref. 5

The results of this analysis are not intended to provide sufficient information to determine the failure criteria which should be used in a state program. The test fleet used to demonstrate this analysis was composed of the total model-year mix of the 1972 California vehicle population. The individual failure criteria would have to be determined for each model-year such that the commission errors were reduced to an acceptable level. However, Table B-3 does demonstrate the impact of the trade-off between commission errors and the fleet emission reduction potential for idle-mode test.

Appendix C

LOADED-MODE TRUTH CHART AND DIAGNOSTIC PROCEDURES

Appendix C

LOADED-MODE TRUTH CHART AND DIAGNOSTIC PROCEDURES

C.1 TRUTH CHART USAGE

The truth chart (Table C-1) shows failure patterns resulting from various types of malfunction or maladjustment. Also shown on the truth chart is a general description of the probable cause of failure and diagnostic code for each failure pattern.

The test results of failed vehicles are compared with the truth chart to determine the correct failure pattern. The inspector then determines the general cause of failure and refers to the appropriate diagnostic procedures, as indicated by the diagnostic code, for a more detailed analysis of the problem.

Example: A vehicle fails HC and CO in the idle-mode. The inspector uses the truth chart and finds the correct failure pattern. The probable cause of failure, in this case, is the idle air/fuel mixture is too rich, the diagnostic code is 1. This portion of the diagnostic truth table is shown below.

	IDLE	LOW	HIGH	COMMENTS/PROBABLE CAUSE OF FAILURE	DIAGNOSTIC CODE
CO	F	(F)			
HC	(F)			Idle air/fuel mixture rich	1

The inspector refers to diagnostic procedure 1 and finds that a rich air/fuel mixture at idle may be caused by one or more of the following:

Table C-1. DIAGNOSTIC TRUTH CHART

	TEST MODE Idle	Low	High	COMMENTS/PROBABLE CAUSE OF FAILURE	DIAGNOSTIC CODE
NO_x		F[a]	F[b]	Faulty ignition advance and/or EGR.	6
CO	F	(F)			
HC	(F)			Idle air/fuel mixture rich.	1
HC	F			HC emission fluctuate.	
CO	N/L			CO emission normal or low.	2
				Idle air/fuel mixture lean.	
	(F)	F	F		
CO	(F)		F	Faulty carburetion or air induction	3
	(F)	F		system.	
	(F)	F		Faulty spark plug(s), spark plug	
HC	(F)	F	F	wire(s), or ignition components.	4
	(F)		F		
HC	(F)	F	F		
CO	(F)	F	F	Faulty exhaust valve action and/or faulty	5
				rings.	

[a]1971 through 1974 model LDV.

[b]1975 and later model LDV.

F = Mode must fail.

(F) = Mode may also fail.

- Faulty idle mixture adjustment
- PDV restriction
- Faulty air injection system (if equipped)
- Clogged carburetor idle air-bleed passages.

In addition, diagnostic procedures for determining which of the above case causing the failure are listed. The diagnostic procedures are to be completed in the order shown. This will help to insure that the simplest, quickest and least costly repair will be found to resolve the problem. The repairs are then performed per the manufacturer's specifications.

Diagnostic Procedure 1 - Idle A/F Mixture Rich

The following procedures are to be completed in the order shown. Refer to service manuals for specific repair information.

Diagnosis

Rich A/F mixture at only idle can be caused by PCV restriction, faulty idle mixture adjustment, air inspection (if equipped), or clogged carburetor idle air-bleed passages. Rich idle A/F mixture causes failing CO and high, possible failing HC emission at idle. Since this malfunction occurs only at idle, the air cleaner, carburetor choke, and carburetor mainsystems are satisfactory.

A. Carburetor Idle Adjustment - Make a gross adjustment of idle mixture to determine whether CO can be brought within the specification. If CO can be corrected by adjustment, complete the final adjustments. If not, continue with diagnosis.

B. PCV System - Test PCV valve by disconnecting tube to crankcase and feeling for vacuum ahead of the valve at idle. Replace valve if vacuum cannot be detected. Check all components for free flow. Listen for clicking of valve to changes in vacuum.

C. Air Injection System (if equipped) - Disconnect from air injection pump. Feel for pressure and flow. If no flow can be detected, service pump.

D. Clogged Idle Air-Bleed Passages - If CO cannot be corrected by one of the above, carburetor must be rebuilt.

Diagnostic Procedure 2 - Idle A/F Mixture Lean

Diagnosis

Lean idle A/F mixture can be caused by excessive air leaking into the engine at idle or too lean an idle screw adjustment. Lean A/F mixture results in normal or low CO emissions (may be less than 1 percent) and high fluctuating HC emissions. High HC emissions can also be caused by grossly advanced ignition timing.

A. Gross Lean Adjustment of Idle Mixture - If idle CO emissions are less than 0.5 percent, richen idle mixture to determine if HC emissions can be brought within specification. If they can, then perform ADJUSTMENT.

B. Vacuum Leak - Inspect for vacuum leaks in the induction system by spraying a heavy hydrocarbon onto the carburetor body and intake manifold. Idle speed will increase and engine idle will smooth out if vacuum leaks are present. Check for loose or missing vacuum hoses. Check PCV ventilation valve to determine if it is stuck in full flow position.

C. Ignition Timing - Check timing and advance with timing light. Check dwell with oscilloscope.

Diagnostic Procedure 3 - Faulty Carburetion

Diagnosis

Faulty carburetion results in excessive carbon monoxide emissions during low and high cruise and may contribute to excessive idle emissions. Faulty carburetion causes excessive quantities to fuel to be supplied to the engine. It may also be due to problems with the air induction system rather than the carburetor itself.

A. Air Cleaner - Inspect air cleaner element. Replace if CO emissions at 2,500 rpm with and without air cleaner element installed change more than 1 percent CO.

B. Carburetor Choke - Check to ensure that the choke is not stuck partially closed. Repair or adjust if not fully open at normal engine temperature.

C. Carburetor Main System - With air cleaner removed and choke open, measure CO emissions at 2,500 rpm. Carburetor main system is satisfactory if CO emissions decrease to less than one half of idle CO emission level.

D. Fuel Pump Pressure - Check for excess fuel pressure. If excess pressure is present, check for restricted fuel return line and pump bypass valve.

Diagnostic Procedure 4 - Faulty Spark Plug, Spark Plug Wire, or Ignition Components

Diagnosis

Spark plug, spark plug wire or ignition component failures resulted in secondary ignition misfire in at least one cylinder producing very high HC emissions during low and high cruise and may contribute to high idle emissions.

A. Conduct an ignition system diagnosis. Check for erroded plugs, incorrect gap, disconnected or open wires, crossfire, distributor cap and rotor condition.

B. Conduct a diagnosis of the following components to determine where the expected fault is occurring; coil, condensor, distributor advance mechanisms, electronic ignition components.

Diagnostic Procedure 5 - Faulty Exhaust Valve Action/Bad Rings

Diagnosis

Faulty exhaust valve action and/or bad rings result in producing high HC and CO emissoins in low and/or high cruise. This condition may also cause high HC and/or CO emissions in the idle-mode.

A. Conduct a compression check to determine if the valve(s) are seating. The compression check should show no more than 20 percent variation from highest to lowest cylinder and be within the manufacturer's recommended specification.

B. If the compression check is not satisfactory, perform a cylinder leak down test to determine whether the rings or valves are at fault.

Diagnostic Procedure 6 - Faulty Ignition Advance and/or EGR

Diagnosis

On NO_x system equipped vehicles, either original equipment or retrofit equipment, the ignition advance is modified to inhibit NO_x formation. Many vehicles also employ exhaust gas recirculation (EGR). These systems may malfunction resulting in excessive NO_x emissions during the low or high cruise.

A. Determine whether emission failure is due to NO_x system malfunction. Repair or replace the system according to applicable service procedures. Check for plugged EGR valves or disconnected hoses.

B. Check for vacuum or mechanical advance malfunction, incorrect basic timing or dwell. Repair and adjustment of the timing malfunction may correct the NO_x failure.

Appendix D

EMISSIONS-RELATED PARTS LIST

Appendix D

EMISSIONS-RELATED PARTS LIST

The following list of components are examples of emissions-related parts.

I. CARBURETION AND AIR INDUCTION SYSTEM

A. Air Induction System:

1. Temperature sensor elements
2. Vacuum motor for air control
3. Hot air duct and stove
4. Air filter housing and element

B. Emissions Calibrated Carburetors:

1. Metering jets
2. Metering rods
3. Needle and seat
4. Power valve
5. Float circuit
6. Vacuum break
7. Choke mechanism
8. Throttle control solenoid
9. Deceleration valve
10. Dashpot
11. Idle stop solenoid, anti-dieseling assembly
12. Accelerating pump
13. Altitude compensator

C. Mechanical Fuel Injection:

1. Pressure regulator
2. Fuel injection pump
3. Fuel injectors
4. Throttle-position compensator
5. Engine speed compensator
6. Engine temperature compensator
7. Altitude cut-off valve
8. Deceleration cut-off valve
9. Cold-start valve

D. Continuous Fuel Injection:

1. Fuel pump
2. Pressure accumulator
3. Fuel filter
4. Fuel distributor
5. Fuel injectors
6. Air-flow sensor
7. Throttle-position compensator
8. Warm-running compensator
9. Pneumatic overrun compensator
10. Cold-start valve

E. Electronic Fuel Injection:

1. Pressure regulator
2. Fuel distribution manifold
3. Fuel injectors
4. Electronic control unit
5. Engine speed sensor
6. Engine temperature sensor
7. Throttle-position sensor
8. Altitude/manifold-pressure sensor
9. Cold-start valve

F. Air Fuel Ratio Control:

1. Frequency valve
2. Oxygen sensor
3. Electronic control unit

G. Intake Manifold

II. IGNITION SYSTEM

A. Distributor:

1. Cam
2. Points
3. Rotor
4. Condenser
5. Distributor cap
6. Breaker plate
7. Electronic components (breakerless or electronic system)

B. Spark Advance/Retard Systems:

1. Centrifugal advance mechanism:

    a. weights
    b. springs

2. Vacuum advance unit

3. Transmission controlled spark systems:

    a. Vacuum solenoid
    b. Transmission switch
    c. Temperature switches
    d. Time delay
    e. CEC valve
    f. Reversing relay

4. Electronic spark control systems:

    a. Computer circuitry
    b. Speed sensor
    c. Temperature switches
    d. Vacuum switching valve

5. Orifice spark advance control systems:

    a. Vacuum by-pass valve
    b. OSAC (orifice spark advance control) valve
    c. Temperature control switch
    d. Distributor vacuum control valve

6. Speed controlled spark systems:

    a. Vacuum solenoid
    b. Speed sensor and control switch
    c. Thermal vacuum switch

C. Spark Plugs

D. Ignition Coil

E. Ignition Wires

III. MECHANICAL COMPONENTS

A. Valve Train:

1. Intake valves
2. Exhaust valves
3. Valve guides
4. Valve springs
5. Valve seats
6. Camshaft

B. Combustion Chamber:

1. Cylinder head or rotor housing*
2. Piston or rotor

*Rotary (Wankel) engines only

IV. EVAPORATIVE CONTROL SYSTEM

A. Vapor Storage Canister and Filter

B. Vapor Liquid Separator

C. Filler Cap

D. Fuel Tank

V. POSITIVE CRANKCASE VENTILATION SYSTEM

A. PCV Valve

B. Oil Filler Cap

C. Manifold PCV Connection Assembly

VI. EXHAUST GAS RECIRCULATION SYSTEM

A. EGR Valve:

1. Valve body and carburetor spacer
2. Internal passages and exhaust gas orifices

B. Driving Mode Sensors:

1. Speed sensors
2. Solenoid vacuum valve
3. Electronic amplifier
4. Temperature-controlled vacuum valve
5. Vacuum reducing valve
6. EGR coolant override valve
7. Backpressure transducer
8. Vacuum amplifier
9. Delay valves

VII. AIR INJECTION SYSTEM

A. Air Supply Assembly:

1. Pump
2. Pressure relief valve
3. Pressure-setting plug
4. Pulsed air system

B. Distribution Assembly:

1. Diverter, relief, bypass, or gulp valve
2. Check or anti-backfire valve

3. Deceleration control part
4. Flow control valve
5. Distribution manifold
6. Air switching valve

C. Temperature sensor

VIII. CATALYST, THERMAL REACTOR, AND EXHAUST SYSTEM

A. Catalytic Converter:

1. Constricted fuel filler neck
2. Catalyst beads (pellet type converter)
3. Ceramic support and monolith coating (monolith type converter)
4. Converter body and internal supports
5. Exhaust manifold

B. Thermal Reactor:

1. Reactor casing and lining
2. Exhaust manifold and exhaust port liner

C. Exhaust System:

1. Manifold
2. Exhaust port liners
3. Double walled portion of exhaust system
4. Heat riser valve and control assembly

Appendix E

NOISE TESTING

Appendix E

NOISE TESTING

E.1 INTRODUCTION

To control the vehicle noise emission, effective state and local noise regulations for vehicles-in-use (VIU) are required. Table E-1 shows that Michigan, among a few other leading states, already has noise standards for VIU.

A good noise regulation for VIU alone will not control the noise environment. Its success depends on a good enforcement program. At the heart of a solid enforcement program for VIU is a simple and reliable vehicle noise test that can be included in the regular state I/M inspection procedure. So far, Michigan, Minnesota, Colorado, and California are the only states that are aware of this and are considering its incorporation.

The ideal test needs to be simple in its requirements for test time, skill, site, and equipment. Most of the time, passby test methods are used as the ultimate standards because of the belief that passby represents the common vehicle operating modes. EPA promulgated noise standards are all based on vehicle passby tests. These tests are not simple by any of the criteria mentioned above.

Most of the stationary tests are substantially simpler but not very useful. This is because their results correlate poorly with those of the tests adopted by the EPA standards which preempt all state and local standards

Table E-1. IN-USE SOUND LEVEL LIMITS

STATE	ON-ROAD MOTOR VEHICLES	ON-ROAD MOTORCYCLES	OFF-ROAD MOTORCYCLES	OFF-ROAD VEHICLES	SNOW-MOBILES	MOTOR-BOATS
Alabama	-	No	No	-	-	-
Alaska	-	No	No	-	-	-
Arizona	-	No	No	-	-	Yes
Arkansas	-	No	No	-	-	-
California	Yes	Yes	Yes	Yes	Yes	Yes
Colorado	Yes	Yes	Yes	Yes	-	Yes
Connecticut	Yes	Yes	No	-	Yes	-
Delaware	-	No	No	-	-	-
Florida	Yes	Yes	No	-	-	-
Georgia	-	No	No	-	-	-
Hawaii	Yes	Yes	No	-	-	-
Idaho	Yes, for passenger motor vehicles	Yes	Yes, on public land	-	-	-
Illinois	-	No	No	-	-	-
Indiana	Yes	Yes	No	-	-	-
Iowa	-	No	No	-	Yes	-
Kansas	-	No	No	-	-	-
Kentucky	-	No	No	-	-	-
Louisiana	-	No	No	-	Yes	-
Maine	-	No	No	-	Yes	-
Maryland	-	Yes	Yes	Yes	-	Yes
Massachusetts	-	No	No	Yes	Yes	-
Michigan	Yes	Yes	Yes	-	Yes	-
Minnesota	Yes	Yes	No	-	-	-
Mississippi	-	No	No	-	-	-
Missouri	-	No	No	-	-	Yes
Montana	-	Yes	No	-	Yes	-
Nebraska	Yes, for over, 10,000 lb.	No	No	-	-	-
Nevada	Yes	Yes	No	-	-	Yes
New Hampshire	-	No	Yes	Yes	Yes	Yes
New Jersey	-	No	No	-	-	Yes
New Mexico	-	No	No	-	-	-
New York	Yes, for over, 10,000 lb.	No	No	No	Yes	No

Table E-1. IN-USE SOUND LEVEL LIMITS (Continued)

STATE	ON-ROAD MOTOR VEHICLES	ON-ROAD MOTORCYCLES	OFF-ROAD MOTORCYCLES	OFF-ROAD VEHICLES	SNOW-MOBILES	MOTOR-BOATS
North Carolina	-	No	No	-	-	-
North Dakota	-	No	No	-	-	-
Ohio	-	No	No	-	-	-
Oklahoma	-	No	No	-	-	-
Oregon	Yes	Yes	Yes	Yes	-	Yes
Pennsylvania	Yes	Yes	No	-	Yes	-
Rhode Island	-	Yes	No	-	-	-
S. Carolina	-	No	No	-	-	-
South Dakota	-	No	No	-	-	-
Tennessee	-	No	No	-	-	Yes
Texas	-	No	No	-	-	-
Utah	-	No	No	-	-	-
Vermont	-	No	No	-	Yes	-
Virginia	-	No	No	-	-	-
Washington	Yes	Yes	Yes	Yes	-	-
West Virginia	-	No	No	-	-	-
Wisconsin	-	No	No	-	Yes	-
Wyoming	-	No	No	-	-	-

for new vehicle noise. However, some efforts in developing simpler and correlatable stationary tests have been made and deserve some attention. These will be discussed later.

E.2 NOISE TEST PROCEDURES

There are numerous noise test procedures proposed or in effect for passenger cars, light trucks, vans, and motorcycles. Most of them require open-field testing. These outdoor testing procedures can be classified into the following categories:

- Accelerated Passby Noise Tests - These test standards usually require low speed acceleration of vehicles at fixed throttle in such a manner that a specific engine speed called the closing rpm is reached in the end zone of a prescribed vehicle path. Once the closing rpm is reached, the throttle is closed. The maximum noise level observed by a microphone 1.2m above the ground and 15m (7.5m in Europe) from the vehicle path is recorded as the noise level of the vehicle.

  This type of test is usually employed for vehicle noise certification or regulatory purposes. The established tasks can be endorsed by the Society of Automotive Engineers (SAE) standards, the California Highway Patrol procedures, and the International Organization for Standards (ISO) Recommendation R362.

  The Environmental Protection Agency (EPA) has also proposed accelerated passby noise tests for motorcycles and light vehicles (Ref. 25 and 26). Reference 26 proposed a complicated test which requires both specified acceleration and speed be reached in a narrow endzone on the vehicle path.

- Constant Speed Passby Noise Tests - This type of test is designed mainly for roadside enforcement purpose. California Highway Patrol has looked into this type of test. Boulder and Colorado Springs, Colorado, and Minnesota Authorities have developed improved versions where even a single highway patrol car can be used to monitor and pursue high noise emitters. Reference 18 also suggested a constant speed passby test. These tests do not correlate well with the EPA tests.

- Stationary Engine Acceleration Noise Tests - The U.S. Department of Transportation has adopted a stationary engine acceleration test in Reference 25; for interstate motor carriers. Chang (Ref. 26) has studied the engine operation theories and their applications in transforming accelerated passby noise tests into highly correlatable and much simpler stationary engine acceleration tests. One such transformation has been proven so successful that the stationary engine acceleration test is included for consideration in the EPA's proposed motorcycle noise emission regulations.

- Stationary Constant Engine Speed Noise Test - The Swiss stationary test, the International Organization of Standards, and the Motorcycle Industrial Council proposed stationary vehicle noise test methods have been known for some time. These tests are simpler to perform than the passby tests but were not designed to correlate with U.S. EPA tests.

Other procedures have been developed for use in inspection facilities such as the noise tunnels in Richmond, British Columbia but the results do not correlate directly with U.S. Federal primary passby test standard.

E.3 NOISE TEST FACILITY AND EQUIPMENT

The requirements on noise testing facilities, acoustic instrumentation, and auxiliary equipment are different for each type of testing.

For outdoor noise testing, a large open plane about 90m by 75m free of large reflecting surfaces is usually required for a 15m microphone distance test. The measurement zone should be a hard flat surface such as a concrete or sealed asphalt pad. The ambient noise level should be 10 dB less than the vehicle noise level.

These requirements are difficult to meet in a populous urban environment having no large vacant lots and high ambient noise levels. Recently, Chang (Ref. 26) has developed the acoustic similarity theory which has been successfully applied to reduce the noise measurement distance for motorcycles by fivefold. Accordingly, the area requirement of the open plane is reduced by 25 times. This may be a solution to the problems in selecting urban testing facilities.

For the indoor-type of testing, the acoustic environment of the enclosure is of importance in determining the number of microphones required. The facility should have adequate ventilation systems to handle the vehicle exhaust for safety reasons.

Usually ANSI Type 1 sound level meters are specified in prevailing vehicle noise standards. ANSI Type 2 sound level meters are less expensive and are accepted in OSHA and local noise regulations. Other factors should include the instrument ruggedness and its ability to interface with a computer.

Most established test procedures specify the use of wind speed, barometric pressure, temperature, and humidity gauges. Some also require the connection of tachometer, accelerometer, and ignition disable device to the vehicle. The benefit of including this equipment in an inspection noise test procedure should be carefully reviewed as should the associated costs and other problems (e.g., possible tampering charges on attaching tachometers to private vehicles).

E.4 STATIONARY ENGINE ACCELERATION NOISE TEST

Most vehicle passby noise test procedures specify a measurement distance of 15m (50 feet) which requires a large hard testing plane and low ambient noise levels. For inclusion into the I/M program it is desirable to test vehicle noise at a shorter distance in the stationary mode and have the results correlate with the passby tests at 15m.

Previous studies have shown weak correlation among noise measurements made at various microphone distances ranging from 5m to 30m when the microphone is at a fixed height above ground. Reference 26 discusses methods to improve the correlation by preserving the acoustic interference pattern at various measurement distance by adjusting the microphone heights. Then the noise levels closely follow the spherical spreading law and tests at short distances with high correlation are possible. Simple stationary tests correlatable with the Federal passby procedures can be devised without using tedious external loads; e.g., dynamometers. This is because the instantaneous vehicle noise is dependent primarily on the engine power (throttle setting) and the engine speed.

An example is given in Reference 26 where a 15m passby motorcycle test is transformed into a 3m stationary test. Experiments performed at Sandusky, Ohio and California showed near perfect correlation (97 percent) between the two procedures.

The stationary noise test would serve within the noise-I/M integrated testing as a screening for noise enforcement of in-use vehicles.

Further simplification is possible in eliminating the use of tachometers as reported in Reference 26. If that simplification is successful, we would have an ideal candidate for inclusion of the noise test in the state I/M program.

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16. ABSTRACT

The State of Michigan, pursuant to the Clean Air Act as amended (1977), is required to consider an Inspection/Maintenance (I/M) program for part or all the State because the five-county Detroit metropolitan area, at least, is expected to be unable to meet applicable air quality standards prior to the 1982 deadline. This study evaluates a range of possible I/M program configurations to assist in the identification of a short list of alternatives that would be appropriate in Michigan.

The findings of this study are presented in two volumes. Volume I explores a broad range of I/M options while Volume II performs a comprehensive evaluation of costs and benefits for a matrix of 24 program configurations differentiated by administrative mode, inspection procedure and scope. As a result of the comparative analysis, a short list of candidate options is proposed for further study.

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