# Evaluation Of Motor Vehicle Emissions Inspection And Maintenance Programs In Minnesota

## Final Report

Contract No. 68-02-2887
Work Assignment No. 6

EPA-905/2-79-001

February 1979

GCA/TECHNOLOGY DIVISION
BEDFORD, MASSACHUSETTS 01730

GCA-TR-79-03-G

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION V
Chicago, Illinois

Contract No. 68-02-2887
Work Assignment No. 6

EPA Project Officer

Carlton Nash

# EVALUATION OF MOTOR VEHICLE EMISSIONS INSPECTION AND MAINTENANCE PROGRAMS IN MINNESOTA

*Final Report*

February 1979

by

Theodore P. Midurski

Frederick M. Sellars

Nancy K. Roy

Donna L. Vlasak



GCA CORPORATION
GCA/TECHNOLOGY DIVISION
Bedford, Massachusetts

## DISCLAIMER

This Final Report was furnished to the U.S. Environmental Protection Agency by GCA Corporation, GCA/Technology Division, Bedford, Massachusetts 01730, in fulfillment of Contract No. 68-02-2887, Work Assignment No. 6. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency or of cooperating agencies. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

ABSTRACT

Recent data for the State of Minnesota indicate that the National Ambient Air Quality Standards for CO and $O_x$ will not be attained in all areas of the State by 1982, even if all reasonable available control technologies are applied. In view of this, it is likely that the State will request from U.S. EPA an extension of the compliance date beyond 1982. In order for this request to be considered, the State must, among other things, have adopted a firm schedule for implementing a motor vehicle inspection and maintenance (I/M) program in the highly urbanized nonattainment areas. In this connection, the State of Minnesota is currently planning for the implementation of an I/M program. As a part of this effort, detailed analyses have been performed of the costs, personnel requirements, rationale for selecting the particular option, scheduling requirements, and effects that the cold climate in Minnesota might have on emission testing associated with the particular program option being considered. This document reports these analyses.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

No.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the individuals and organizations who provided the necessary inputs for this study. Specifically, we would like to express our appreciation to the Minnesota Pollution Control Agency, the Department of Public Safety, Division of Motor Vehicles, and the Metropolitan Council of the Twin Cities Area. We would especially like to thank Mr. Richard Sandberg of the Minnesota Pollution Control Agency, and the EPA Task Officer, Mr. Carlton Nash for their assistance throughout the study effort.

# SECTION 1

# INTRODUCTION

## BACKGROUND

Amendments to the Clean Air Act that were adopted during 1977 have established that the National Ambient Air Quality Standards (NAAQS) for pollutants such as carbon monoxide (CO) and photochemical oxidants ($O_x$) must be attained in all areas of the U.S. no later than 31 December 1982. The U.S. Environmental Protection Agency (EPA), the federal agency charged with the responsibility of administering and enforcing the Clean Air Act and amendments thereto, has set the requirement that each state containing an area (or areas) currently in violation of the NAAQS must submit a revision to its State Implementation Plan (SIP) during January 1979 demonstrating compliance in all areas by 31 December 1982. That all states will not be able to demonstrate total compliance by the end of 1982 is recognized in the Amendments and provisions are made for extending the compliance date to 31 December 1987. In order to obtain the extension, however, the revised SIP to be submitted in January 1979 must include (among other things) a specific schedule for the implementation of a motor vehicle emissions inspection and maintenance (I/M) program in those nonattainment areas that have an urbanized population greater than 200,000. Failure to submit an acceptable I/M schedule (or if a reasonable effort toward submitting an acceptable schedule is not being made) will result in rather severe sanctions being imposed on the state.

Preliminary reviews of the status of air quality control regions in the State of Minnesota have indicated that the NAAQS for $O_x$ and/or CO will not be achieved by 31 December 1982 in all instances. Given the requirements of the Clean Air Act Amendments mentioned above, a decision was made to initiate a preliminary planning effort for the eventual implementation of an I/M program in the State. This planning effort is being forwarded by the Minnesota Pollution Control Agency (MPCA).

To date, several decisions have been made concerning the format of the I/M program that will be implemented in Minnesota. These decisions concern the technical aspects of the test, the basic operational and administrative structures that will be utilized, and the specific areas within the State that will be affected; for the most part, these decisions have been made by the MPCA.

Several additional parameters have been defined as well, but these are based on requirements specified either in the Clean Air Act Amendments or by policy established by EPA. For example, program start dates are either defined or limited by EPA regulation.

## OBJECTIVES

In order to understand the full range of implications associated with the proposed I/M program, several additional parameters have to be defined. Of prime concern is the cost of the program, particularly as it relates to the individual motorist. In this connection, a detailed analysis was performed to identify the approximate fee that would have to be charged for an inspection in order for the program to be self-supporting. A primary objective of this report is to describe the assumptions, methods, and data used in developing this estimate, and to discuss the actual fee thus calculated.

Further, it is considered important to delineate the specific rationale that was used in defining the proposed program scenario. Specifically, the options that were available should be presented and discussed on a relative basis, and in doing so, the rationale for selecting a particular option should become clear. Documenting the rationale is also a prime objective of this report.

From the standpoint of State planners and decisionmakers, an important consideration concerns the timetable with which they must work in developing and implementing the program. The third objective of this report is to discuss both the statutory and practical factors that will undoubtedly affect the overall implementation process, and to provide a suggested schedule for implementation.

Finally, there has been concern expressed regarding the effects that the cold climate in Minnesota might have on emission testing. It is noted that most of the existing I/M programs are located in states that have much warmer climates - Arizona, California, Nevada - although similar programs are being operated in Chicago and Cincinnati, which certainly experience prolonged periods of very cold weather. The final objective, then, is to provide discussion concerning possible impacts of the cold Minnesota climate on emission testing.

## REPORT ORGANIZATION

This report is organized into seven principal sections including this introductory section. Section 2 provides a detailed discussion of the technical aspects of I/M programs. Included are comparisons among various options that are available for testing automotive emissions, administering the program, enforcing the test requirements, etc. This section provides the rationale for the particular I/M program scenario proposed by the MPCA. The actual scenario for the proposed program is discussed in detail in Section 3. Although the discussion focuses on the basic inspection program, some specific recommendations are included regarding support program elements. A key element in this study is the derivation of the test facility requirements and the number of individuals to both run the test facilities and provide admistrative support. The development of these requirements is reported in Section 4. Based on the I/M program scenario, supporting program elements, network and personnel requirements developed in the first few sections, costs associated with the program are discussed in detail in Section 5. The actual costs are discussed by category and a break-even fee is developed. Section 6 presents a discussion of several aspects of implementation scheduling. Current scheduling requirements established by EPA regulation are discussed, as are other elements such as construction phasing, startup time, etc. Finally, a technical discussion of the potential impacts of a cold climate on an emissions inspection program are discussed in Section 7.

The reader is cautioned at this point that several elements of this report must be considered tentative and, therefore, subject to change. Cost estimates were developed in terms of 1978 dollars, therefore the actual, in place cost of the program will be somewhat different from the costs developed here; this difference, however, should primarily reflect the rate of inflation from 1978 through 1987.

## SECTION 2

## MOTOR VEHICLE INSPECTION AND MAINTENANCE

### INTRODUCTION

The required implementation of motor vehicle emissions inspection and maintenance (I/M) programs in certain areas of the U.S. under provisions of the 1977 Amendments to the Clean Air Act was discussed in Section 1. At this point, then, a detailed discussion is in order regarding the technical concepts and objectives of I/M.

The first questions that will be considered here are: what is an I/M program, and how does I/M fit into the overall effort of reducing pollution from automobiles? Following this is a discussion of the general I/M program configurations that have been or will be used in various states. Finally, a detailed discussion is provided of the specific options available in developing an I/M program, and what the impacts and benefits are of various options.

### NEED FOR AND OBJECTIVES OF I/M

Beginning with 1968 model-year vehicles, automobiles manufactured in or imported into the U.S. have had to comply with emission standards specified in the Federal Motor Vehicle Emission Control Program (FMVECP). Under this program, maximum emission rates are established for new vehicles, and manufacturers must demonstrate through an auditing program that their vehicles are in compliance with these emission limits. The emission standards specified by the FMVECP require progressively more stringent control of emissions with each subsequent model year.

To comply with the emission standards, manufacturers have retained their existing engine design concepts, but developed emission control devices (crankcase ventilation control, catalytic converters, etc.) and revised certain system parameter specifications (air-to-fuel ratio, ignition timing, etc.). This approach to emission control ostensibly satisfied the requirements of the FMVECP for new vehicles. However, surveillance studies conducted by EPA disclosed that the emission rate for these "controlled" vehicle generally increased with time at a much greater rate than was expected, therefore reducing greatly the overall effectiveness of the FMVECP. Further analyses determined that the root causes of the rapid deterioration of these emission control systems could be traced to either improper or inadequate maintenance, or tampering with the devices or system settings.[1]

In light of these findings, effort has been expended on developing techniques for reducing the air quality impact of poor maintenance practices and tampering. One result of this effort is the evolution of the inspection and maintenance concept.

In its most basic sense, inspection and maintenance refers to a program where vehicle exhaust emission levels are measured during specified operating conditions and compared with a specified standard for that particular vehicle configuration. If the measured rate exceeds the standard, the need for some form of maintenance, adjustment or repair is indicated. This is a very simplistic explanation of I/M, but it does serve to define the basic concept involved. A more precise discussion of various technical aspects of I/M may be found in the EPA report entitled "Summary Report on Vehicle Emissions Inspection and Maintenance Programs."[2]

GENERAL PROGRAM FORMATS

As indicated previously, several individual parameters must be defined in the development of an I/M program. For the purposes here, these parameters can be considered to deal with either the technical or administrative aspects of the program. Almost any combination of individual parameters can be used in developing a particular I/M program, therefore, it is perhaps of more value at this point to discuss these parameters on an individual basis rather than attempting to discuss them in the context of a particular program; the following discussion is intended to be somewhat superficial, merely acquainting the reader with the basic concepts; a detailed treatment of these parameters appears later in this section.

Test Mode

Currently, there are two primary test modes used in emissions inspections. The first type - idle mode - involves the quantitative analysis of pollutants, namely, hydrocarbons (HC) and carbon monoxide (CO), present in the exhaust gas while the vehicle is at idle. The second type - loaded mode - involves the quantitative analysis of pollutants (CO and HC) during simulated driving and idle modes. The primary differences between the two test types, aside from test equipment required, is that (1) the loaded mode test may provide more diagnostic information regarding engine malfunctions over a wider range of operation, and (2) loaded mode must be used if $NO_x$ emissions are to be tested;* the relative validity of the two modes (that is, which one of the two test modes more accurately defines the vehicle's emissions characteristics) can be argued. It is generally agreed that both modes provide an adequate assessment of the effectiveness of a vehicle's emissions control components and systems.

Both idle and loaded-mode testing are utilized in current programs. New Jersey, Nevada, Oregon, and Rhode Island utilize idle-mode testing, while loaded-mode testing is conducted in California. It is noted that Arizona

*It is noted that there currently are no requirements for inspecting $NO_x$ emissions although this may become a requirement at some future point in time.

utilizes both types - the loaded test provides diagnostic information and serves to precondition the test vehicle, while the actual pass-fail criterion is based on the idle-mode emissions.

Types and Management of Inspection Facilities

I/M programs can be formatted such that inspections are performed in either centralized test facilities or privately operated service stations. A public authority can be delegated the responsibility of establishing the network of centralized inspection lanes, or a contractor may be commissioned to design, finance, construct and operate the facilities. The contractor is selected through a competitive bid process and is monitored by and accountable to the responsible state agency. A third alternative is to license and certify private service stations and garages to operate the program using their existing facilities. These facilities would also be monitored by and accountable to the public authority responsible for overall program administration. A fourth alternative is to have a system with some combination of testing at both central lanes and private garages. In New Jersey, for example, the initial testing is performed at the state-operated lane while the retesting of vehicles is done either at central lanes or certified garages. Rhode Island's program utilizes private garages for testing with a central station run by the State serving as a referee lane.

Failure Rate

The failure rate refers to the portion of the tested vehicle population that is expected to fail the test, and therefore require maintenance. The rate is a function of the emission characteristics of the affected vehicle population and the emissions standards established for the program. For example, if the 70th percentile rate in the frequency distribution of emission rates for the vehicle population is selected as the standard, then the failure rate can be expected to be 30 percent. The failure rate is also referred to as the stringency factor.

In the relationship between the stringency factor and emission standard, the stringency factor is the independent variable. This parameter is defined on the basis of effecting a specific level of emission reduction from the I/M program. Selection of a particular stringency factor must consider the deminishing rate of return (i.e., rate of emission reduction) as the stringency factor increased; this is discussed more fully in a subsequent section. The emission standard, then, is set entirely as a function of the stringency factor.

Vehicles Affected

Another important consideration is the portion of the vehicle population that will be required to undergo testing. Theoretically, it would be possible to require all vehicles registered in the state (or a subarea) to be inspected and repaired as required, but this approach would not be practical, or even desirable. Certain vehicles, such as antique autos, and older vehicles (say, 12 to 15 years or older), diesel or gaseous-fueled vehicles, should not necessarily be required to undergo testing. Also, consideration is usually given to exempting heavy-duty, commercial vehicles (gross vehicle weight greater than 8500 pounds) from inspection requirements because of special problems that arise in areas such as defining appropriate emission standards, or providing facilities that will accommodate large, heavy vehicles, Generally, I/M programs are most efficient if their focus is limited to the light-duty vehicle population.

Inspection Frequency

Since the efficiency of emission control systems generally decreases with time, inspection and maintenance must be performed periodically. Since the deterioration in control effectiveness is a more or less continuous process, the frequency of vehicle inspection and maintenance significantly affects the overall benefits derived from an I/M program. It is generally agreed that the most practical approach is to require either annual or semi-annual testing.

Area Coverage

The general requirement established by EPA regarding the area to be included in an I/M program is that, as a minimum, all nonattainment counties with populations of 200,00 or more, and surrounding urbanized areas must be included in the program. In certain instances it may be appropriate to include the entire state, or at least expand the coverage beyond the minimum requirement; this decision might be based on issues regarding equity, devices to improve air quality on a larger scale, etc.

Supporting Programs

In order to ensure the success of an I/M program, several supporting elements must be incorporated. Although from the technical standpoint these supporting elements are very different from the inspection and maintenance processes, they should be considered integral to the overall I/M program and, as such, the manpower and costs associated with establishing and operating these should be reflected in the overall program cost and resource analysis. Specific support elements are introduced below.

Public Information Program--

An ongoing information program serves to familiarize the public and the repair facility owners with their respective roles in the I/M program. An information program is required to explain both the objectives of the program in terms of air quality, and the direct benefits to the public such as fuel conservation. The public should be assured that most vehicles will pass the tests and that most of those that fail will require only minor maintenance. Another function is to provide vehicle owners with information regarding station locations, inspection times, and consumer protection measures.

Consumer Protection--

Provisions must be made to insure that vehicle owners are protected from abuses that could appear in the system (e.g., overcharging by repair shops and unnecessary repairs) just as care must be taken to avoid hardships in terms of extremely costly repairs or the denial of vehicle registration without due cause. One facet of the consumer protection program is the exemption of certain classes of vehicles; for example, new cars and antique vehicles. In addition, some areas have considered a ceiling on the cost of repairs required for compliance. The ceiling could be either a flat rate or a percentage of the market value of the vehicle. This would eliminate the potential for certain vehicle owners experiencing undue hardships.

Finally, some kind of mechanism should be established to handle consumer complaints concerning overcharging and unnecessary repairs by garages as well as complaints about the program in general. This consumer affairs office could also be responsible for the licensing of repair facilities. If too many complaints about any one repair facility are received, the consumer affairs office could investigate and revoke the license of the garage if the claims were justified.

Mechanic Training--

A mechanic training program increases the efficiency of the repair industry performance and is prerequisite to the effective testing and proper maintenance of vehicles. Familiarity with the emission test procedure and equipment promotes objective and competent testing as well as insuring that emission testing is uniform and consistent among stations. Mechanics need to understand the functioning and maintenance of emission control devices in addition to knowing which engine parameters affect emissions and how to tune to minimize emissions.

Mechanic training helps alleviate the problems of ineffective repairs and excessive repair. The latter is caused by overadjustment by inadequately trained mechanics in an effort to avoid missing the problem. For instance, California has developed a mechanics' handbook which describes a repair sequence, or step-by-step procedure, for each type of emissions failure. Mechanics are instructed to proceed only as far as the step that corrects the malfunction. This California program was developed to meet a legislative requirement that mechanics repair vehicles according to specifications established by the Bureau of Automotive Repair. The specifications are an attempt to eliminate the guesswork involved in repairs and also serve as a basis for the evaluation of repair work.

Repair Facility Certification--

The certification of repair shops for emission work serves two purposes. First, it gives vehicle owners some guarantee of the credibility and competence of the repair facility. Second, to retain its certification, a repair facility would be required to perform quality work. Certain criteria could be established upon which to base decisions concerning certification. Minimum criteria should include the employment of a certified mechanic and ownership (or leasing) of approved emission analyzer instrumentation. Additional requirements could be established with regard to the availability of tools and service manuals required to perform effective repairs.

Integrated Inspection Programs--

The nature and intent of emission inspections is very similar to other vehicle inspection programs such as those for safety and noise. In this connection, it is logical to assume that emissions, safety, and noise could be integrated into one inspection program. In fact, an integrated program where all three parameters - safety, noise, and emissions - are inspected at the same time would undoubtedly be much more cost effective and more readily accepted by the public than separate programs would be.

## DETAILED EXAMINATION OF I/M PROGRAM ELEMENTS

While the previous discussion served primarily to acquaint the reader with the basic elements of an I/M program, a more detailed examination of these elements is in order. This detailed analysis will provide some insight regarding the rationale for selecting specific parameters for the proposed I/M program being considered here. Specifically, the following topics will be discussed:

- Test Mode
- Program Administration
- Vehicle Exemption and Waivers
- Inspection Frequency
- Mechanic's Training Program
- Phasing Considerations

## SELECTION OF TEST MODE

The function of emission testing is to identify those motor vehicles that exceed established exhaust emission standards for hydrocarbons (HC) and carbon monoxide (CO). One decision that must be made in defining an I/M program is the test mode that will be utilized. The following presents a discussion of four types of test modes that are commonly used for emissions inspection programs; these particular test modes include: (1) idle mode, (2) high idle mode, (3) loaded (key) mode, and (4) modified key mode.

### Test Mode Descriptions

Idle Mode--

The idle-mode test involves sampling exhaust gases while the vehicle is idling; no attempt is made to determine the actual idle speed while the sample is being taken. Of the four test types being considered here, the idle test is the simplest test available and involves the least amount of instrumentation. The test is performed essentially with only an emissions analyzer. The inspector inserts the analyzer probe into the exhaust pipe of an idling vehicle, takes the reading, and compares the measured emissions levels with established standards for the particular vehicle type being tested.

There has been some discussion presented concerning the reliability of the basic idle mode test when engine preconditioning* is not performed prior to analyzing the exhaust sample. For this reason, EPA has specified (in the

---

*Preconditioning is simply allowing the engine to run at a speed of approximately 2,500 rpm for 60 to 90 seconds immediately before the exhaust is sampled. This purges the exhaust system and also reduces some of the heat buildup that occurs under the hood during long idle periods (these could be encountered while waiting for an inspection), which could affect the air-to-fuel ratio and hence, the CO and HC exhaust levels.

draft Appendix N, at least) that: "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 60 seconds."

High-Idle Mode--

The high-idle mode test is very similar to the basic idle mode with respect to equipment required and the fact that exhaust pollutants are measured with the engine idling rather than under a load. The difference, however, is that rather than testing the vehicle at its normal idle speed, the engine is adjusted to a speed of between 2,250 and 2,500 rpm. Since the engine speed is specified for this test mode, a tachometer must be attached to the engine prior to testing. After attaching the tachometer, the inspector inserts the probe into the exhaust pipe and then increases the engine speed to from 2,250 to 2,500 rpm. The engine speed is held constant until the analyzer stabilizes. At that point, the engine is returned to normal idle speed and sampling continues until the analyzer again stabilizes. CO and HC readings are recorded when the analyzer stabilizes both during the high-idle and normal-idle phase of the test, and are compared with established standards to determine whether or not the vehicle fails.

Loaded Mode--

Loaded mode testing involves analyzing exhaust pollutants while the vehicle is being operated under load (through the use of a chassis dynamometer). A chassis dynamometer consists of a pair of parallel rollers that support the drive wheels of the vehicle. Inertial weights and a power absorption system are attached to the rollers to resist changes in speed, simulating the various loadings (i.e., rolling resistance, wind resistance, and vehicle weight) that the engine would have to respond to under normal driving situations.

Loaded-mode tests allow for a variety of test cycles, one of which is the Clayton Key mode test. In this test, emissions are measured at three specific steady-state conditions; typically, these are 50 mph, 30 mph and at idle.

Modified Loaded Mode--

The modified loaded mode test is identical to the basic loaded mode test described above, except that the 30 mph phase is eliminated. The primary reason for eliminating this phase is that the total test time can be reduced with very little sacrifice in either test reliability or diagnostic information produced.

## Factors Influencing Choice of Test Mode

The following are the main factors that are generally considered in selecting a particular test mode:

- Effectiveness in identifying vehicles that exceed emission standards;

- Level of diagnostic information provided by the test;
- Costs associated with the test;
- Correlation with Federal test procedure;
- Test time requirements; and
- Repeatability by the repair industry.

Effectiveness--

Research concerning the effectiveness of loaded mode versus idle mode generally indicates that both test modes are about equally effective in identifying hydrocarbon (HC) and carbon monoxide (CO) violations. Research, however, on nitrogen oxides ($NO_x$) indicates that because $NO_x$ control systems are not designed to operate at idle conditions and $NO_x$ emissions at idle are negligible, the idle-mode test has generally very marginal ability to adequately test $NO_x$ emissions. The following discussions summarize the research to date on idle/loaded mode testing in relationship to the effectiveness issue.

Earlier research had indicated that the loaded mode test was superior to the idle mode, both in its ability to identify gross emitters, but more importantly, in its ability to provide valuable diagnostic information.[3,4] Until recently, the U.S. EPA had been recommending the loaded test as the preferred procedure.

Conclusions from the following test results help to indicate why there has been confusion about the comparative effectiveness of the testing procedures. The Riverside California Trial Program Summary Report[5] includes a comprehensive evaluation of the program operations from September 1975 to February 1976 during which 20,000 inspections and reinspections were performed. Also included in this report is an analysis of emissions reductions and cost effectiveness of repairs on failed vehicles. The inspection phase of this program utilized a three-mode dynamometer test to measure CO, HC, and $NO_x$ emissions. In addition, the engine test included ignition system parameter measurements. The exhaust emission test results and ignition data were subjected to a diagnostic test to determine the probable cause of malfunctions and recommended repairs for failed vehicles. These results appeared on a computer printout, which was identified as Vehicle Inspection Report (VIP).

A surveillance program[6] was conducted in conjunction with the Riverside Pilot Program to evaluate the Riverside loaded-mode test and compare it to an alternative idle mode procedure; the conclusions of this study are interesting. Although "Either an idle or a loaded-mode inspection has the potential to provide significant and cost/effective reductions in hydrocarbons and carbon monoxide with a slight improvement in fuel economy... there may be little justification for the extra cost of a loaded mode inspection program since an idle inspection can do nearly as good a job in detecting gross emitters." It was further stated that "Both an idle and a loaded-mode inspection and maintenance program have the ability to detect catalyst-equipped gross emitters."

Other comparative studies have reached similar conclusions in comparing the idle and loaded mode. Jerome Panzer of Exxon Research reported[7] that "The data show that nonloaded testing can be as effective as loaded testing in reducing emissions if the nonloaded diagnostic procedure is used." Two aspects of this particular study are worth noting here. One is that the idle test included both idle and high speed (2,500 rpm) in neutral. Secondly, a diagnostic and repair procedure was formulated using this data and data from other studies. The repair procedure appears to be as critical as the test itself because identifying gross emitters is but the first step in the process of controlling automotive emissions; the subsequent repair of these vehicles is perhaps of greater importance.

Jerome Panzer's research at Exxon indicates that a nonloaded mode has the potential for identification of $NO_x$ problems when the high speed (2,500 rpm) is included in the test procedure. In a later report[8] Panzer compared this test with key mode tests and found a correlation of at least 0.8 which is comparable to the best correlations between short test cycles and the standard in emission testing, the Federal Test Procedure (CO and HC testing). The study concluded that "$NO_x$ measurements at 2,500 rpm and Key Mode conditions were equally effective in identifying cars with high $NO_x$. However, the range of $NO_x$ values in the car population was so great that it appears impossible to establish test standards which would correctly identify a higher percentage of malfunctioning cars and avoid rejecting cars not needing repairs."

The General Motors Company performed an analysis of several comparative studies of idle versus loaded-mode testing. Based on their analysis of earlier studies (including several referenced here), and based on their own use of the idle test in GM assembly plants, they recommend "...the idle test for those states required to implement a mandatory vehicle emission inspection program..."[9]

In summary, most research gives strong evidence to the ability of the idle test to perform as well as the loaded-mode test in identifying gross emitters of CO and HC.

Diagnostic Information--

This issue may have a major impact on the effectiveness of an I/M program. While it is generally assumed that the loaded-mode test provides considerably more diagnostic information than idle tests, this assumption is not without challenge. The California study cited previously[10] indicates that the service industry was unable to make use of the additional diagnostic data provided by the loaded-mode test. The implication, then, extends beyond the issue of test mode selection; apparently, the auto repair industry must be considered a crucial factor in assessing the relative merits of idle versus loaded-mode testing from the standpoint of diagnostics.

It is noted here that the very short loaded-mode tests do not provide detailed diagnostic information regarding engine performance. Inferences can be made, however, concerning which system is most likely to be the cause of the emission problem based on the readings at various points in the test. As an example, an excessively high HC level at 50 mph with a normal level at idle indicates that there may be a problem in the ignition system; normal HC levels at 50 mph and abnormally high levels during idle, on the other hand, would indicate that the carburetor is not adjusted properly.

In summary, research and practical experience generally indicate that a loaded-mode test provides more and presumably higher quality diagnostic data than does the idle or high-idle test. Without a sound, comprehensive mechanics training effort, however, it is doubtful that the repair industry can effectively make use of the additional diagnostic data. On the other hand, consideration must be given to the possible requirement for testing $NO_x$ emissions as part of the I/M program, at some point in the future. Again, $NO_x$ emissions can only be measured using loaded mode or high idle mode testing. This possibility and the differences in diagnostic information must be weighed against the higher inspection fee associated with either high idle or loaded-mode testing in deciding on the particular test type to be adopted.

Variability of Inspection Cost with Test Mode--

The basic equipment requirements for emissions testing will vary with mode utilized. In all four test types described previously, the same emission analyzer is employed. The idle-mode test is the least expensive since no other testing equipment is required. The high-idle test employes a tachometer in addition to the analyzer, resulting in a slightly higher equipment cost. (Less than $1,000/lane). The loaded-mode tests necessitate a chassis dynamometer costing $10,000 to $14,000 per lane, plus additional facility space making the loaded-mode test the most expensive in terms of equipment and facilities costs. Since both facilities and equipment costs are amortized, however, the resultant increase in the fee paid by the motorist is slight, generally $0.20 to $0.25.

Correlation with Federal Test Procedure--

Most loaded mode tests correlate well with the Federal Test Procedure (FTP), the standard for emissions testing. The 1975 FTP, which is a nine-mode, 125-second test, is considered the best method for the following reasons:

1. It measures emissions from vehicles over a simulated driving cycle and, therefore, presumably approximate actual in-use emissions;

2. Available evidence indicates that it is a reasonably reliable test;

3. It is the test used in certifying new vehicles to show that they are designed to meet Federal emissions standards; and

4. It measures emissions in terms of their total mass (in g/mile) and, hence, is directly related to ambient levels whereas idle tests only measure the relative concentrations of pollutants in the exhaust gas.

Because of its complexity, long test time, and the need for more rigorously controlled conditions, the FTP has not been considered an appropriate test for inspection/maintenance programs. Rather, attempts have been made to establish acceptable correlations between the FTP and shorter tests including various loaded modes such as the Clayton Key mode, the New Jersey ACID test, as well as with the idle test. Indications are that these tests all correlate reasonably well with the FTP

Test Time Requirements--

The test time requirements of an emission test are perhaps the single most crucial element to be considered in selecting the test mode to be utilized. The inspection fee charged will be highly dependent on the "throughput time" of the test facility. The throughput time is the time elapsed during the slowest part of the inspection, and will determine how many lanes are necessary to handle the vehicle population. A test mode having a 2-minute throughput will require twice as many lanes as one with a 1-minute throughput. The test time requirements for the four modes being considered here are discussed below.

The idle-mode test can be performed in as little as 30 seconds. As mentioned previously, there has been some discussion concerning the reliability of the idle-mode test when preconditioning is not performed. Preconditioning the engine for 60 to 90 seconds increases the test time to 90 to 120 seconds. It is not clear at this point if the proposed Appendix N preconditioning requirement necessitates the attachment of tachometer leads to the engine. If this is indeed required by the proposed Appendix N, the test time requirements would be increased an additional 15 seconds (for induction tachometers, more for the "clip on" type), making the total test time 105 to 135 seconds.

The high idle-mode test involves taking readings at 2,500 rpm and at normal idle. The complete test time for the high idle-mode test is 2.5 to 3.0 minutes.

The Key mode test, where emissions measurements are taken at 50 mph, 30 mph, and at idle, has been automated by at least one manufacturer. This enables a complete loaded-mode test to be conducted in 2 minutes or less.

The modified loaded mode is identical to the Key mode, with the elimination of the 30 mph phase. Modified loaded-mode testing can, therefore, be performed in less than 90 seconds. Table 1 summarizes the test times discussed for each test mode.

The test times shown in Table 1 indicate that there may be little difference in throughput time between the idle-mode and loaded-mode test, and the modified loaded-mode may be the fastest to perform. This is dependent on the type of preconditioning procedure required when Appendix N is finalized.

TABLE 1. ESTIMATED TEST TIME REQUIREMENTS FOR FOUR I/M TEST MODES

| Mode | Test time (seconds) |
|---|---|
| Idle | 30 - 90 - 120* |
| High idle | 150 - 180 |
| Loaded (Key) | 120 |
| Modified loaded | 90 |

*30 seconds without engine preconditioning, 90 seconds with preconditioning (no tachometer leads attached), 120 seconds with preconditioning and attachment of tachometer leads.

Repeatability by the Repair Industry--

An important indirect cost of I/M is the cost of equipment purchased by private garages in order to duplicate the test performed at the inspection station. The garage mechanic will want to utilize, whenever possible, testing procedures that ensure that vehicles repaired at his shop will pass reinspection. This could present some limits on the overall appropriateness of loaded-mode test, as most garages would be either unable or unwilling to purchase chassis dynamometers. A solution to this potential problem has been successfully employed in Arizona, whereby the loaded-mode test is used, but the pass/fail decision is based only on the idle phase results. This enables the inspection to provide the mechanic with diagnostic information as well as enabling him to use easily affordable equipment that can replicate the pass/fail portion of the test performed at the inspection station.

## Conclusions

The advantages and disadvantages associated with idle versus the loaded-mode testing procedure have been summarized in Table 2. With respect to overall effectiveness for hydrocarbon and carbon monoxide emissions, most research and field experience indicates that the idle mode can identify gross emitters equally well in comparison with the loaded mode procedure. The idle mode is also considered sufficient to identify HC and CO from catalyst equipped vehicles. Until a better test can be devised, the measurement of $NO_x$ requires the use of the loaded mode or high idle mode test.

In terms of diagnostic information, because the loaded mode simulates actual driving conditions, it generally provides more in-depth diagnostic information. However, some studies indicate idle testing can generate enough data to produce as good repair work and as much emission reduction. One study indicates that the repair industry cannot effectively make use of the more complicated diagnostic data which the loaded mode test produces, therefore the additional diagnostic information provided by the loaded-mode test will be of little use without the existence of a sound, comprehensive mechanics training program.

TABLE 2. ADVANTAGES AND DISADVANTAGES OF VARIOUS TEST MODES

| Mode | Advantages | Disadvantages |
|---|---|---|
| Idle | 1. Can identify gross CO, HC emitters as well as loaded mode | 1. Cannot identify $NO_x$ emitters. |
| | 2. Can be duplicated at repair garage | 2. Cannot simulate actual driving conditions. |
| | 3. Equipment least costly. | 3. Diagnostic information less comprehensive than loaded mode. |
| High Idle | 1. Good preconditioning for idle results. | 1. Must attach tachometer leads. |
| | 2. Better than idle test at identifying $NO_x$ emissions. | 2. Takes most time. |
| | 3. Can be duplicated at repair garage. | 3. Cannot simulate actual driving conditions. |
| Loaded Mode | 1. Can identify $NO_x$ emissions. | 1. Chassis dynamometer required. |
| | 2. Simulates driving conditions. | 2. Equipment more costly than idle mode. |
| | 3. Provides most comprehensive diagnostic information. | 3. Cruise portion of test cannot be duplicated in many repair garages. |
| Modified Loaded Mode | 1. Shortest test.* | 1. Chassis dynamometer required. |
| | 2. Can identify $NO_x$ emissions | 2. Cruise portion cannot be duplicated in many repair garages. |
| | 3. Diagnostic information almost as comprehensive as loaded mode. | 3. Equipment more costly than idle mode. |

*Provided preconditioning is required for idle mode.

Idle mode equipment costs less than loaded mode equipment. The U.S. EPA proposed preconditioning requirements, however, may cause the idle test to take longer than the loaded or modified loaded test resulting in more inspection facilities, thus greater cost to the motorist.

Since it would be difficult, if not impossible, for the repair industry to acquire the equipment necessary so that, in the process of repairing vehicles, they could duplicate the loaded-mode test (dynamometer required), the loaded-mode test (if employed) should include pass/fail criterion based only on the idle portion.

An additional issue to be considered is $NO_x$ testing. With emphasis being placed on development of a three-way catalyst system for $NO_x$ control, it is possible that in the future $NO_x$ testing may become a requirement for I/M. Since $NO_x$ testing is best accomplished by using either a loaded-mode or high-idle test, Minnesota would be wise to plan for <u>at least the conversion to loaded mode</u> or high-idle test if the basic idle mode test is adopted initially.

## ORGANIZATIONAL APPROACHES

### Introduction

There are three main types of organizational structures for conducting inspection/maintenance programs:

1. Government: centralized test facilities operated by state, city, or local government (as in New Jersey, California, Cincinnati, Ohio, Oregon, and Chicago, Illinois),

2. Contractor: centralized facilities operated by a private corporation under contract to a government (as in Arizona), and

3. Private garage: decentralized facilities operated by private automobile service garages, certified or licensed by a government (as in Rhode Island and Nevada).

In addition to these primary types, there can be combinations. For example, a decentralized private system may also include one or several state-run facilities as quality control measures and to discourage unethical or ineffective testing or maintenance.

In Rhode Island, the system is the decentralized private garage approach but the state has one publicly run "challenge station" which acts essentially as a referee to retest unsatisfied customers from any private station.

### Issues Affecting Choice of Organizational Structure

In choosing one of the possible organizational approaches, several relevant issues should be considered: costs, vehicle owner protection, vehicle-owner convenience, and startup time. These issues will be discussed in the following sections. The particular significance of each factor of course may vary from one locality to another and may depend in some circumstances on political factors external to the project itself.

Costs--

The costs that are considered most relevant here include:

1. capital costs (startup costs) land, buildings, equipment,

2. annual costs (recurring costs) salaries, fringe benefits including pensions, overhead, and leasing.

A program's organizational structure to a large degree determines both the particular capital categories in which startup expenditures occur and also which sector (public or private) bears the direct burden. Both public and private (government and contractor) centralized approaches entail large expenditures in all three capital costs areas - land, buildings, and equipment. In centralized public (e.g., state-run) systems these expenditures are clearly the responsibility of the government running the program. In the contractor-run program, the private corporation has the responsibility for these capital expenditures. It should be noted, however, that regardless of who incurs the direct responsibility, the vehicle owner ultimately bears the cost through the inspection fee charged. Land and building costs vary in different regions and consequently have a different influence depending on the price, scarcity of land, and associated building costs. In decentralized private systems, the only capital expense is the purchase of equipment. For the same vehicle population, centralized systems incur annualized capital costs that are only slightly larger than capital costs for decentralized systems.

In terms of existing programs, in New Jersey and Riverside, California, both state-owned and operated programs, the capital costs per lane were $484,000 and $225,000, respectively, whereas in Maricopa and Pima Counties in Arizona, a centralized contractor approach, the cost per lane was $247,000.

The primary recurring annual cost is labor, which generally ranges from 63 to 90 percent of the total recurring costs. The remaining 10 to 37 percent of operating costs are for overhead and leasing expenses. Labor costs are involved in a variety of individual program tasks including inspection, general administration, maintenance and repair of inspection equipment, public relations, and data collection. The largest portion of labor costs is for inspection. In Arizona and Portland, Oregon (both with centralized approaches) approximately 75 percent of the total labor is expended for the inspection function, compared to 10 to 14 percent for administration and public relations.

At this point there is little data on the effects of organizational structures on labor costs. However, the limited available data suggests that centralized systems incur lower labor costs than private decentralized systems. One reason for this difference is the different prevailing wage rate for the "inspectors" in each system. In the centralized systems, the station inspectors generally earn $4.75 to $5.00 an hour whereas the private garage mechanic inspectors earn an estimated $6.50 to $12.50 an hour. Also, in the private garage approach, there would be a sizable government administrative staff needed to oversee and inspect the large number of individual inspection stations.

Another important cost factor to be considered is the long-term economic effect of fixed pension obligations. Generally, it would seem that in the centralized, state-run approach there would be created the larger number of new, state positions, and in the contractor approach there would be the least new positions. However, the decentralized private garage system may require many new positions with pension obligations due to the necessity of the large staff to administer the program. The private contractor not only requires the least administration but also would take care of all the fringe benefits and pensions of the inspectors, which, in the long term, is likely to be less costly than would the similar State benefits.

Consumer Protection--

Consumer protection is an important issue that is significantly influenced by the organizational structure. Centralized systems, both public and private, owing to their higher inspection capacity per lane, involve many fewer inspection sites. Fewer sites means more effective monitoring of inspections and equipment, thereby reducing test variability that may result from inadequate or substandard instrumentation. Also the fewer inspectors associated with centralized systems reduce inspector training costs.

Centralized systems both public and private have two additional important consumer protection advantages over the private, decentralized approach. One is an inspection process that is independent from the repair process. Unlike centralized systems, in the decentralized system, the private garages have both I/M elements - inspection and maintenance - taking place at one location. This lack of separation presents a potential conflict of interest as the "inspector" who determines emission violations and their causes is also the mechanic who stands to gain from the necessary repairs. This situation may put the public at the mercy of unscrupulous mechanics unless very thorough checks are built into the system. At the other extreme from the possibility of unnecessary repairs being made on failed vehicles is the situation where the local garage or service station may come under pressure from his regular local customers to pass failed vehicles in need of tune-ups or other repairs. These types of problems frequently occur in connection with various states' safety inspection programs that are operated by private garages.

Consumer Convenience--

The greater number of inspection sites in a decentralized private system has two kinds of convenience advantages. By increasing the number of inspection stations within a given area, the greater is the likelihood that a given motorist will be located near an inspection site whether he is traveling from work or home. This minimizes his costs since he travels less distance and less time. Secondly, the greater number of stations potentially means the motorist would have to wait less time in line waiting for inspection. This, however, may not be the case unless the inspection times are spread out sufficiently.

Startup Time--

Each type of organizational structure has associated with it, unique startup time requirements. Publicly operated centralized systems seem to involve the longest startup time, owing to the need to purchase buildings, land, and equipment for centralized systems, and the requirement of competitive bidding process in government projects, the time required between legislation and actual operation is larger than for the private decentralized approach. In this case, the private garages already have the land and buildings. What requires time is setting up the overall administration, and training of mechanics and inspectors.

## Summary

Each organizational structure has various advantages and disadvantages associated with it. In Table 3, these factors, discussed in more detail in the previous sections, have been summarized.

In terms of consumer protection both the public and contractor-run centralized system seem to be superior to the private garage approach. This is primarily due to the separation of the inspection from repair functions and secondarily due to the efficient monitoring and quality control of centralized systems.

The cost factors vary in each organization approach. Both centralized approaches incur higher capital costs in terms of land and buildings although with the larger number of instruments needed in private garages this may be somewhat offset. The recurring costs of the centralized systems - both public and private - are somewhat lower than the private approach because of lower labor costs. In the centralized state-run program, there is the additional burden of long-term pension and other fringe benefits. The private garages necessitate considerable administration labor costs, also incurring some long-term pension obligations.

Consumer convenience is potentially greatest in the decentralized program due to the larger number of stations dispersed throughout the population.

# EXEMPTIONS AND WAIVERS

## Introduction

The total emission reductions resulting from I/M are dependent on (1) the number and type of vehicles inspected, (2) the failure rate, and thus (3) the number of vehicles that undergo maintenance. In this regard, there are various advantages and disadvantages that must be weighed in determining which vehicles should be exempt from the inspection process. The major considerations when judging whether any particular vehicle type should be exempt include: (1) the potential hardships that may result for certain vehicle owners; (2) feasibility of testing certain vehicle types, from both the technical and practical standpoints; and (3) the costs associated with including certain vehicle types in relation to the incremental reduction in emissions.

## TABLE 3. ORGANIZATIONAL STRUCTURE: ADVANTAGES AND DISADVANTAGES*

| | Advantages | Disadvantages |
|---|---|---|
| Public Centralized | <u>Consumer Protection</u>:<br>1. Inspection separate from repair: no conflict of interest.<br>2. Independent basis for judging the performance of the service industry.<br>3. Monitoring of instruments' and inspectors' performance facilitated, thereby reducing testing variability.<br><u>Costs</u>:<br>1. Lower (inspection) labor costs, thus generally lower recurring costs.<br>2. More efficient use of equipment.<br><u>Information</u>:<br>1. Data collection facilitated.<br>2. Loaded mode testing possible. | <u>Consumer Convenience</u>:<br>1. Fewer inspection facilities, thus an increase probability of longer travel and wait times.<br><u>Cost</u>:<br>1. Start-up requires large public capital outlay<br>2. All program costs born by public sector.<br>3. Risk of increasing long-term fixed costs to government due to increase in number of potential retirement/pension beneficiaries. |
| Private (Nonservice industry) Centralized | <u>Consumer Protection Information</u><br>Same as public centralized.<br><u>Cost</u> Same as public centralized, plus<br>1. All program costs born by private sector except those associated with administrative oversight.<br>2. No risks of increasing long-term fixed governmental costs.<br>3. Permits use of corporate tax structure to reduce burden of start-up capital expenditures. | <u>Consumer Convenience</u> Same as public centralized.<br><u>Consumer Protection</u>:<br>1. Possible adverse public reaction to corporation earning profits from "captive market." |
| Private (Service industry) Decentralized | <u>Consumer Convenience</u>.<br>1. Greater number of facilities increases probability of minimizing travel and wait times<br>2. Possibility for one-stop inspection/maintenance.<br><u>Cost</u><br>1. Lower start-up costs.<br>2. All program costs born by private sector except administration and monitoring. | <u>Consumer Protection</u>:<br>1. Inspection not separate from repairs presents potential for conflict of interest and reduction of program effectiveness<br>2. No independent basis for judging performance of service industry.<br>3. Effective monitoring of inspectors and instruments is more difficult.<br><u>Cost</u>:<br>1. Higher administrative costs to manage and oversee large number of garages, higher labor costs, hence, higher recurring costs.<br>2. Less efficient use of equipment.<br>3. Inspector training involves greater numbers and is therefore more costly<br><u>Information</u>.<br>1. Uniform and detailed data collection is more difficult.<br>2. Loaded mode testing is improbable if not impossible. |

*From Bentz, [illegible], Jr. Inspection/Maintenance Cost-Effectiveness and Feasibility of Implementation. U.S. Environmental Protection Agency. Washington, D.C. May 1977.

Vehicle Classes Considered

Currently, EPA classifies vehicles into six separate categories as defined below:

- Light-Duty Vehicles (LDV) - Gasoline-powered automobiles of less than 8,500 lbs Gross Vehicle Weight (GVW).
- Light-Duty Truck 1 (LDT1) - Trucks designed for highway use and weighing less than 6,000 lbs GVW (i.e., pickup trucks).
- Light-Duty Truck 2 (LDT2) - Trucks designed for highway use and weighing between 6,000 and 8,500 lbs GVW.
- Heavy-Duty, Gasoline-Powered Trucks (HDG) - Any gasoline-powered motor vehicle designed for highway use that has a GVW of more than 8,500 lbs.
- Heavy-Duty Diesels (HDD) - Any diesel-powered motor vehicle designed for highway use and weighing more than 8,500 lbs GVW.
- Motorcycles (MC) - A motor vehicle having a seat or saddle for use of the rider and designed to travel on not more than three wheels in contact with the ground, but excluding a tractor.

Minnesota's proposed I/M legislation calls for the annual inspection of all motor vehicles weighing less than 9,000 lbs GVW, registered in the seven-county metropolitan area. The legislation also proposes two categories of exemptions:

"Subd. 2 [EXEMPT VEHICLES.] The agency shall by rule exempt from all or any part of the mandatory periodic inspection:

(a) motor vehicles registered as classic, pioneer, or collector, pursuant to Minnesota Statutes, Section 168.10'

(b) any class of motor vehicle which presents prohibitive inspection problems."

Under the Clean Air Act Amendments of 1977, specific requirements for the implementation of motor vehicle I/M programs are established. With regard to requirements concerning the types of vehicles to be inspected, only light-duty vehicles (LDV) must, by mandate, be included in the program. States are encouraged, of course, to develop more stringent programs (and hence, more classes of vehicles), whenever possible. Quite clearly, the focus of I/M is on light-duty vehicles (LDV's and LDT's), as these vehicle categories have been found to be the major contributions to high CO and HC levels, primarily because vehicles in these categories generally constitute approximately 90 percent of the urban vehicle population. Discretion is left to the states to include motorcycles and heavy-duty vehicles in the inspectable fleet to provide additional reductions.

It is important that exemptions for certain vehicle classes and waivers for specific vehicles be provided under certain circumstances. Issues such as vehicle age and repair cost for compliance, and matters of practicality such as vehicles that present difficulties in the actual performance of the inspection, must be considered since arbitrarily including all vehicles (in general or even within any particular category) may jeopardize the success of the entire program.

According to the above discussion, six functional categories of motor vehicles can be defined. Vehicle categorization is often not so clear-cut at the state level, however. It is noted that Minnesota utilizes 19 specific categories of motor vehicles in it registration process, yet the proposed legislation defines the inspectable vehicle population to include any "... self propelled motor vehicle weighing less than 9,000 pounds gross vehicle weight and licensed for use upon the public highways of the State for transportation of persons or property."* For discussion purposes here and throughout this report, it is assumed that, regardless of the registration class, the specific vehicles weighing less than 9,000 pounds (GVW) can be identified in the registration files, which will serve to identify those vehicles required to participate in the I/M program.

Basis for Exempting Certain Vehicles

As indicated above, the practicality of cost, inconvenience, and potential hardships weighed against the overall or incremental reduction in emissions must be considered in defining which segments of the vehicle population to include in the program. At this point, the term "exempt" will be defined to mean not affected by the I/M program; hence, an exempt vehicle would not be required to become involved with any facet of the I/M program. Exemptions, then, apply to classes or categories as a whole.

Typically, exempt categories include:

- heavy-duty vehicles (gasoline and diesel) as defined previously;
- vehicles that are more than a specified age;
- special purpose vehicles; and
- vehicles not licensed for use on the highway.

Exempting Heavy-Duty Vehicles--

Of these categories, the heavy-duty vehicle exemption is often the most controversial. The public's viewpoint is that the real pollutors are the trucks, since, occasionally, visible emissions are produced by these types of vehicles. An examination of a typical mobile source emissions profile,

*Several exempt classes are also defined including antique vehicles and prototype or test vehicles.

however, shows quite vividly the relative importance of various motor vehicle categories with regard to total emissions produced. Such a profile is provided in Table 4.

Table 4 shows that about 75 percent and 83 percent of the carbon monoxide and reactive hydrocarbon emissions from mobile sources result from those vehicles generally included in I/M - that is, the light-duty vehicle fleet.

In spite of the statistics cited above, it certainly could be argued that, on the surface, it might be effective to include at least the heavy-duty, gasoline-powered vehicles in the program since they do contribute about 22 percent and 12 percent of the urban CO and HC emissions. Several issues must be considered, however, prior to reaching a conclusion regarding whether or not to include heavy-duty, gasoline-powered trucks. A basic issue concerns the need for information on the present state of routine maintenance practices in the heavy-duty vehicle sector. It is quite likely that there would be a tendency for commercial fleet owners to maintain their vehicles more adequately than do individual vehicle owners, primarily because the higher operating costs associated with an improperly maintained vehicle are generally more visible and considered more crucial to commercial fleet operators. The question, then, is do commercial fleets routinely operate at higher efficiency levels than do privately-owned vehicles? It is noted that emission reduction credits have not been published for heavy-duty vehicles undergoing I/M; apparently, the data base regarding the state of in-use heavy-duty vehicles, and the potential emission reductions achievable from these has not been adequately developed at this point. The first argument against including heavy vehicles is that there may not be sufficient data to show that there is a real need to include these vehicles because current maintenance practice may already be achieving the objectives of the I/M concept.

Secondly, commercial vehicles typically accumulate mileage at very high rates; it certainly would not be unusual for a long haul unit to average over 100,000 miles annually, or for a delivery truck to travel over 40,000 miles yearly. With these high rates of such mileage accumulation, one could question the effectiveness of an annual emissions inspection. Related to this is the issue of where the commercial vehicle travel occurs. Long haul and certain private carrier operations are likely to involve travel almost exclusively outside a relatively small area (such as the seven-county area being considered here), therefore, if I/M requirements were imposed, most of the benefits would accrue outside the area. On the other hand, it is noted that the State has a registration category for trucks that operate exclusively in the metropolitan areas. I/M could be imposed on vehicles registered in this category, although vehicle owners may simply register their vehicles in another category if they perceive that there would be an advantage in doing so (i.e., not being required to undergo emissions inspection and related repair).

Finally, the technical aspects of testing heavy vehicles should be considered. If loaded-mode testing is to be performed, special, high capacity dynamometers and, generally, much larger facilities and parking areas must be utilized. Also, the personnel operating these facilities would require special training in operating heavy vehicles and performing the tests. If diesel

TABLE 4. SAMPLE EMISSIONS PROFILE FOR AN URBAN COUNTY* - 1985 EMISSIONS (kg/day)

| Pollutant | LDV† | | HDV-G | | HDV-D | | Total | |
|---|---|---|---|---|---|---|---|---|
| | kg/day | (% Total) | kg/day | (% Total) | kg/day | (% Total) | kg/day | (% Total) |
| CO | 92,870 | (75.5) | 26,725 | (21.7) | 3,337 | (2.8) | 122,932 | (100.0) |
| HC | 9,607 | (83.1) | 1,360 | (11.8) | 592 | (5.1) | 11,559 | (100.0) |

*Data for Butler County, Ohio.

†Includes all light-duty vehicles (LDV, LDT, and LDT2).

vehicles are included, special laboratory grade analyzers would be required to measure the CO and HC readings. Further, it is of interest to note that neither CO nor HC exhaust levels are considered in the diagnostic criteria for diesel engine maintenance, therefore, it is likely that the repair industry would have to receive special training on engine diagnosis based on CO and/or HC exhaust levels.*

Exemptions by Vehicle Age--

Exemptions of vehicles over a certain age is a commonly used method to protect owners from undue financial hardships. The older vehicles generally cost more to bring into compliance and are more likely to need extensive repairs such as ring or valve jobs. Moreover, given the small fraction of the total vehicle population they represent, such exemptions ential a minimum sacrifice in overall emissions reduction benefits. To illustrate, a comparative analysis was performed of the total emissions reductions achievable in the Milwaukee, Wisconsin area with an I/M program very similar in scope, format, and size (vehicle population) to the proposed program for the Twin Cities area, reflecting two different age exemption criteria. First, it was assumed that all light-duty cars and trucks less than 15 years would be included in the program, and, second, this exemption was redefined to include light-duty cars and trucks less than 10 years old. The percent reduction in emissions of CO and HC, as a function of the overall program stringency factor are tabulated in Table 5.

Considering the defined stringency factor of 30 percent, Table 5 shows that there would be an incremental difference of 6 percent and 4 percent in total vehicle emissions of CO and HC, respectively, depending on the specific vehicle-age exemption criterion established.

Special-Purpose and Off-Highway Vehicles--

Vehicles that would be considered special-purpose are prototype vehicles, vehicles powered by unique, nonproduction engines or motors (i.e., gas turbine, Sterling engines, electric powered, etc.). Also, certain types of farm, construction, or industrial equipment that may require licensing and is perhaps used on public roads occasionally would be included. Off-road vehicles would be defined similarly.

These vehicles would generally not be included because of the difficulty that would be encountered in both setting standards and performing the inspections. Also, from the standpoint of emissions benefits, there would likely not be any perceptible reduction in total emissions by including these vehicles. Other arguments based on practical considerations could be presented as well.

## Waivers

Waivers are considered to be different from exemptions in that waivers apply to individual vehicles or subsets of particular vehicle categories.

---

*At this point, it is uncertain whether this type of engine diagnosis is even feasible.

TABLE 5. IMPACT OF VARYING VEHICLE-AGE EXEMPTIONS AND STRINGENCY FACTOR ON EMISSIONS REDUCTIONS ACHIEVABLE FROM LDV's AND LDT's.

| Pollutant | Age exemption | Vehicles considered | Percent reduction in emissions by stringency factor | | | |
|---|---|---|---|---|---|---|
| | | | 10% | 20% | 30% | 40% |
| CO | ≥ 15 years old | All light-duty vehicles only | 37 | 44 | 49 | 52 |
| | ≥ 10 years old | All light-duty vehicles only | 35 | 38 | 41 | 43 |
| | ≥ 15 years old | Entire vehicle population | 26 | 31 | 34 | 36 |
| | ≥ 10 years old | Entire vehicle population | 22 | 26 | 28 | 30 |
| HC | ≥ 15 years old | All light-duty vehicles only | 25 | 30 | 33 | 36 |
| | ≥ 10 years old | All light-duty vehicles only | 22 | 26 | 28 | 31 |
| | ≥ 15 years old | Entire vehicle population | 20 | 24 | 27 | 29 |
| | ≥ 10 years old | Entire vehicle population | 18 | 21 | 23 | 25 |

Source: Reference 11.

Notes: Includes mechanic training; reflects emissions in 1987 assuming program start-up in 1982. I/M program applies to LDV's and LDT's only.

Generally, waivers are granted to release a vehicle owner from the responsibility of complying with the inspection standard; the implication here is that the vehicle must still be inspected.

Waivers are generally on the basis of costs associated with complying to the standards. Usually, states set specific limits on the amount of money that has to be spent on the type of repairs that have to be made before a waiver is granted to release the vehicle owner from compliance. Limits of $50 to $100 are common, or the limit can be based on the value of the particular vehicle. Also, waivers can be granted to owners of either new vehicles being registered for the first time, or vehicles that, for some technical reason, cannot be tested easily. For instance, testing full-time, four-wheel drive vehicles on a dynamometer may not be practical; a waiver could be granted or an idle test could be prescribed for these special vehicles.

In the case where emissions inspections are combined with safety and/or noise inspections, waivers may be granted separately for each type of test. Because a waiver was granted for emissions compliance would not necessarily mean that the safety or noise standards would not still have to be met.

## FREQUENCY OF INSPECTIONS

U.S. Environmental Protection Agency (EPA) policy states that I/M program emission inspections may be performed on any regular, periodic basis. No specific time-interval is stipulated, however there is a requirement that the program achieve a 25 percent reduction in emissions from those vehicles included in the program by 1987. The reduction that will be achieved (or, more precisely, can be expected at this point) depends primarily on two factors - the stringency level and the frequency of inspection. As a practical matter, the inspection frequency is generally defined as annual in order to coincide with registration renewal cycles and, more importantly, to maximize the effectiveness of the program; the issue of maximizing program effectivenss is discussed in detail, below.

### Factors Relating Inspection Frequency and Program Effectiveness

Generally, the more frequently a motor vehicle is inspected, the more likely it is that its emissions will approach the minimum level. There is a point, however, where inspections performed more or less frequently are much less cost effective, therefore, a primary consideration in establishing the inspection frequency requirement for an I/M program is to approach this point where cost effectiveness is maximized. In this connection, the topic of deterioration becomes relevant.

#### Deterioration--

In theory, emission rates for carbon monoxide (CO) and hydrocarbon (HC) are at the lowest level possible when various engine systems and components, such as the carburation and ignition systems, are operating at maximum efficiency. The most likely condition for these systems to be at maximim efficiency is right after the engine has been tuned (new ignition components, timing reset, and carburator adjustments made, etc.). With use, these systems begin to loose their efficiency resulting in overall degradation of engine efficiency.

Several studies have been or are currently underway to define the exact nature of deterioration. Preliminary analyses indicate that deterioration rates increase quite rapidly shortly after the engine is tuned, but the rate slows substantially with time. Other studies have indicated that the rate of deterioration is slow at first, but then increases with time. While the general conclusions regarding the deterioration rate versus time function appear to be somewhat contradictory, the general conclusion that over a series of annual tune-ups, the emission rates of both CO and HC rates just prior to the tune-up and approximately 9 months after the tune-up, are about equal; in other words, a tune-up will provide improvements for only about 9 months. A theoretical emission deterioration curve is shown in Figure 1 below.

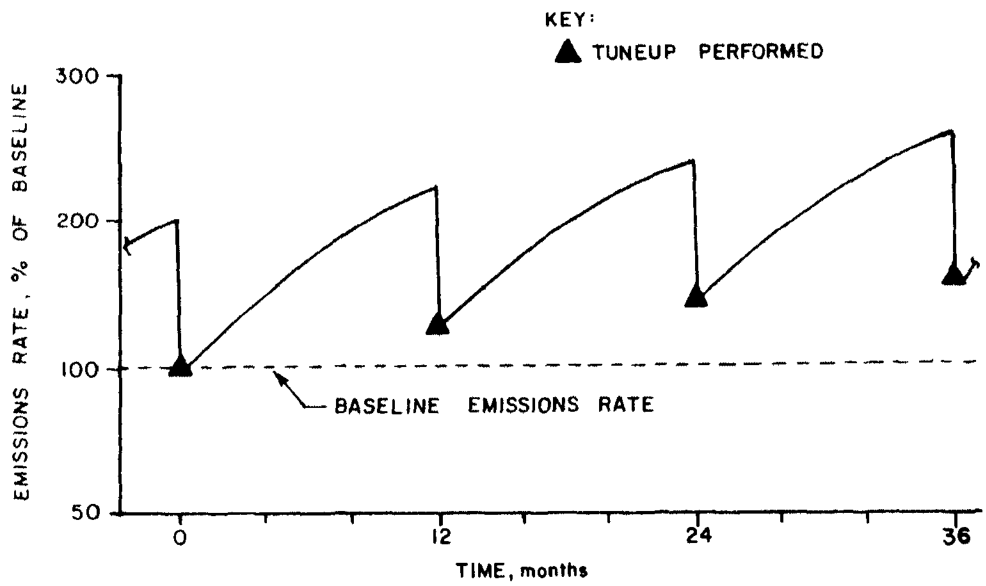



Figure 1. Theoretical emissions deterioration curve.

Note in the curve that the emission rates for the newly tuned conditions are shown to be increasing year to year. This reflects the impact of normal engine wear and loss of effectiveness of various engine components. To bring the rate for a newly tuned engine down to the baseline rate, significant repairs, such as a major overhaul, would likely be required.

Public Convenience and Cost Impacts--

The deterioration characteristics indicate that there could be some justification for requiring semi-annual inspections. Overriding the benefits that would be gained - additional emission reductions - would be the likely rejection of the program by the public. Although at this point the relative nonacceptance of a semi-annual versus annual program can only be considered in a subjective manner, it is quite likely that more and stronger opposition to a semi-annual program would occur. On the other hand, a biennial program would likely be more readily accepted; however, the effectiveness of such a program would undoubtedly be challenged by individuals truly concerned with either improving air quality and/or protecting the public from being required to participate in an ineffective (and therefore nonessential) program.

Costs associated with a semi-annual program would likely be between 80 and 90 percent more than an annual program, and a biennially scheduled program cost would be approximately 60 percent (on an annual basis) of the annual program cost. Maintenance and indirect costs (such as travel to and from inspection facilities and waiting for inspections) are directly related to the frequency of required inspections. Overall, then, the choice of a specific inspection frequence parameter will have a strong influence on the <u>total</u> program cost; a general conclusion is that, on a relative basis, the highest benefit-cost ratio would result from an annual program.

Other Considerations--

Two additional factors merit discussion here. First, the issue of coordinating I/M schedules with other vehicle inspection programs is relevant. If, for instance, a safety inspection program is going to be integrated into the I/M program, then it is obvious that the inspection frequency for both inspections ought to be the same.

The second consideration deals with the enforcement mechanism that will be used. If, for instance, registration renewals are required annually and the I/M enforcement mechanism requires proof of recently passing an emissions test, then certainly inspection frequency ought to be coordinated with the registration renewal cycle.

<u>Experiences of Other States</u>

Table 6 shows that an annual inspection frequency is utilized by most I/M programs. Several exceptions are noted, however. In Nevada, inspections are currently required only upon change of ownership. A similar requirement is currently utilized in the California program (startup phase) although annual inspections will soon be required. This initial phase will provide essential information on the test procedure, stringency rates, public opinion, etc.

Biennial inspection currently is used only in the Portland, Oregon program. Biennially scheduled inspections were selected basically to coincide with the registration renewal cycle. Oregon does require that trucks and government vehicles be inspected annually.

TABLE 6. I/M INSPECTION FREQUENCY

| Location | Inspection frequency |
|---|---|
| Arizona | Annual |
| Chicago | Voluntary, no requirement |
| Nevada | Change of ownership |
| New Jersey | Annual |
| Portland | Biennial for LDV's, annual for trucks and government vehicles |
| Rhode Island | Annual |
| California (South Coast Air Basin) | Currently upon change of ownership, ultimately, annual |

## ENFORCEMENT MECHANISMS

### Introduction

There are two methods of enforcing a program such as I/M, sticker ticketing and registration enforcement. The sticker ticketing method involves issuing compliance stickers that must be displayed prominently (usually on the windshield) on vehicles, proving that the vehicle passed an emissions inspection. In contrast, motor vehicle registration enforcement means that the motorist must present proof of compliance in order to register his vehicle. Without proof of having passed the inspection, the motorist is simply denied the right to register and, hence, to operate his vehicle. The registration enforcement system generally requires that the frequency of inspection correspond with the frequency of registration; there is no similar requirement for the sticker ticketing method. The actual enforcement of the sticker ticketing method is through levying fines on motorists who have not complied. Noncomplying vehicles are identified either by a special police force, state, or local police, or during routine traffic patrolling by regular law enforcement personnel. Those vehicles not displaying the appropriate sticker are given tickets. The violators are then given, in some instances, the opportunity to have fines lessened or eliminated by complying within a specified number of days. If the motorist still does not comply, he can be subject to appropriate civil penalties accordingly.

In comparing the two enforcement mechanisms, the primary issues to be examined are the effectiveness and cost. These are discussed separately, below.

### Effectiveness

Because motor vehicle registration is a legal prerequisite to vehicle operation, a high level of compliance can be expected for the registration enforcement approach. Other than avoiding the registration process altogether and operating illegally, the only way to circumvent the procedure would be to forge or tamper with the forms used to demonstrate proof of compliance. Given sufficient checks, a well designed form, and a crossreferencable numbering system, it is unlikely that many motorists could successfully avoid inspection and still receive registration.

Many states currently having operational I/M programs or pilot programs have utilized or will be adopting the motor vehicle registration enforcement procedure. Included are Arizona; New Jersey; Portland, Oregon; and Nevada. The notable programs using sticker ticketing for emission inspection are Cincinnati, Ohio; Chicago, Illinois; and Rhode Island. These programs are discussed below.

The sticker ticketing approach is effective primarily for statewide programs. Rhode Island, for example, has utilized the sticker ticketing for a number of years in connection with its safety inspection enforcement. By maintaining the sticker system, Rhode Island did not have to change its registration process; registration is not staggered in Rhode Island but would have to be under a registration enforcement system. One reason for success of this system in Rhode Island is that since the safety program had been enforced with stickers, the public was used to the system and enforcement mechanisms had already been established. The state has used "random pullover" for many years both as a direct enforcement tool as well as a quality assurance mechanism. Any vehicle that, despite having a recently issued valid sticker, has obvious safety or emissions control deficiencies, is required to be fixed accordingly and reinspected. In addition, the garage that performed the initial inspection is visited by appropriate state personnel who check on inspection procedures, recordkeeping, etc. Rhode Island is now purchasing two vans equipped with emissions analyzers for the purpose of extending the random pullovers to include emission tests.

In an I/M program limited to urban areas only, however, the sticker ticketing approach is inherently more difficult to administer and less effective in terms of compliance levels. In the Cincinnati, Ohio program, for example, compliance is estimated at only 25 to 30 percent. The most important reason for such low compliance is the inability of enforcement officials to distinguish among vehicles registered in the affected area and other areas of the State. One solution would be to have a specially coded license plate for the affected vehicles. This, unfortunately, would result in significant additional costs even before the actual enforcement would take place. For the registration enforcement procedure, however, the clerk handling the registration would only have to check the registrant's address to verify whether or not an emissions inspection is required prior to registration. It is possible that under these circumstances, motorists may attempt to register their vehicles in counties without I/M to avoid inspection. From these considerations, it may be seen that potential problems with enforcement of a program limited to urban counties are inevitable regardless of enforcement procedure adopted. The problems associated with identification of affected vehicles under the sticker ticketing approach, however, makes enforcement considerably more difficult than when registration enforcement is used.

Program Costs

The motor vehicle registration method of enforcement is generally less costly than the sticker ticketing approach. Costs for the registration procedure are minimal provided that the motorists bring certificates of compliance (printed sheet or a stamp affixed to the registration renewal form) to the registry prior to the annual registration. There will, of course, be some additional clerical costs, the extent of which will depend on the form the compliance verification will be in (i.e., stamp on the registration form, separate sheet of paper, etc.). Sticker ticketing costs, however, may be very substantial, particularly if additional enforcement personnel are required.

The Cincinnati Air Pollution Control Board employs four special enforcement officers, the "Green Hornets," whose primary responsibility is issuing tickets to motorists whose vehicles do not have valid inspection stickers. The costs of salaries, overhead, vehicles, etc. for the "Green Hornets" are estimated to total $100,000 per year. In addition, the City of Cincinnati Police Officers also issue tickets as part of their normal patrolling routine. The city estimates that this activity costs roughly a half million dollars annually. Other additional costs stem from court costs, administration costs, costs involved in collection and handling of fines. Some of these costs are recovered through the fines.

A summary of advantages and disadvantages of both methods of enforcement is presented in Table 7.

TABLE 7. ADVANTAGES AND DISADVANTAGES OF TWO ENFORCEMENT MECHANISMS

| Enforcement mechanism | Advantages | Disadvantages |
|---|---|---|
| Sticker ticketing | 1. Frequency of inspection may be independent of frequency of registration<br>2. High level of compliance for statewide programs<br>3. No need to change registration process. | 1. May require additional enforcement personnel<br>2. Poor level of compliance for substatewide programs.<br>3. High enforcement costs.<br>4. Must devise means for identification of subjected vehicles in substatewide program. |
| Registration | 1. High level of compliance.<br>2. Can be easily adapted for substatewide program.<br>3. Additional costs less severe.<br>4. No additional law enforcement officials needed. | 1. Frequency of inspection should be the same as frequency of registration.<br>2. Registration must be staggered. |

## SUPPORTING PROGRAMS REQUIRED

Several supporting programs are considered essential to the successful implementation of an I/M program. Three specific programs that are particularly important are mechanics' training, public information, consumer protection and quality assurance. These are discussed in the following paragraphs.

### Mechanics Training

#### Need for Mechanics Training--

Mechanics training is a highly important part of an effective I/M program. Mechanics training may occur through a government-sponsored series of courses, through auto industry programs, as a regular part of vocational training courses, or informally through repair shop on-the-job training. Most government-sponsored mechanics training courses include both background content, or orientation towards the basic need and benefits of I/M and the mechanic's role in the program, as well as technical content on automobile emission control systems, correct diagnosis and repair of emission control tuneup procedures. EPA and the automobile industry have focused attention on mechanics training for two basic reasons. One is the increasing technical complexity of automobile emissions control systems. Owing to the growing complexity and sophistication of the basic ignition and carburetion systems, and the use of electronic devices and power systems, there is an ever increasing need for constant training and retraining of mechanics. In recognition of this, automobile manufacturers have themselves instituted in-service training programs for mechanics.

The second basic reason for mechanics training relates to the employment situation in the automobile repair industry itself and public attitude towards it. Owing to skill shortages, relatively high employee turnover rates, and the growing complexity of the motor vehicles and repair shop procedures, it is generally felt that there are widespread substandard (and unethical) repair practices in the repair industry. In the past few years there has been much publicity on consumer dissatisfaction with the quality of service experienced throughout the country. In response to this general dissatisfaction, there have been proposals to place rather stringent regulation of the repair industry through licensing or certification of repair facilities and/or mechanics. The potential effects of such regulation have been debated widely. Most industry spokespersons strongly oppose stringent controls because they feel that they would restrict competition. Therefore, mechanics training appears to be a sound alternative to licensing or other forms of direct regulation of the repair industry.

A related development of major concern to the I/M program itself, is the widespread practice of motor vehicle owners tampering with their emissions control systems and fuel switching. Misunderstanding on the part of both the public and the auto repair industry on the technical aspects of emission controls and the relationships between emissions control, fuel economy, and performance have encouraged these practices. U.S. EPA has stated that 35 percent of 1976 and 1977 model cars have had their emission systems tampered with in some way, ranging from minor adjustments away from manufacturer specifications to major sophisticated disconnections or modifications.

Benefits of Mechanic Training--

The benefits of mechanics training may readily be seen from the above analysis of the needs for it: better understanding of the need for emission tuneups and repairs, a more positive attitude toward emissions reduction and the I/M program, higher quality emission repairs and tuneups, fewer consumer complaints about emission repairs, reductions in illegal tampering and fuel switching, and a generally better relationship between the auto repair industry and the public. In conjunction with mechanics training a comprehensive public education program is, of course, necessary to ensure that the public at large does not encourage or contribute to practices such as tampering. Tampering reduces the overall effectiveness of mechanics training programs in particular and the I/M effort in general.

Approaches to Mechanics Training--

A variety of approaches have been instituted for mechanics training in various states, ranging from very comprehensive government-sponsored programs to informal industry-sponsored efforts. In this discussion, the emphasis will be on providing an understanding of the range of methods that could be employed in Minnesota.

Many states have instituted formal mechanics training programs in conjunction with the implementation of their I/M programs. In terms of the actual timing of these courses, it is important to begin training mechanics several months to a year before the mandatory inspection process begins. However, the difficulty in implementing early training programs relates to the fact that attendance is generally voluntary. Consequently, there must be an incentive to participate. The primary incentives are: first, government requirements for for the official certification of a repair shop that it employ at least one mechanic who has completed an approved mechanics training course, and second, the economic incentive to the repair facilities and mechanics that result from the certification process. The repair shops that meet the certification requirements can increase their repair business and this serves as a significant incentive to other shops and mechanics to join the program. Obviously, as the I/M program becomes operational and repair demand grows, so does the demand for mechanics training.

The government sponsored programs may be held in a classroom setting at local vocational schools or community colleges or, at the private facilities that wish to become certified. Typically, such courses may be held in the evenings and last for 12 total hours. Subject matter includes basic orientation to the needs and benefits of I/M and the role of emission tuneup personnel in the I/M program and familiarization with basic emission control systems equipment and emission control tuneups.

Another approach, which was found useful in Arizona's program, is on-the-job training where special two-person instructor teams hold courses at local repair facilities, training mechanics from nearby shops. This approach emphasizes practical experience and overcomes the problem of reaching mechanics who are unable to take the time to attend classroom courses. It also has the added advantage of making mechanics feel comfortable in the course setting. If not already a piece of standard shop equipment, an emissions analyzer may be brought to the local repair facility to provide "hands-on" experience during the "on-the-job" training course. Equipment manufacturers, themselves, offer training when their products are purchased.

In addition to government-sponsored I/M program mechanics training courses, it is important to consider industry-sponsored efforts and resources. General Motors Training Centers are located in many metropolitan areas. These centers regularly hold special emission control repair and tuneup courses for GM equipment at no charge to the mechanics. Some dealers send mechanics regularly to these centers to update their knowledge and skills. The other major automobile manufacturers also offer training opportunities. Manufacturers, both domestic and foreign, may send instructors with mobile vans to dealers or localities upon request from local car dealers to conduct mechanics training courses.

Another important resource is the statewide vocational education school system. Regular mechanics training courses of longer duration than those described above, are held for students seeking basic automobile mechanic skills. These courses should receive continuously updated information on the new technologies and skills so that students graduating from them are competent to do emission control repair and tuneup work. As mentioned above, most of the instructors trained through the Colorado State University program incorporate emissions-related information into their ongoing mechanics classes. This assures that new mechanics entering the trade will have a substantial background, thus enabling the repair industry to handle the increased number of repairs due to I/M and the more complex technology of today's vehicles.

An important footnote to the mechanics training approaches noted above is that, no matter what approach(es) are used, there is a constant need to update both the instructors and the students on a regular basis. As the automotive technology grows, short courses which incorporate the new aspects of the motor vehicle industry should be offered as often as possible.

## Public Information Programs

Experiences in several states that recently established inspection/maintenance programs emphasize the importance of an effective public relations program. A well-designed, comprehensive program that introduces the public to the basic need for, and benefits of, I/M and clarifies the misunderstandings that surround I/M is critical during the early stages of implementation. A well-thought-out program can help eliminate potentially adverse reactions that other states with inadequate public relations programs have experienced (e.g., Arizona; Cincinnati, Ohio; and Chicago, Illinois).

A comprehensive public relations program should consist of three basic phases: (1) early initial public education on the basic need and benefits of I/M; (2) an intensive public relations effort 6 months prior to the actual beginning of mandatory inspection; and (3) an ongoing public relations program. These are discussed below.

### Phase I: Initial Public Information Program--

The emphasis of this phase, which should begin in the early planning and design stages, should be in basic education as to the needs for I/M, the benefits of I/M, and what it means to the public. It is essential that the public begin to gain a familiarity with the I/M concept and that this concept have time to grow in the public awareness. By beginning early grass roots activities, support for the I/M program can be obtained. The elements of this phase would consist of a slide presentation, mobile emission testing display, a generalized brochure, and press releases. Presentations can be given to specialized interest groups such as clean air groups, environmental groups and conservation clubs, the League of Women Voters, automobile clubs, automobile service industry groups, and local civic or service clubs. Also, metropolitan and regional planning agencies can be involved at this point. A mobile emissions test demonstration van has been found useful to acquaint the public or special groups with the inspection process. Many states have prepared brochures explaining I/M and distributed it widely among the general public. As important decisions are made and implementation begins, periodic press releases should be made. This initial public information effort may be accomplished by the state itself or through assistance provided by private organizations with experience in I/M public relations programs.

Phase II: Preinspection Public Relations--

About 6 months prior to the opening of test lanes for mandatory testing with voluntary maintenance, there should be an intensive public relations effort. During this time every motorist must be informed of the needs and benefits of I/M and also of his obligations and rights and the basic organization and procedures in the program. Also, this is the period during which the training of the inspectors, in either state or contractor lanes would occur. An important part of the training is dealing effectively and courteously with the public.

The basic elements of Phase II public relations would be a mailing to each motorist, inspector training, news relations and media advertising. The mailing would consist of a pamphlet not only explaining the basic reasons for having I/M and the benefits such as air quality and fuel economy improvements but also the times and places of the inspection stations operation, what consumer rights and obligations are, what the complaint procedures are, and also important details of the maintenance phase. During this phase, media advertisements or announcements are important because it is critical that every affected motorist receives the right information. All the employees of both the State and the contractor who deal directly with the public, especially the emission inspectors, station managers, hotline operators, complaints investigators, and calibration officials should receive training in how to deal with the public and an understanding of the basics of I/M.

Phase III: Ongoing Public Relations--

The emphasis in the ongoing public relations program is largely informational. States with existing I/M programs such as New Jersey and Arizona have indicated that as the public becomes used to the program there may be somewhat less need for an intensive public relations effort. There would still be a need to inform motorists of any significant changes in program operations or other modifications of program elements such as waivers, exemptions, repair cost ceiling, inspection fees, or registration procedures. This would entail periodic mailing and possibly some media announcements. Also, new employees who deal with the public would be required to receive the same orientation that the initial personnel received at the beginning of the program. The public should also be made aware of the status of the program in terms of the emissions reductions achieved and other benefits accrued.

Consumer Protection

An effective consumer protection program is highly important for a successful I/M program. It is important from the point of view of protecting the public from unnecessary costs and inconveniences and equally important in securing general public acceptance and avoiding a significant buildup of adverse publicity. Among such consumer protection and convenience measures are public relations elements, although the primary aim of these elements is ensuring protection from inequities in either the inspection or the maintenance phase of the program.

Consumer protection mechanisms are generally of two types. First, there are specific active procedures set up to deal with consumer complaints as they occur. These are the consumer hotlines and complaints investigators. Second, there are features built into the system that directly or indirectly protect consumers from potential inequities or abuses. These include state motor vehicle repair regulations, repair cost ceilings, waivers or exemptions, repair facility or mechanic licensing or approval, and warranty regulations (both federal and state).

Consumer Hotlines--

Consumer hotlines would serve two important functions. First, they would provide valuable information to the public regarding basic operating times and locations of the inspection lanes, procedures, consumer rights and obligations, and other related information. Second, and equally important, the hotlines would be centralized referral points to guide the consumer after an evaluation of his problem to the correct department. In many cases, all that may be needed is correct information, but when a significant problem requires the attention of a particular department, the consumer can then be routed to the right office. Also, the hotline personnel are trained in dealing with the public and thus, can make a significant contribution to the overall public relations effort of the overall I/M program. It is very important that all contacts between the public and I/M personnel be smooth and harmonious, especially given the somewhat controversial nature of the program.

Complaints Investigation--

Some of the problems reported to the hotlines would require referral to other departments, depending on the nature of the complaint. As an example, complaints that require legal actions would be routed to the Attorney General's office. Of course some problems would presumably involve more than one department's involvement. Any problem could potentially involve the Attorney General's office at some point if illegal proceedings were uncovered that required legal action or resolution. Hopefully, most problems could be resolved without resorting to legal action.

Repair Cost Limits--

The repair cost limit is a maximum cost that a motorist may be obligated to spend on repairs for his motor vehicle in order to meet the emission standards. This cost ceiling helps to prevent the program from becoming an excessive burden, especially on those vehicle owners in lower income brackets. Also, on certain vehicles the cost of complying may be so great as to make operation prohibitively expensive. However, it should be clearly stated that the vehicle owner is in no way compelled to keep the repairs below the specified limit. For those who can easily afford the extra costs or who desire to achieve full compliance, there should be strong encouragement to do so.

Repair costs may be cumulative. In some cases a motorist may fail the retest and return to the repair shop again for repairs. The repair cost limit applies to the cumulative emission repairs for the entire sequence within a specified time limit after failing the emission test.

Repair cost limits are generally of two types. First, an absolute dollar limit and second, a sliding scale related to the value of the vehicle. In the first approach generally a fixed upper limit of from $50 to $100 is set which applies to all vehicles regardless of their age, conditions, or resale value. In the second approach, which in theory would be more equitable, the price ceiling relates to the vehicle value as determined by an accepted reference such as the used car Blue Book of average retail prices.

Waivers and Exemptions--

Granting of waivers or exemptions for specific vehicle types, in addition to vehicles exceeding the repair cost ceiling, is another consumer protection mechanism. Exemptions of vehicles over a certain age is a commonly used method to protect owners from undue financial hardships. The older vehicles generally cost more to bring into compliance and are more likely to need extensive repairs such as ring or valve jobs. Moreover, given the small fraction of the total vehicle population that they represent, such exemptions entail a minimum sacrifice in overall emission reduction benefits. Other vehicle types commonly given exemptions are electric, experimental, antique, and off-the-road vehicles. The major considerations when judging whether any particular vehicle type should be exempt would be the potential hardships on vehicle owners, balanced by effects on overall emissions reductions. A more detailed discussion of waivers and exemptions appears earlier in this section.

Licensing, Certification, or Approval of Repair Facilities and Mechanics--

Licensing or certification of repair shops and mechanics are mechanisms for ensuring that repairs are done adequately and at a reasonable cost to the consumer. As such, they may be important as consumer protection elements. The type and degree of regulation of private industries such as repair shops by state government is a sensitive issue but given the need to ensure protection of the consumer and the adequacy of repair, some type of interaction or influence on repair industry practices is crucial. An active mechanic training program in emission-related tuneup and emission repairs has been shown to have a very beneficial impact on upgrading mechanic skills and fostering a positive attitude toward emission control.

Most states and repair industry groups do not look favorably at formal licensing of repair shops and mechanics; rather, they view it as expensive interference in private industry. Of course, when the repair facilities are designated as official inspection stations then some sort of official licensing and closer supervision is very important for both consumer protection and quality assurance considerations. Generally, there are two reasons for needing some supervision or influence on the private repair facilities: emission analyzer calibration and accuracy and control of unauthorized repair practices. Rather than formal licensing of repair facilities, by which is meant that only licensed facilities could perform emission repairs, a lesser degree of control in the form of certification or approval would be appropriate. Given the need for using reasonably accurate and reliable analyzers, many states publish lists of approved emission analyzers. New Jersey has one such list. A repair facility may become approved or certified if it utilizes an approved analyzer. In addition, the state may require that the facility employ emission tuneup mechanics who have taken approved mechanic training courses. Furthermore, the state could have each approved analyzer calibrated at regular intervals.

Warrantees--

The ability of in-use vehciles to maintain the emission standards for which they were designed depends largely on the integrity of the catalytic converters: it is significant to have a mechanism that ensures that failed equipment will be identified and replaced. This problem was recognized by the Clean Air Act Amendments warranty provisions in Section 207(b).

The intent of the Federal Clean Air Act 207(b) warranty provisions was to ensure that the basic emission control equipment be manufactured such that it would last up to 50,000 miles or 5 years, whichever came first. As such 207(b) may be seen as an incentive to the manufacturers to design the basic emission control equipment to last at least up to the end of the warranty period if not longer. There is still much debate about what should be the best warranty period and suggestions have been made to have the warranty extended to the entire useful life of the vehicle or 100,000 miles. The actual working of section 207(b) is as follows:

"(b) If the Administrator determines that (i) there are available testing methods and procedures to ascertain whether, when in actual use throughout its useful life (as determined under section 202(d), each vehicle and engine to which regulations under section 202 apply complies with the emission standards of such regulations, (ii) such methods and procedures are in accordance with good engineering practices, and (iii) such methods and procedures are reasonably capable of being correlated with tests conducted under section 206(a)(1), then -

(1) he shall establish such methods and procedures by regulation, and

(2) at such time as he determines that inspection facilities or equipment are available for purposes of carrying out testing methods and procedures established under paragraph (1), he shall prescribe regulations which shall require manufacturers to warrant the emission control device or system of each new motor vehicle or new motor vehicle engine to which a regulation under section 202 applies and which is manufactured in a model year beginning after the Administrator first prescribes warranty regulations under this paragraph. The warranty under such regulations shall run to the ultimate purchaser and each subsequent purchaser and shall provide that if -

(A) the vehicle or engine is maintained and operated in accordance with instructions under subsection (c)(3),

(B) it fails to conform at any time during its useful life (as determined under section 202(d)) to the regulations prescribed under section 202, and

(C) such nonconformity results in the ultimate purchaser (or any subsequent purchaser) of such vehicle or engine having to bear any penalty or other sanction (including the denial of the right to use such vehicle or engine) under State or Federal law,

then such manufacturer shall remedy such nonconformity under such warranty with the cost thereof to be borne by the manufacturer. No such warranty shall be invalid on the basis of any part used in the maintenance or repair of a vehicle or engine if such part was certified as provided under subsection (a)(2). For purposes of the warranty under this subsection, for the period after twenty-four months or twenty-four thousand miles (whichever first occurs) the term "emission control device or system" means a catalytic converter, thermal reactor, or other component installed on or in a vehicle for the sole or primary purpose of reducing vehicle emissions. Such terms shall not include those vehicle components which were in general use prior to model year 1968."

The basic meaning of the warranty is that the manufacturer will be responsible for the costs of replacement of the emission control devices or system up to 50,000 miles or 5 years whichever comes first provided that the vehicle is operated and maintained in accord with written instructions furnished by the manufacturer. In relation to the I/M program, what is particularly important is the definition of the acceptable test procedures referred to in the first paragraph of section 207(b). The basic question is what actual emissions test will be reasonably correlated with the basic standard of emission testing which is the Federal Test Procedure (FTP) used to determine if prototype vehicles and vehicles selected from the assembly line meet the applicable emission test standards under the Federal Motor Vehicle Emission Control Program (FMVCP). The purpose of this program is to ensure that cars being designed and manufactured meet the Federal emission standards. 207(b) requires that there be a reasonable correlation between the short emission test used in the I/M program with the lengthy FTP. To date five short tests have been proposed as suitable for use in light-duty vehicle and light-duty truck emission inspection program. These include the following tests:

- the idle test
- the Federal 3-mode
- the Clayton Key mode
- the Federal Short Cycle
- the New York/New Jersey short cycle.

These tests, then, have been proposed as being suitable for use in an I/M program to implement the warranty provisions of 207(b). An associated issue is the determination of appropriate cutpoints, that is, correct emission test standards. There are three options for developing these standards: states can determine them, or they can be provided by EPA or the manufacturers could provide the date on the basis of which standards would be set either by the states or the EPA. With EPA's adoption of official cutpoints,however, in order for the 207(b) warranty provisions to be activated by an I/M program test failure, then the state's I/M cutpoints must be at least as stringent as the promulgated EPA cutpoints.

## Quality Assurance

Maintaining a high degree of precision and uniformity in emission test results is vital to the success of an inspection/maintenance program. Accurate information must be generated to correctly analyze the impact of the program on lowering emissions and to maintain public interest in the program. If I/M is perceived as a haphazard, arbitrary program, enforcement problems will become intractable.

The repeatability of the actual test results is central to the issue of quality assurance. The test must be carried out correctly and with a high degree of uniformity on all vehicles included in the program. A program utilizing a network of centralized inspection facilities will facilitate the standardization and repeatability of tests. Such a system contains a relatively small number of high quality exhaust gas emission analyzers that can be closely monitored.

It is technically feasible and desirable to automate the testing sequence in this situation, tieing all operatings associated with the test into a central computer system.

The key or loaded-mode test procedure is a sophisticated test that measures vehicle exhaust emissions under a variety of different "loads" or conditions that simultate the actual emissions generated by a vehicle under normal driving conditions. To correctly perform a loaded-mode test, a series of samples must be taken from a vehicle's exhaust when it is experiencing loads within certain parameters. The results of this sampling series are integrated to provide a composite assessment of the vehicle's emissions characteristics.

Automating a loaded-mode test by interfacing the control of the analyzer and dynamometer with a computer routine removes a large portion of the cause of test result variability, human error. This approach to test control limits human involvement to (1) identifying the vehicle to the computer by means of entering the vehicle identification number (VIN) into an input/output device (i.e., a "CRT" or TV screen-type computer terminal), (2) manually inserting the analyzer probe into the tailpipe (or tailpipes) of the vehicle being tested, and (3) operating the vehicle on the chassis dynamometer. The computer routine can monitor the "load" being generated by the dynamometer and automatically take exhaust samples at the appropriate times. The samples results can be integrated by the computer and compared with test standards stored in the computer.

Once such a system has been installed and its software has been found accurate and reliable, a series of relatively simple checks should be made to insure its continued correct operation. Analyzers must be calibrated periodically. This procedure is straightforward. By analyzing a set of "calibration gases" that have known precisely-blended contents and checking the analyzers readings of actual gas content, the analyzers accuracy can be determined. At the very least, an exhaust gas analyzer should be checked in this fashion whenever it is turned on and adjusted if its readings are different from what they should be. With an automated system, the analyzer can be calibrated regularly at frequencies of 1 hour to minimize the possibility of inaccuracies resulting from equipment malfunction.

In the contractor-operated system, periodic inspections should be made by the state to verify the accuracy of data submitted by the contractor. Ninety days is the generally accepted interval for such checks on central test lane equipment. In addition to scheduled inspections, the state may perform unannounced checks if there have been complaints about test accuracy or other indications that an analyzer has not been functioning properly.

In order for such state inspections and checks to be useful, there are certain informational requirements that should be placed on the contractor. Most importantly, periodic reports on the frequency and results of equipment calibrations should be mandatory. A log of any adjustments made in the process of calibrating equipment should also be kept. Experience to date shows that the operation of automated test systems is relatively trouble free, and that downtime resulting from equipment malfunction is minimal. In addition to direct equipment maintenance and calibration records, there are a number of items that should be recorded to provide data for use in analyzing the effectiveness of the program.

Another quality assurance issue that should be considered is prohibiting an inspection contractor from engaging in any other type of business that leads to a conflict of interest. The contractor must not be in a position to profit from one test result, but not another.

Standards should be set regarding the type of analyzing equipment that may be used by the contractor. There is a wide range in the quality and capacity of such equipment on the market today. Use of equipment that is inappropriate to a centralized network type application could provide a very low level of test accuracy and uniformity between tests. Equipment performance standards can be set by two methods. First, a list of approved equipment, by manufacturer and model type, can be compiled. Alternately, the actual specifications and tolerances that acceptable equipment must meet may be promulgated.

There are a number of performance parameters that should be specified to insure that only high quality equipment is used. Most obviously, the accuracy (in plus or minus percent) of the actual hydrocarbon and carbon monoxide readings must be specified. The consistency of a unit's analysis over time should also be subject to limits. If this "zero drift" is large over time, either more frequent recalibrations should be stipulated or the unit should not be approved for use. The "purge time" of an exhaust gas analyzer is another important parameter. This refers to the time interval that must pass between tests to assure that the emission readings are influenced only by the exhaust of the vehicle being tested. The "purge time" is a measure of the time that a unit must remain unused before it has been cleansed of all gases introduced by the previous test sequence. In high speed units of the type suitable for use in the high volume contractor-operated system, an inert or "neutral" gas such as nitrogen is run through the analyzer after each test sequence to remove all traces of material introduced into the analyzers system by previous tests.

## PHASING CONSIDERATIONS

Planning considerations, or phasing, serve to enhance the likelihood of successful program implementation not only in terms of meeting deadlines and achieving efficiency, but also in terms of gaining public confidence in the intent and equity of the program. With regard to the overall phase-in of an

I/M program, there exists a general sequence of events that must be undertaken in logical order to ensure the program will be implemented by the EPA deadline of Mandatory Inspection and Maintenance by January 1, 1983. These issues have been discussed in detail in Section 6, Implementation Scheduling. Apart from these issues that concern mandatory phasing elements are additional issues that are connected with program phasing, but are somewhat less crucial in nature. These deal primarily with expanding or otherwise changing the format of the program for purposes other than meeting statutory requirements. Several of these are discussed below.

Mandatory Inspections - Voluntary Maintenance Phase

Current EPA guidance on I/M program implementation endorses the practice of scheduling at least one full year of mandatory inspections but voluntary maintenance. This permits motorist to become somewhat familiar with the program and provides an opportunity for both a shakedown of the inspection facilities and procedures, and to collect specific emissions data, which can be used to define cutpoints for the fully-mandatory phase.

Additionally, one year of voluntary maintenance would give the repair industry additional time to "gear-up" to the anticipated work load created by the program. In New Jersey, for example, it was felt that the repair industry was not ready for the fully mandatory phase after one full year of voluntary maintenance. As a result, the voluntary maintenance phase was extended an additional 6 months to allow the industry more time to prepare.

A voluntary maintenance phase does not necessarily mean that motorists will not repair failed vehicles, particularly if an effective public information program stressing benefits supplementary to emission reduction (fuel savings, increased vehicle life, etc.) is implemented concurrently. In the Arizona program, for example, there was a measurable reduction in tailpipe emissions during the voluntary maintenance phase.

One criticism of the one year voluntary maintenance phase is that it may slow the program's momentum somewhat by creating two critical implementation dates, one for the original implementation of the program and one for the initiation of mandatory repair. It could also be argued that a year of voluntary maintenance is not desireable because it does not fully utilize the program's potential for reducing emissions, therefore, the public is being required to pay for a program that is by design not as effective in meeting its primary objective as it could be.

An alternative to the one year voluntary maintenance phasing strategy would be to require mandatory repairs from the beginning of the program, but to employ initial emission standards so lenient as to fail only the most gross emitters during the first year and then gradually tighten standards. It should be pointed out that the two strategies are not mutually exclusive. For example, New Jersey utilized a voluntary maintenance phase followed by three phases of increasingly stringent cutpoints.

## Progressively Stringent Cutpoints

Vehicle emission standards or "cutpoints" determine the overall emissions reduction potential of an I/M program. They distinguish between those vehicles requiring emissions-related maintenance and those that do not. The principal objective of an I/M program is to achieve maximum possible reductions of automotive exhaust pollutants. This objective, however, must be balanced against equity considerations of public convenience and repair industry capacity. Implementing progressively more stringent cutpoints is one means of achieving this balance.

Experience from various states implementing I/M programs shows that, despite a very exhaustive research program to establish cutpoints, it is very difficult to predict accurately the number of vehicles that will fail the initial emissions test. The number failed is dependent on the overall emissions characteristics of the vehicle population, a factor which is difficult, if not impossible, to predict. Should a larger fraction of the vehicle population than that anticipated fail the initial test, negative public sentiment could develop that would jeopardize the I/M program's success. Further difficulties could arise if the total of noncomplying vehicles exceeds the ability of automotive repair industry to perform required maintenance. These problems, of course, can be alleviated by setting initial standards such that only the "gross emitters" will fail the emissions test. Both the public and the repair industry are then afforded the opportunity to become accustomed to the program and its economic effects before standards are in full force.

It should be noted that the cutpoints chosen should be periodically reviewed to assure that the maximum reasonable emissions reductions are being attained. As the program continues, it is not unreasonable to expect that the general condition of the inspectable fleet will improve; this will require revising the standards to be more stringent in order to maintain the same failure rate. Revising the cutpoints should be based on vehicle emissions data compiled during the testing.

## Expanding Geographic Coverage

Policy guidance from the U.S. EPA, dated 17 July 1978, suggests that the minimum acceptable geographic coverage for an I/M program is not only the designated nonattainment area, but also certain areas beyond, including "the entire urbanized area and adjacent fringe areas of development."

Seven counties comprising the Minneapolis/St. Paul Metropolitan area have currently been designated as the bounds of the I/M program proposed here. At some future time, it may be desirable to expand coverage of the program to include all counties within the State. A prime example of this would be when the program itself is expanded to include safety inspections as well as emission and noise testing.

Although an I/M program involving only the seven Metropolitan counties would satisfy EPA requirements, such a policy may serve as an incentive for motorists to illegally register their vehicles in counties outside the covered area.

If the decision were made to expand coverage to include the entire State's population, it may be best to perform this expansion all at once rather than on a county-by-county basis. Greater economies of scale in construction can be realized with the former approach, keeping the cost to the motorist as low as possible.

Expanding Coverage to Include Additional Vehicle Types

Given U.S. EPA policy guidelines that require at least a 25 percent reduction in light-duty vehicle (LDV) exhaust emissions of HC and CO by 1987, it is obvious that the burden of responsibility for emissions inspection and maintenance will fall upon the LDV population. Definition of this population is flexible, up to a point. Once maximum weight limits are set by policy decisions, the inspectable vehicle population may be defined, and facilities designed to handle this population. So long as inspection facilities are designed to handle a certain motor vehicle population over a period of years, it is not practical to phase-in additional vehicle types. It is more cost-effective from the contractor's viewpoint, and probably more equitable from the state's viewpoint, to initiate a testing program for all the vehicles in the design population at the outset rather than including additional vehicles at a later date.

## INTEGRATING SAFETY, NOISE, AND EMISSIONS TESTING

### Introduction

The concept of mandatory motor vehicle inspection is not new. Many states in the U.S. currently conduct periodic motor vehicle safety inspections of some sort, ranging in comprehensiveness from random spot inspections of a relatively small fraction of the vehicle population for obvious defects (tire wear, nonfunctioning lights, wipers, or horn, etc.), to regularly scheduled, detailed inspections of various major systems such as the brakes, suspension, and steering. Several states go further still with requirements for inspecting vehicle emission characteristics to ensure that the pollution control devices are functioning properly and that the engine's overall performance (with regard to emissions) is within design specifications.

In addition to safety and emission considerations, interest has recently evolved in the noise aspects of motor vehicles. This interest has risen to the point where several states and cities as well as the Federal government have set noise standards on motor vehicles, and are actively enforcing these standards.

In that standards have been established, there are obviously requirements for ensuring compliance with the standards. It would appear at this point that there would be many similarities among programs concerned with monitoring and enforcing compliance in these three areas, since each focuses on various physical attributes of a motor vehicle that are wholly quantifiable and controllable. The primary questions at this point should concern whether or not there are distinct advantages or, for that matter, disadvantages, to combining any of these programs, and secondly, whether it is possible from a technical or administrative standpoint to operate a combined program. The following paragraphs provide a discussion of various aspects of each program that tend to make them either compatible or incompatible in the context of program consolidation.

## Current Status of Inspection Programs in Minnesota

Currently, the State of Minnesota has only a random pullover safety inspection program instituted. The need for an automotive emission inspection program, however, has been defined by the Minnesota Pollution Control Agency as indicated previously, in that the national ambient air quality standards for photochemical oxidants ($O_x$) and carbon monoxide (CO) will not be achieved in all areas by 1982 and, therefore, a request from the State to the U.S. EPA for a time extension for compliance is almost a certainty. As indicated previously, a requirement for considering time extensions is that the State have a definite schedule established for implementing an acceptable motor vehicle emissions inspection and maintenance program.

Minnesota currently has regulations dealing with vehicle noise, however these focus on establishing limits on drive-by noise only. It has been indicated that standards will be established for exhaust noise levels, as well. In this connection there will be a need for exhaust noise testing in the foreseeable future.

Given the current status of inspection programs in the State and the time frame within which the emissions inspection program must be implemented, it is perhaps a realistic viewpoint that I/M will be developed either separately or in conjunction with noise testing, but not with safety. This is not to say, however, that the development of the I/M program should not consider the possibility that either or both of the other programs would be integrated in the future. At this point, it is prudent to consider the potential for combining inspection programs and to perhaps base some of the decisions regarding the I/M program development on the possibility that safety and/or noise inspection programs will be implemented in the future.

## Technical Considerations

A first consideration in the overall concept of consolidating inspection programs is that, in the most basic sense, all three types are very similar from the technical viewpoint. Each is concerned with testing a component or series of components to ensure their conformance with established standards. Further, the level of effort, the type of individual qualified to perform the inspections, and the basic facilities required to perform the three types of inspections are similar, for the most part. Considering individual testing programs, it is clear that the degree to which these similarities exist can be greatly influenced by specific options selected for each program. In fact, if the intent is truly to combine these programs, several specific options become inappropriate at the outset.

To assist in identifying common features and elements of each program, a listing was developed, which describes the general features of various options available in selecting a program. This listing, shown in Table 8, is subjective to some degree, but it does provide a reasonable indication of

## TABLE 8. ELEMENTS OF SAFETY, EMISSION, AND NOISE INSPECTION PROGRAM OPTIONS

| Program | Option | General Description of Related Features[a]: Level of Effort Involved | Inspector Qualifications | Facilities Required | Equipment Required | Technical Limitations |
|---|---|---|---|---|---|---|
| I. Safety | A. Periodic, Mandatory (Annual, Semiannual) | A | E | I | M,N | T |
| | | B | E | I,J | N,O | U |
| | | C | F | J | O | U |
| | | D | G | K,L | O,P | U,X |
| | B. Inspection Required Upon Title Transfer | A | E | I | M,N | R,S,T |
| | | B | E | I,J | N,O | R,S,U |
| | | C | F | J | O | R,S,U |
| | | D | G | K,L | O,P | N/A |
| | C. Random Pullover | A | E | H | N | R,S,T |
| | | B | E | H | N | R,S,U |
| | | C | F | H | O | R,S,U |
| | | D | N/A | N/A | N/A | N/A |
| II. Emissions | A. Periodic, Mandatory (Annual, Semiannual) | A | E | I | M | T,W |
| | | B | F | I | O,P | U |
| | | C | F | I | O,P | U |
| | | D | G | K | P,Q | U,X |
| | B. Inspection Required Upon Title Transfer | A | E | I | M | R,S,T,W |
| | | B | F | I | O,P | R,S,T,W |
| | | C | F | I | O,P | R,S,T,W |
| | | D | G | K | P,Q | R,S,T,W,X |
| | C. Random Pullover | A | E | H | M,N | R,S,T,W |
| | | B | F | H | P | R,S,T,W |
| | | C | F | H | P | R,S,T,W |
| | | D | N/A | N/A | N/A | N/A |
| III. Noise | A. Periodic, Mandatory (Annual, Semiannual) | A | E | I | M | U,W |
| | | B | E | I | P | U,V,W |
| | | C | F | K | P | U |
| | | D | G | K | P | U |
| | B. Inspection Required Upon Title Transfer | A | E | I | M | R,S,T,W |
| | | B | E | I | P | R,S,T,V,W |
| | | C | F | K | P | R,S,T,W |
| | | D | G | K | P | R,S,T,W |
| | C. Random Pullover | A | E | H | M | R,S,T,W |
| | | B | E | H | P | R,S,U,V,W |
| | | C | F | H | P | R,S,U |
| | | D | G | H,K | P | R,S,U |

[a]Refer to notes below for each letter code.

## TABLE 8 (continued).

Level of Effort Involved

A. Minimal

- Safety: visual inspection only
- Emissions: visual inspection for smoke only
- Noise: subjective pass/fail based on listening to exhaust noise

B. Moderate

- Safety: visual inspection, inspect underside of vehicles, check suspension items using lift or jack
- Emissions: visual inspection for smoke, check emissions using idle mode test and emission testing instruments
- Noise: test using sound level meter placed near exhaust tip (similar to the California static test)

C. High

- Safety: visual inspection, inspect underside of vehicle, check suspension items, remove one or more wheels to check brake and wheel items
- Emissions: visual inspection for smoke; check emissions using idle and high idle modes and emission testing instruments
- Noise: test using sound level meter placed near exhaust tip; examine exhaust system to ensure conformance to original equipment specifications, perform run-by test under simulated conditions (cannot be conducted in or close to a building)

D. Maximum

- Safety: visual inspection, check underside of vehicle, check suspension items, remove wheels and check brakes and wheel assemblies, perform diagnostic checks
- Emissions: visual check, perform loaded mode emission test
- Noise: conduct run-by tests, perform field monitoring and testing program, inspect exhaust system to insure conformance to original specifications. provide retest for failures

Inspector Qualifications

E. Instruction desirable

F. Formal training desirable

G. Formal training required

TABLE 8 (continued).

<u>Facilities Required</u>

H. Safe area on side of the road, rest area, etc.

I. Single garage bay

J. Garage bay with lift

K. Garage lane; may be private garage or service station; for noise, require suitable outdoor test facility

L. Garage lanes; size requirements out of range of private garages or services stations; also suitable outdoor test facility

<u>Equipment Required</u>

M. Common mechanic's tools

N. Mostly common mechanic's tools, some special tools may be required

O. Specialized tools and equipment generally found in garages and service facilities involved in auto repair (e.g., floor jack or lift, headlight aimer)

P. Highly specialized equipment not often found in typical garages or service facilities (e.g., emission testing equipment)

Q. Highly specialized, sophisticated equipment generally never utilized in ordinary automotive repair work (e.g., dynamometer, scuff test pads, brake analyzer, engine analyzer)

<u>Technical Limitations</u>

R. Cannot be scheduled

S. Affords very limited coverage (less than about 20 percent of the vehicle population affected)

T. Effectiveness highly questionable

U. Effectiveness may be challenged

V. Appropriate technology may not be available

W. Not recognized as a technically-acceptable option

X. Usually requires centralized test facilities the major common elements in safety, emission, and noise inspection programs. Based on Table 8, several individual program configurations can be considered inappropriate at the outset; these are the programs where the effectiveness is highly questionable or the particular configuration is not recognized as a technically acceptable option, as indicated by letter code T or W, respectively, in the column indicating Technical Limitations.

Further, several combinations of options within the three programs are not compatible. These combinations include both periodic inspections and inspections that cannot be scheduled (i.e., title transfer or random pullover). The problem, obviously, is that one of the primary advantages of a combined program is the capability of performing the three types of inspections during one visit to the inspection site; this advantage would not be gained unless (1) all three were either periodic, required upon title transfer, or conducted during random spot checks; or (2) all were periodic as well as required either (or both) upon title transfer or as part of a random spot check (or other similar combinations).

An additional issue in this connection concerns the general operation of test facilities. For optimal efficiency, the tests should be conducted at the same facility, therefore it is obvious that a combined program should be operated entirely (1) within private garages, (2) at centralized facilities, or (3) using mobile inspection units.

The primary obstacles from a technical standpoint to combining any two or all three programs are those described above. Other issues should also be considered, which might influence decisions regarding more detailed aspects of the testing programs. In general, it would be an advantage to develop programs that are approximately on the same level of comprehensiveness. If, for instance, the emission program is to be fairly rigorous requiring mechanic training, an investment in facilities and equipment, etc., it would be reasonable to integrate a safety inspection program that would also include training (presumably for the same individuals trained in emission testing), and maximum utilization of the equipment and facilities requires for the emission program. The intent should be to gain the maximum benefit from each dollar expended on the program this type of optimization requires analyzing in detail the incremental costs and benefits for various combined program scenarios.

In summary, then, there are no major technical obstacles to combining any or all three types of inspection programs, provided that the most obviously incompatible options for each type are not selected. This implies that the existing random safety inspection program would, at best, be very difficult to combine with the I/M program. In that the national trend has been toward periodic safety inspections, it is perhaps appropriate that the initial I/M planning at least recognize the possibility that this type of safety program may be instituted in the future and therefore allowances made for possibly consolidating the programs.

## Administrative Issues

The consolidation of inspection programs is not likely to result in any major problems from the viewpoint of program administration. In fact, it is quite likely that the administration of a combined program is much more efficient than that of two or three separate programs. Interagency coordination and cooperation, however, is essential to program efficiency. Considering that, as a minimum, agencies representing law enforcement, highway safety, environmental protection, and motor vehicle registration would play major roles in a consolidated program, the need for a high degree of cooperation and coordination is obvious. From the experience to date with combined programs, there is no basis for skepticism regarding the likelihood that the required interagency coordination can readily be established.

## Summary

From both a review of the available literature, and conversations with individuals responsible for the operation and administration of combined programs, it can be concluded that combined programs are entirely feasible and, in fact, may be more desirable than separate programs. From the technical standpoint, the primary consideration in consolidating programs is to ensure that the basic features of each program are mutually compatible. This obviously has some implications regarding the existing motor vehicle safety inspection program in Minnesota. It is doubtful that the safety program in its present format would be combined with I/M, because of the basic differences in the programs. The possibility of a periodic safety inspection being implemented in the future and perhaps being combined with the I/M program should be considered.

It can also be concluded that there are no significant administrative obstacles to overcome in combining programs. Obviously, coordination among various state agencies is required, which should not prove to be an implementation barrier.

## REFERENCES

1. U.S. Environmental Protection Agency, Mobile Source Enforcement Division, Technical Support Branch, Washington, D.C. Motor Vehicle Tampering Survey (1978). November 1978.

2. Kincannon, B. F., and A. H. Castaline. Information Document on Automobile Emissions Inspection and Maintenance Programs. GCA Corporation, GCA/Technology Division, Bedford, Massachusetts. Prepared for U.S. Environmental Protection Agency, Office of Transportation and Land-Use Policy. Washington, D.C. Report No. EPA-400/2-78-001. February 1978.

3. Olson Laboratories, Inc. The Short Cycle Test Project. U.S. Environmental Protection Agency Contract Office of Mobile Source Air Pollution Control. July 30, 1973.

4. Clayton Manufacturing Company. The Key Mode Evaluation System, El Monte, California. 1971.

5. California Vehicle Inspection Program, Riverside Trial Program Summary Report. May 1976.

6. Rubenstein, G., R. Ingels, R. Weis, and A. Wang. Vehicle Inspection and Maintenance - The California Program, Society of Automotive Engineers Publication No. 760557, presented at Fuels and Lubricants Meeting. St. Louis, Missouri. June 1976.

7. Panzer, J. Idle Emissions Testing - Part II, Society of Automotive Engineers Publication No. 740133, prepared for Automotive Engineering Congress, Detroit, Michigan. February 25 through March 1, 1974.

8. Panzer, J. Idle Emissions Testing, Some Effects of Engine Malfunctions on Emissions, Exxon Research for presentation at MVECC-IV. Anaheim, California. November 1975.

9. General Motors Company, General Motors Position on Motor Vehicle Emission Inspection Procedures. February 28, 1975.

10. Rubenstein, et al., op. cit.

11. Midurski, T. P., et al. Evaluation of Motor Vehicle Emissions Inspection and Maintenance Programs in Wisconsin - Phase 3. Final Report. GCA Corporation, GCA/Technology Division, Bedford, Massachusetts. Prepared for U.S. Environmental Protection Agency, Region V Office, Chicago, Ill. Report No. EPA-905/2-78-004. November 1978.

SECTION 3

PROGRAM OPTION

OPTION DEFINITION

Based on a rather detailed review of several possible inspection and maintenance program (I/M) scenarios, the Minnesota Pollution Control Agency (MPCA) selected a specific configuration that appears to be best suited for implementation in the State. Essentially, the program selected involves establishing a network of centralized inspection stations where loaded mode emissions testing and stationary noise inspections will be conducted. The basic loaded mode, centralized facility concept was selected for several reasons. First, it was considered that the loaded mode option offers several advantages over the idle mode, including more comprehensive diagnostic capabilities, and more flexibility in testing procedures. Also, there will likely be an $NO_x$ standard defined in the near future for motor vehicles and $NO_x$ testing may become necessary as part of the I/M program; $NO_x$ testing can only be performed with the loaded or high idle test. Since the high idle test necessitates attaching tachometer leads to the engine, the throughput time for the loaded mode test is 20-30 percent less than for the high idle test. With the high idle test, therefore, additional test lanes would be required and the cost to the motorist would increase accordingly. The major disadvantage of the loaded mode test is that it is slightly more expensive than the regular idle test to perform (provided the throughput rates are the same*), since additional test equipment is required. The incremental cost difference, $0.20 to $0.25 per test, is not considered to be significant.

The primary reasons for selecting the centralized facility approach over private garages concerned program control and anticipated public acceptance of the program. Specifically, the State would be able to exercise much closer control over the inspection program with fewer personnel, which should result in a much higher quality program than would be achievable if the decentralized option were used. Further, it was considered that the public would be much less skeptical of a program where inspections were performed by an impartial entity who would not benefit from vehicles either failing or passing (primarily since repairs are not performed at the centralized facilities, nor are any individuals undergoing inspections considered "regular custormers" who could bias the inspector).

A number of additional elements must be defined in order to fully describe the program. The program is currently being considered for implementation in the following counties:

*The throughput rate for idle mode testing will depend on the pre-conditioning requirements adopted when Appendix N is finalized.

- Anoka County
- Carver County
- Dakota County
- Hennepin County
- Ramsey County
- Scott County
- Washington County

The inspection frequency has been defined as annual with inspections being staggered throughout the year. Generally, inspections will be scheduled to the extent that they should be performed within a certain time period prior to registration. A method that could be used is to forward registration renewal material to motorists, say, 60 days before the renewal deadline. In order for the motorist to renew his registration, a certificate of compliance would be required along with the registration form; this certificate of compliance would be obtained by successfully passing the emissions inspection (or being granted a waiver) at an inspection station. The 60-day lead time would assure adequate time to obtain an inspection and a reinspection if required.

The vehicle population to be tested consists essentially of all light-duty vehicles (LDV's), light-duty trucks (LDT's) with a gross vehicle weight (GVW) of 9,000 pounds or less, and motorcycles. Some exemptions will be made, however, including (tentatively):

- motor vehicles registered as classic, pioneer, or collector, pursuant to Minnesota Statutes, Section 168.10
- any motor vehicle that presents prohibitive inspection problems.

A stringency level (for emissions tests only) of 30 percent has been defined for this analysis. It has also been indicated that the program would operate on a mandatory inspection - voluntary repair basis during the first year. This will serve primarily to acquaint the public with the program as well as to gather baseline emissions and noise data from which cutpoints can be established.

Several supporting programs will also be established in conjunction with the I/M program. Included are programs for: (1) public information, (2) consumer protection, (3) quality assurance, and (4) mechanics' training. These programs may be operated by the State or portions of each may be operated by contractors. These ancillary programs are discussed in detail in Section 2.

INSPECTION SCENARIO

In order to illustrate how the I/M program will work and where some of the ancillary programs tie in, the following description of the test procedure is offered.

The requirements for an emissions inspection in each instance will be related to the annual registration procedure; that is, emissions inspections will be required generally during the period when registration renewals are due. To initiate the registration renewal process, the Division of Motor Vehicles will mail out registration renewal forms to motorists within the seven counties. Mailings will be staggered such that approximately one-twelfth of the total registrations are processed each month (slightly lower in winter months) approximately 2 months prior to the renewal deadline. Sometime during this 2-month period, motorists will take their vehicles to the centralized inspection facilities for the emissions test.

At the inspection station, the motorist will present his renewal forms, from which certain information will be collected and entered into a computer file. This information would include:

1. A serial number which allows the test record to be retrieved and identified with the computer;

2. Exact date and time of the test;

3. The vehicle identification number (VIN);

4. Vehicle registration number;

5. Vehicle model, year, and make;

6. Owner's name;

7. Engine configuration;

8. Emissions control equipment;

9. Vehicle weight class; and

10. Test number (first, second, third, etc.).

Based on this information, test personnel can determine whether or not the vehicle is exempt from the emissions inspection. If the vehicle is exempt, the noise emissions level is measured by placing a sound level meter near the tailpipe outlet while the engine speed is increased. Upon passing the noise test, the motorist is issued a certificate of compliance, which he submits along with other registration renewal forms to the Division of Motor Vehicles. Should the vehicle fail the noise test, the motorist is advised as to the likely causes (usually defective, inadequate, or inappropriate exhaust system components) and given a form stating that he has failed the test. The motorist is then required to have appropriate repairs made to the exhaust system at the repair facility of his choice; he then returns for a reinspection. Upon passing the reinspection, he is issued a certificate of compliance and the registration renewal process continues as usual.

If the vehicle is not exempt from the emissions inspection, it proceeds through the test lane where it is subjected to both the emissions and noise tests. Pass-fail criteria for both tests are automatically adjusted to the particular characteristics of the vehicle. If the vehicle passes both tests, the certificate of compliance is issued and the registration process continues. If the emissions and/or noise tests are failed, the motorist is advised of the likely problems and is given a form stating which portions of the tests the vehicle failed. The owner then takes the vehicle (and failure forms) to a repair station where appropriate repairs or adjustments are made. The mechanic completes a repair form indicating:

1. repair actions taken;
2. parts replaced;
3. cost of parts and labor; and
4. name and address of repair facility.

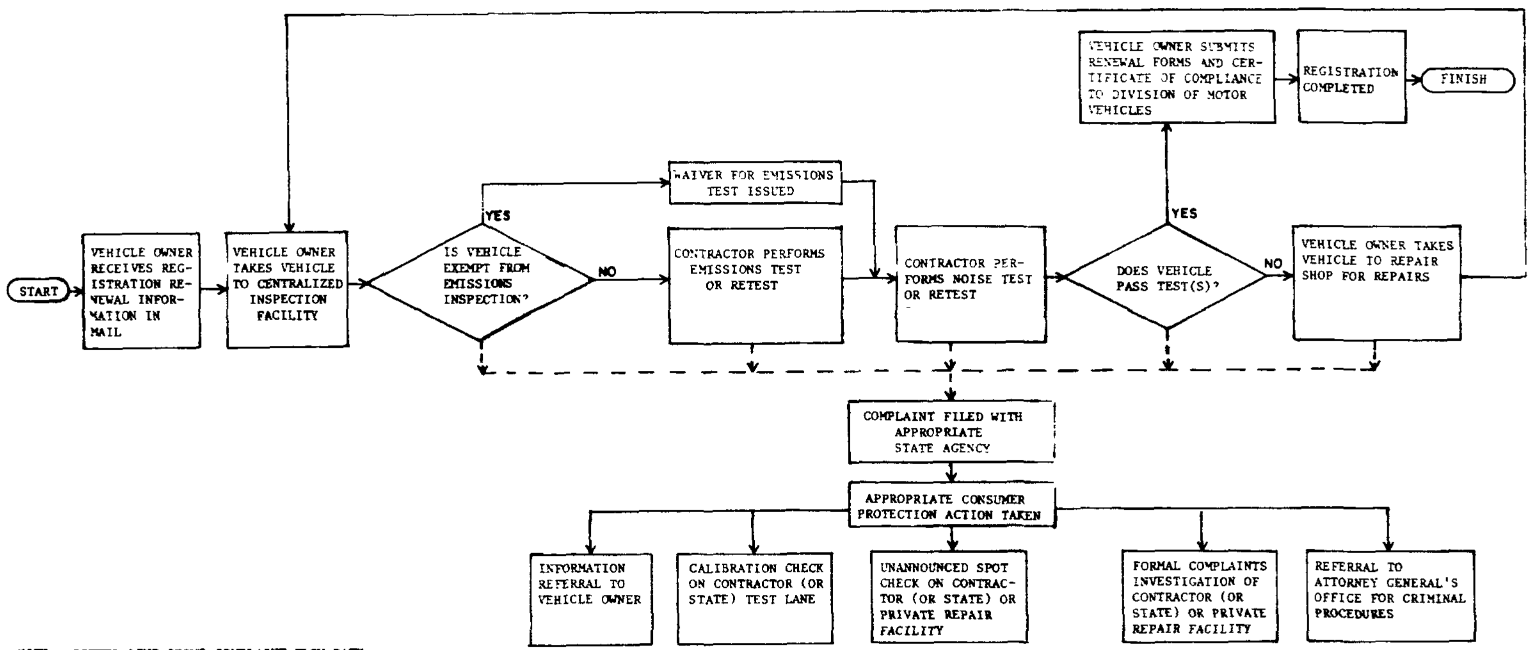
It is noted that for emissions-related repairs, the vehicle owner is obligated to spend only a certain amount of money before he is granted a waiver; the repair form substantiates that the motorist is eligible for a waiver. There has not been a limit placed on repairs required for noise compliance, however.

The vehicle owner then returns to the inspection facility with the repair form, and the vehicle undergoes the test that was previously failed. If it passes, a certificate of compliance is issued; if the repair ceiling was reached for emissions-related repair work, a waiver and annotated certificate of compliance are issued. The retest is performed free of charge.

If the vehicle fails the first retest, the vehicle owner is obliged to go through the repair and reinspection cycle once again; however, if the accumulated total of repair costs exceeds a specified repair cost limit, he may be granted a waiver as before. A fee will be charged for second (and subsequent) retests; this fee will be somewhat lower than the initial fee, however.

Should the motorist at any point in the above process have a complaint concerning either the inspection or the maintenance phase, he may register the complaint with the appropriate State agency by calling a toll-free "hotline" telephone number. Depending on the nature of the motorist's complaint, the hotline operators can take a variety of different actions in response. If the complaint is due to lack of information, the motorist can be referred to a public relations official who can provide more information about the program and its methods. If the complaint concerns actions of the contractor or questions the accuracy of the contractor's equipment, the operators refer the complaint to an appropriate official concerned with quality assurance. The Quality Assurance coordinator would decide upon the appropriate action; he could visit the test lane in question and check the calibration of its emissions analysis equipment, or have a complaints investigator conduct either an unannounced spot check or a formal investigation of the test lane in question. If the motorist's complaint concerns actions on the part of the private automotive repair industry, the operators refer the complaint to the designated consumer protection official or agency that has the authority to investigate consumer complaints concerning private garages. Should any complaint uncover criminal actions, then the operators could refer the complaint to the Attorney General's Office for criminal proceedings.

A general flow chart showing the registration process described above is provided in Figure 2.




NOTE DOTTED LINE SHOWS COMPLAINT FLOW PATH.

Figure 2. Motor vehicle inspection and registration flow chart.

## SECTION 4

## NETWORK AND PERSONNEL REQUIREMENTS

### INSPECTION NETWORK

Two determinants establish the basic inspection facilities requirement for any I/M program. These determinants include, first, the expected number of inspections to be performed annually, and, second, the average throughput rate for each inspection lane.

#### Annual Number of Inspections

The number of inspections that will be performed annually is a function of the affected vehicle population size within the area of concern, and the number of reinspections that are expected to be required. Further, the total number of annual inspections will change over time as a result of changes in the vehicle population.

In deriving the network requirements for the Minnesota program, several conditions were assumed. First, it was assumed that the program would start in early 1982, and, as a minimum, extend through 1987. The vehicle population, then, that was used as the basis for determining the number of facilities was the projected 1987 population in each of the seven affected counties. Also, it was assumed that only a small fraction of the total population of affected vehicles would require more than one reinspection; therefore, the basic computations reflect only the base population plus the expected number of first failures. These factors are discussed in detail below.

Motor Vehicles Population--
Data regarding the motor vehicle and human populations for each of the seven counties were obtained from the Department of Public Safety, Division of Motor Vehicles, and the Twin Cities Metropolitan Council, respectively. These data included tabulations of the 1970 and 1978 human populations, and the numbers of vehicles by various categories registered in 1977.

To develop an estimate of the number of vehicles that would be inspected in 1987, both the population and registration data were used. First, the average annual growth rate for each county from 1970 to 1978 was established. Table 9 shows both the populations and the growth rates.

TABLE 9. AVERAGE ANNUAL GROWTH FACTORS, HUMAN POPULATION, 1970-1978

| County | 1970 population | 1978 population | Average annual growth factor |
|---|---|---|---|
| Anoka | 154,712 | 197,780 | 1.0312 |
| Carver | 28,331 | 37,250 | 1.0348 |
| Dakota | 139,808 | 192,870 | 1.0410 |
| Hennepin | 960,080 | 939,060 | 0.9972 |
| Ramsey | 476,255 | 466,840 | 0.9975 |
| Scott | 32,423 | 44,540 | 1.0405 |
| Washington | 83,003 | 112,610 | 1.0389 |
| Total | 1,874,612 | 1,990,950 | |

These average annual growth factors were then applied to the 1978 county population to arrive at an estimate of the 1987 populations in each county, which is tabulated in Table 10 below.

TABLE 10. PROJECTED POPULATION BY COUNTY FOR 1987

| County | Projected population in 1987 |
|---|---|
| Anoka | 260,800 |
| Carver | 50,700 |
| Dakota | 276,900 |
| Hennepin | 915,700 |
| Ramsey | 456,400 |
| Scott | 63,700 |
| Washington | 158,800 |
| Total | 2,183,300 |

Motor vehicle registration data were used to derive a tabulation of the number of vehicles (of the types that would be required to undergo inspection) registered in each county during 1977. Also, the population data for 1978 were adjusted to reflect 1977 conditions; this permitted the establishment of the ownership rates (expressed in vehicles per capita) of inspectable vehicles for each county. These data are shown in Table 11.

TABLE 11. DERIVATION OF VEHICLE OWNERSHIP RATES DURING 1977 BY COUNTY

| County | Number of inspectable vehicles registered in 1977* | Population in 1977† | Ownership rates (vehicles/capita) |
|---|---|---|---|
| Anoka | 75,998 | 191,796 | 0.40 |
| Carver | 17,434 | 31,165 | 0.56 |
| Dakota | 90,745 | 185,274 | 0.49 |
| Hennepin | 544,900 | 941,414 | 0.58 |
| Ramsey | 252,717 | 468,010 | 0.54 |
| Scott | 20,849 | 42,806 | 0.49 |
| Washington | 49,543 | 108,393 | 0.46 |
| Total | 1,052,186 | 1,968,858 | 0.53 |

*Source: Department of Public Safety, Division of Motor Vehicles.

†Derived from 1978 population and growth factors presented in Table 9.

The ownership rates, then, were applied to the 1987 population estimates provided in Table 10 to arrive at a preliminary estimate of the 1987 inspectable vehicle population; this is presented in Table 12. It is noted that the ownership rate has been increasing from year to year, and conversations with planners at the Metropolitan Council indicate that by 1987, the overall ownership rate for the entire seven county area is likely to be approximately 0.60; this translates to a total of 1,309,800 vehicles compared with the 1,156,900 vehicles indicated for an ownership rate of 0.53. The final total number of vehicles in each county that will be inspected during 1987 was derived from the total for each county shown in Table 12, plus a portion of the additional vehicles resulting from the increased ownership rate. The number of additional vehicles added in each county is calculated as a function of the ratio of the particular county's vehicle population to the total seven-county vehicle population presented in Table 12. The resulting distributions are presented in Table 13.

Number of Reinspections Required--

By definition, the tentative failure rate for the Minnesota program is 30 percent. Also, the inspection frequency has been defined as annual. With these two parameters defined and the 1987 inspectable vehicle population identified, the total number of annual inspections can be calculated. This is simply:

$$N_i = P_i (1 + r)$$

TABLE 12. PROJECTED 1987 COUNTY VEHICLE POPULATIONS* BASED ON AN OVERALL OWNERSHIP RATE OF 0.53

| County | 1987 Population | Ownership rate (vehicles/capita) | Projected 1987 vehicle population |
|---|---|---|---|
| Anoka | 260,800 | 0.40 | 104,320 |
| Carver | 50,700 | 0.56 | 28,392 |
| Dakota | 276,900 | 0.49 | 135,681 |
| Hennepin | 915,700 | 0.58 | 531,106 |
| Ramsey | 456,400 | 0.54 | 246,456 |
| Scott | 63,700 | 0.49 | 31,213 |
| Washington | 158,800 | 0.46 | 73,048 |
| Total | 2,183,000 | 0.53 | 1,150,216 |

*Inspectable vehicles only.

## TABLE 13. PROJECTED 1987 COUNTY VEHICLE POPULATIONS* BASED ON AN OVERALL OWNERSHIP RATE OF 0.60

| County | 1987 vehicle population assuming 0.53 ownership rate | | Additional vehicles reflecting 0.60 ownership rate† | 1987 vehicle population assuming 0.60 ownership rate‡ |
|---|---|---|---|---|
| | No. vehicles* | Percent of 7-county total | | |
| Anoka | 104,320 | 9.1 | 14,522 | 118,842 |
| Carver | 28,392 | 2.5 | 3,990 | 32,382 |
| Dakota | 135,681 | 11.8 | 18,831 | 154,512 |
| Hennepin | 531,106 | 46.2 | 73,728 | 604,834 |
| Ramsey | 246,456 | 21.4 | 34,150 | 280,606 |
| Scott | 31,213 | 2.7 | 4,309 | 35,522 |
| Washington | 73,048 | 6.3 | 10,054 | 83,102 |
| Total | 1,150,216 | 100.0% | 159,584 | 1,309,800 |

*From **Table 12**.

†Computed as: $V_i = P_i \left( \Sigma_i^{n=7} V_{0.60} - \Sigma_i^{n=7} V_{0.53} \right)$

where $V_i$ = the number of additional vehicles for county i;

$P_i$ = the percentage of the total 7-county vehicle population registered in county i;

$V_{0.60}$ = 1,309,800 = the total 7-county vehicle population assuming an ownership rate of 0.60;

$V_{0.53}$ = 1,150,216 = the total 7-county vehicle population assuming an ownership rate of 0.53.

‡Computed as the sum of the 1987 vehicle population assuming ownership rate = 0.53, plus $V_i$.

where $N_i$ = the number of inspections to be performed in year i;

$P_i$ = the inspectable vehicle population for year i; and

r = the failure rate, defined here as 0.30.

Substituting specific values of P for each county, then, yields the total number of inspections that will be performed for the year of interest, which, in this instance, is 1987. Table 14 summarizes these computations.

TABLE 14. TOTAL NUMBER OF ANNUAL INSPECTIONS DURING 1987 BY COUNTY

| County | Number of initial inspections | Number of reinspections | Total annual inspections |
|---|---|---|---|
| Anoka | 118,842 | 35,653 | 154,495 |
| Carver | 32,382 | 9,715 | 42,097 |
| Dakota | 154,512 | 46,354 | 200,866 |
| Hennepin | 604,834 | 181,450 | 786,284 |
| Ramsey | 280,606 | 84,182 | 364,788 |
| Scott | 35,522 | 10,657 | 46,179 |
| Washington | 83,102 | 24,931 | 108,033 |
| Total | 1,309,800 | 392,942 | 1,702,742 |

## Inspection Facility Capacity

The annual capacity of a contractor operated emission inspection lane can be calculated given the vehicle throughput time, an efficiency factor to account for random arrival of vehicles, equipment downtime, etc., and the number of hours that the facility will be operated annually. The throughput time for loaded mode emissions testing is 2 minutes (see Section 2, Selection of Test Mode); and based on other I/M programs, facilities of this type operate at approximately 67 percent efficiency. If it is assumed that the facilities will be open 40 hours per week, 52 weeks per year, the annual capacity of each inspection lane can be calculated as:

$$\text{Capacity} = \left(\frac{1 \text{ inspection}}{2 \text{ minutes}}\right)\left(\frac{60 \text{ min}}{\text{hour}}\right)\left(\frac{40 \text{ hours}}{\text{week}}\right)\left(\frac{52 \text{ weeks}}{\text{year}}\right)\left(0.67\right) = 41{,}808 \ \frac{\text{inspections}}{\text{year}}$$

## Derivation of the Network Requirements

The procedure for deriving the number of inspection lanes required in each county is to merely divide the total number of annual inspections required by the lane capacity; the number of inspections for 1987 is presented in Table 14 and it was stated previously that the annual capacity for each lane is 41,808 vehicles per year. Table 15 below, presents the results of these computations.

TABLE 15. INSPECTION LANE REQUIREMENTS BY COUNTY

| County | Total annual inspections during 1987 | Number of inspection lanes required |
|---|---|---|
| Anoka | 154,495 | 4 |
| Carver | 42,097 | 2* |
| Dakota | 200,866 | 5 |
| Hennepin | 786,284 | 19 |
| Ramsey | 364,788 | 9 |
| Scott | 46,179 | 2 |
| Washington | 108,033 | 3 |
| Total | 1,702,742 | 44 |

*From a practical standpoint, one lane could accommodate this demand, however, two will be used since the desire is to be somewhat liberal in deriving the network requirements and associated costs.

Not only must the number of individual lanes be calculated, but also the number and tentative locations of the inspection stations must be determined as well. These basic criteria are used in deriving the number and location of inspection facilities; viz:

- owing to difficulties often experienced in locating and purchasing larger land parcels, the maximum facility size is assumed to be six lanes;
- owing to diseconomies associated with small facilities, the minimum number of lanes for any facility is assumed to be two; and
- the basic intent is to locate facilities in or near the population centers to minimize travel distances and associated inconveniences.

Based generally on the above-mentioned guidelines, the inspection network presented in Table 16 was developed.

## PERSONNEL REQUIREMENTS

The personnel requirements for an I/M can be defined in terms of operating personnel - those persons directly involved in or supporting the actual inspection process - and administrative personnel - those persons involved in the management of the program as well as those involved in support programs such as quality assurance, consumer protection, enforcement, etc. The requirements for both types of personnel are discussed separately in the following paragraphs.

### Operating Personnel

The basic operating personnel requirements were derived based on both an analysis of the tasks involved in conducting the actual inspections (from time-motion studies by AVCO and Hamilton Test Systems), and from the experiences of I/M programs currently in operation. The general operating personnel structure to be utilized by the State of Minnesota for the program being assessed here is summarized as:

- One manager and one assistant manager per facility;
- Three inspectors per test lane; and
- One maintenance/calibration person for every 10 lanes.

Applying these personnel requirements to the inspection network developed in Table 16, results in the operating personnel requirements shown in Table 17.

### Administrative Personnel

The following provides a description of the proposed administrative structure here. This structure, consisting of both State and contractor personnel, is based on an analysis of the specific tasks and responsibilities involved in implementing and operating an I/M program. While most of the personnel described here would be employed directly by the State or contractor, it is not likely that all positions would require new personnel; rather, it is quite likely that existing State personnel could assume some of the responsibilities.

#### State Personnel--

The basic organizational structure, shown in Figure 3, is organized under the Minnesota Pollution Control Agency (MPCA), which would hold ultimate responsibility for the program. Reporting to the MPCA would be the Administrator who would be responsible for operating the program in accordance with regulations established by the MPCA staff. MPCA staff would provide input to the administrator regarding policy decisions and would monitor the effectiveness of the program.

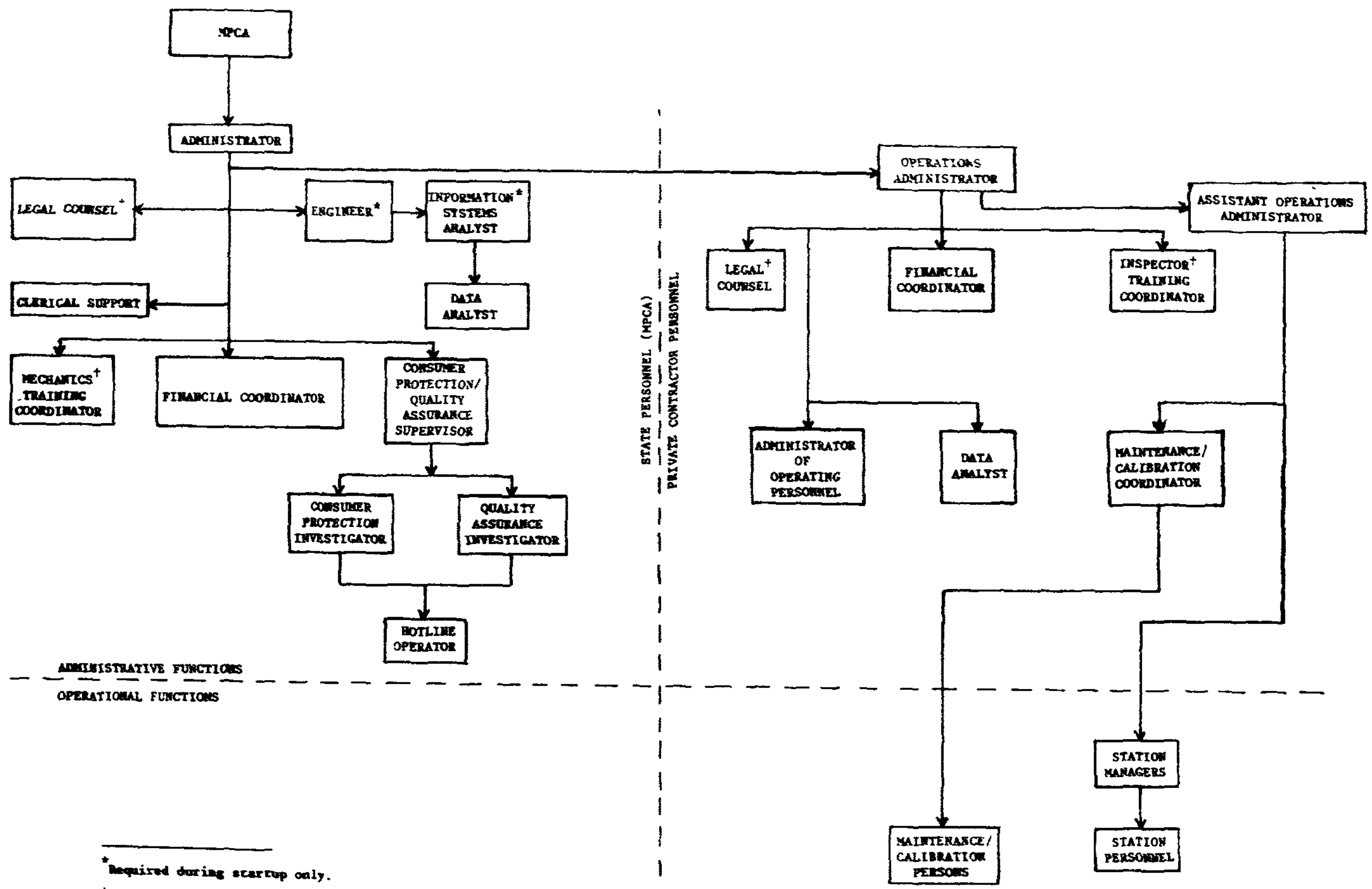
The administrator would be supported by Legal Counsel, as necessary. The function of Legal Counsel would be to advise the Administrator and MPCA on all matters concerning the legal aspects of the program. In all likelihood, this position would be filled as needed by existing staff lawyers within the State government structure.

TABLE 16. INSPECTION NETWORK REQUIREMENTS

| County | Facility configuration (number of lanes) | Suggested location |
|---|---|---|
| Anoka | 4 | Coon Rapids |
| Carver | 2 | Chaska |
| Dakota | 5 | West St. Paul |
| Hennepin | 4 | Minnetonka |
| | 6 | Minneapolis |
| | 3 | Brooklyn Park |
| | 6 | Bloomington |
| Ramsey | 6 | St. Paul |
| | 3 | Roseville |
| Scott | 2 | Shakopee |
| Washington | 3 | Stillwater |
| Total | 44 lanes | 11 facilities |

TABLE 17. OPERATING PERSONNEL REQUIREMENTS

| Position | Number of individuals required per lane or facilty | Number of lanes, facilities | Number of persons required |
|---|---|---|---|
| Facility Manager | 1 per facility | 11 facilities | 11 |
| Assistant Manager | 1 per facility | 11 facilities | 11 |
| Emissions Inspector | 3 per lane | 44 lanes | 132 |
| Maintenance/calibration persons | 1 per 10 lanes | 44 lanes | 5 |
| Total Operating Personnel | | | 159 |




*Required during startup only.

+Not a full-time position.

Figure 3. Suggested administrative structure.

An Engineer, who would be required primarily during the startup phase of the program, would be responsible for overseeing design and construction of inspection facilities, the selection of test equipment, and the development of data handling software.

The Mechanics' Training Coordinator would be responsible for establishing and implementing training programs for the repair industry. After startup, this position would probably not require full-time effort; rather an occasional effort would be required periodically during the actual operation of the program.

Responsibility for the program finances with respect to the State, would be held by the Financial Coordinator. This would likely not be a full-time position, and could perhaps be handled by existing State staff.

An Information Systems Analyst would be responsible for developing the software to be used in the overall data collection system. A Data Analyst, working in conjunction with his contractor counterpart (discussed later) would be responsible for providing the MPCA with periodic summaries concerning program operation (e.g., percent failures, second failures, emission characteristics of the inspectable fleet, etc.).

A Consumer Protection/Quality Assurance Supervisor would be required to administer the quality control and consumer protection aspects of the program. Subordinate to the coordinator would be two Investigators, one for quality assurance, one for consumer protection, and a Hotline Operator.

Contractor Personnel--

The contractor personnel would be headed by an Operations Administrator who would be responsible for management of the operational aspects of the program and for planning of future program operations.

The Operations Administrator would be supported by an Assistant Operations Administrator who would oversee station managers and the Maintenance/Calibration coordinators, as well as holding responsibility for day-to-day operation of the program.

Also subordinate to the Operations Administrator would be a Financial Coordinator and Legal Counsel having duties similar to their respective State counterparts.

The Inspector Training Coordinator would be responsible for the formulation and establishment of a comprehensive training program for all inspection station personnel employed by the contractor.

The Personnel Administrator would handle all matters directly involving any of the contractor's personnel. This administrator would also serve as liaison between station personnel and contractor management personnel, and would represent the employees in any labor disputes which might arise.

The Data Analyst would work in conjunction with the State in preparation of periodic reports on the program, and would be responsible for the daily data processing effort.

The Maintenance/Calibration Coordinator would oversee the maintenance/ calibration persons (described previously under operating personnel), and would hold ultimate responsibility for the repair and overall condition of all contractor equipment.

Administrative requirements for both State and Contractor personnel are summarized in Table 18. This table indicates the number of positions and the appropriate level of activity required during both the startup and operation phases of the I/M program. It should be noted that this is a suggested structure, and should be viewed as such.

TABLE 18. ADMINISTRATIVE PERSONNEL REQUIREMENTS

| Position | Requirement during startup phase | Requirement during operational phase |
|---|---|---|
| <u>State Personnel</u> | | |
| Administrator | 1 full-time | 1 full-time |
| Legal Counsel | 1 quarter-time | 1 as necessary |
| Clerical support | 2 full-time | 2 full-time |
| Mechanics' Training Coordinator | 1 full-time | 1 half-time |
| Financial Coordinator | 1 half-time | 1 full-time |
| Engineer | 1 half-time | - |
| Information Systems Analyst | 1 half-time | - |
| Consumer Protection/Quality Assurance Supervisor | 1 half-time | 1 full-time |
| Data Analyst | 1 quarter-time | 1 full-time |
| Consumer Protection Investigator | 1 as necessary | 1 full-time |
| Quality Assurance Investigator | 1 as necessary | 1 full-time |
| Hot-Line Operator | - | 1 full-time |
| <u>Contractor Personnel</u> | | |
| Operations Administrator | 1 full-time | 1 full-time |
| Assistant Operations Administrator | 1 full-time | 1 full-time |
| Legal Counsel | 1 as necessary | 1 as necessary |
| Clerical Support | 2 full-time | 2 full-time |
| Financial Coordinator | 1 full-time | 1 full-time |
| Inspector Training Coordinator | 1 half-time | 1 quarter-time |
| Personnel Administrator | - | 1 full-time |
| Data Analyst | 1 quarter-time | 1 full-time |
| Maintenance/Calibration Coordinator | 1 half-time | 1 full-time |

# SECTION 5

# COST ANALYSIS

## METHODOLOGY

In developing the cost analysis presented in this section, program elements were separated into specific cost categories. A thorough analysis of the program functions and elements was undertaken to assure that the costs presented reflect, as closely as possible, the actual costs that will be experienced when Minnesota implements the proposed program. However, it must be realized that while conservative assumptions were made whenever possible, considerable variation in the individual cost elements due to fluctuations in markets and the economy are inevitable.

All costs reported in this section, except where otherwise indicated, are in constant 1978 dollars (i.e., effects of inflation are assumed nonexistent). A separate break-even fee reflecting a 7 percent average annual inflation rate, however, was also derived. Analyses were performed to identify the individual costs associated for the several individual categories indicated in Table 19. The methodologies used in deriving these costs are discussed in the following paragraphs.

### Initial Capital Costs

These costs reflect the initial expenditures required for tangible items such as: purchasing and improving land, constructing the test facilities, and purchasing and installing test equipment, ancillary equipment, office equipment, and maintenance equipment. These items are categorized into three primary elements: building investments, land investments, and equipment costs.

#### Building Investments--

Building costs are dependent on specific designs and features utilized; therefore, unit costs (on a dollar per square foot basis) can be expected to vary somewhat. For the centralized facilities being considered here, a general design description was developed based on an analysis of the likely inspection tasks, equipment requirements, and the experiences of states currently operating similar facilities. The general building design, which reflects an attempt to minimize costs, calls for a clear span, metal structure, utilizing metal sandwich panel walls with normal wall and ceiling finish in administrative areas, and no wall or ceiling finish in the inspection areas. Items such as central heating and air-conditioning in the administrative areas and air exchange and forced hot air heaters in the inspection area are included. No provisions were made here for more specialized systems such as exhaust fume

TABLE 19. OUTLINE OF PROGRAM COST CATEGORIES AND ELEMENTS

| Primary category | Principal element | Items included |
|---|---|---|
| I. Initial Capital Costs | 1. Building investment | a. Construction cost |
| | 2. Land investment | a. Actual land cost<br>b. Pavement and landscaping |
| | 3. Equipment costs | a. Primary test equipment<br>b. Ancillary equipment<br>c. Office equipment/furniture<br>d. Maintenance equipment |
| II. One-Time Start-Up Costs | 1. Land acquisition | a. Site location studies<br>b. Title transfer costs |
| | 2. Facilities planning | a. Design study<br>b. Bid evaluation<br>c. Construction monitoring |
| | 3. Program design | a. Devlop equipment specifications<br>b. Develop subprograms (e.g., public information, surveillance, quality control, enforcement, etc.)<br>c. Define personnel organizatonal structure<br>d. Define data handling needs<br>e. Plan program effectiveness studies |
| | 4. Develop data handling systems software | |
| | 5. Personnel training | a. Inspectors<br>b. Managers<br>c. Quality control personnel<br>d. Mechanics training |
| | 6. Personnel salaries and overhead prior to start-up | |
| | 7. Initial public information program | |
| III. Annual Operating Costs | 1. Facility personnel | a. Wages, benefits, etc. |
| | 2. Maintenance | a. Equipment |
| | 3. Utilities/services/supplies | a. Electric<br>b. Heat<br>c. Insurance<br>d. Miscellaneous<br>e. Taxes |
| IV. Annual Administrative Costs | 1. Program administrative personnel | a. Wages, overhead |
| | 2. Enforcement | |
| | 3. Consumer protection/quality assurance | |
| | 4. Public information | |
| | 5. Training, licensing, certification | |

collectors; these are included in equipment costs under the general category of facility furnishings. The above description was submitted to several metal buildings manufacturers for their assessment of the likely costs. Based on the general design features and on general size requirements, a range of costs from $25.00 to $30.00 per square foot was derived. In order to reflect the most conservative case, the upper limit, $30.00 per square foot, was used in the cost computations presented here.

The Minnesota Pollution Control Association has indicated that the emission inspection may eventually be expanded to include safety and noise inspections as well. The facilities, therefore, are designed to accommodate the additional space requirements that would be imposed without additional construction. An analysis of the specific inspection tasks and equipment to be used was made to determine actual size and general feature requirements. Literature searches and interviews with persons involved in similar programs were conducted. A conceptual floor plan for the basic type of facility required for emission, safety, and noise testing resulted; this is presented in Figure 4. Initially, the facilities will be used primarily for emission inspections; Figure 4, however, includes equipment that would probably be included when the (expanded) program (i.e., safety and noise testing) is fully operational. The floor plan shows a single-lane facility; building area requirements for facilities ranging in size from one to six lanes are presented in Table 20.

The construction cost for each facility is computed as the product of (1) the building area, and (2) the unit cost, $30/square foot. The total cost for the network is the sum of costs of the individual facilities shown in Table 21. The total cost for the construction of all facilities is $6,120,450, and is presented, by county, in Table 22.

Land Investments--

A number of issues beyond the obvious one of land area are crucial in deriving an estimate for land costs. The unit cost of land, for example, is lot-specific to the extent that the per square foot cost may easily vary by a factor of 3 or more within any block, and by a factor of 10 or more within any municipality. Available lots may also be limited with respect to size requirements, necessitating the purchase of lots exceeding the general requirements, or even the purchase of unwanted structures. It is obvious, then, that a precise unit cost for land cannot be provided here. Alternatively, estimates were developed by various local assessors' offices, based on the general requirements in terms of zoning, access, lot-size, etc. for each municipality. These estimates, shown in Table 23, reflect mid-1978 average market values of available unimproved, commercially zoned land located generally within a major arterial corridor. Again, it must be noted that these estimates represent the average of a fairly wide range in actual unit costs.

Lot size requirements are a function of facility configurations. Specifically, a relationship of a 5:1 ratio of lot size to building size was developed based on queuing and likely zoning requirements. Since building area requirements have been derived previously in Table 20, land areas may be easily calculated.

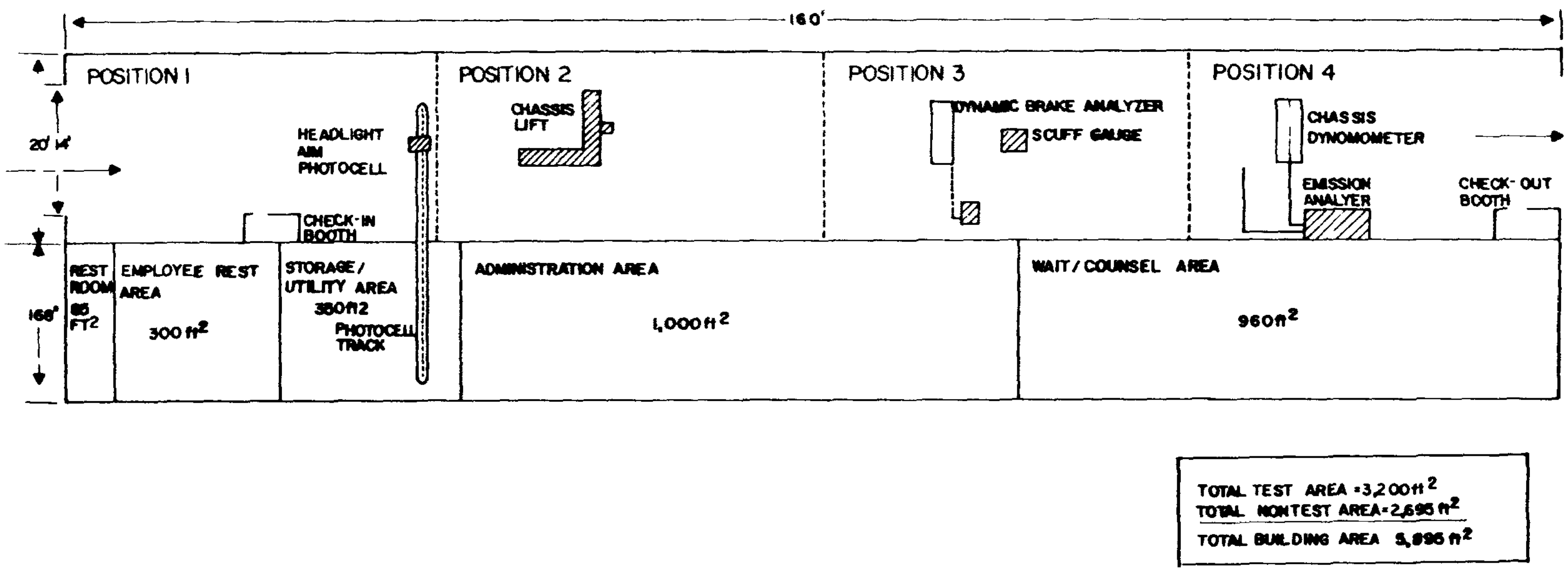



Figure 4. Conceptual floor plan for a combined safety and loaded-mode emission inspection facility.

TABLE 20. BUILDING FLOOR AREA REQUIREMENTS FOR VARIOUS FACILITY CONFIGURATIONS

| Lane configuration | Floor area required ($ft^2$) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Test area | Administration | Employee rest | Storage | Waiting | Restrooms | Total |
| 1 | 3,200 | 1,000 | 300 | 350 | 960 | 85 | 5,895 |
| 2 | 6,400 | 1,000 | 350 | 400 | 1,440 | 85 | 9,675 |
| 3 | 9,600 | 1,000 | 410 | 450 | 2,240 | 85 | 13,785 |
| 4 | 12,800 | 1,000 | 450 | 500 | 3,360 | 85 | 18,195 |
| 5 | 16,000 | 1,000 | 500 | 550 | 4,800 | 85 | 22,935 |
| 6 | 19,200 | 1,000 | 550 | 600 | 6,560 | 85 | 27,995 |

Note: GCA calculations, 1978, based on Formulae from Callender, J. A., Time Saver Standards for Architectural Design. McGraw-Hill, 1974.

TABLE 21. INSPECTION NETWORK REQUIREMENTS

| County | Municipality | Number of facilities | Configuration (lanes) |
|---|---|---|---|
| Anoka | Coon Rapids | 1 | 4 |
| Carver | Chaska | 1 | 2 |
| Dakota | West St. Paul | 1 | 5 |
| Hennepin | Minnetonka | 1 | 4 |
| | Minneapolis | 1 | 6 |
| | Brooklyn Park | 1 | 3 |
| | Bloomington | 1 | 6 |
| Ramsey | St. Paul | 1 | 6 |
| | Roseville | 1 | 3 |
| Scott | Shakopee | 1 | 2 |
| Washington | Stillwater | 1 | 3 |
| Total | | 11 | 44 |

TABLE 22. BUILDING COST ESTIMATES

| County | Facility configuration | Per facility cost, ($) | Number of facilities required | Total cost ($) |
|---|---|---|---|---|
| Anoka | 4-lane | 545,850 | 1 | 545,850 |
| Carver | 2-lane | 290,250 | 1 | 290,250 |
| Dakota | 5-lane | 688,050 | 1 | 688,050 |
| Hennepin | 6-lane | 839,850 | 2 | 1,679,700 |
| | 4-lane | 545,850 | 1 | 545,850 |
| | 3-lane | 413,550 | 1 | 413,550 |
| Ramsey | 6-lane | 839,850 | 1 | 839,850 |
| | 3-lane | 413,550 | 1 | 413,550 |
| Scott | 2-lane | 290,250 | 1 | 290,250 |
| Washington | 3-lane | 413,550 | 1 | 413,550 |
| Total | | | | 6,120,450 |

TABLE 23. UNIT COSTS FOR LAND IN THE SEVEN-COUNTY METROPOLITAN AREA

| County | Municipality | Cost range ($/ft$^2$) | Average cost ($/ft$^2$) | Source |
|---|---|---|---|---|
| Anoka | Coon Rapids | 0.50-2.00 | 1.25 | Anoka County Assessor's Office |
| Carver | Chaska | ~1.50 | 1.50 | Carver County Assessor's Office |
| Dakota | West St. Paul | 0.25-1.00 | 0.50 | Dakota County Assessor's Office |
| | Hastings | 0.25-0.50 | 0.30 | Dakota County Assessor's Office |
| Hennepin | Minneapolis | 3.00-5.00 | 4.00 | City of Minneapolis Assessor's Office |
| | Suburbs | 3.00-4.00 | 3.50 | City of Minneapolis Assessor's Office |
| Ramsey | St. Paul (fringe) | 0.70-1.50 | 1.00 | Ramsey County Assessor's Office |
| Scott | Shakopee | 1.00-4.00 | 2.00 | City of Shakopee Assessor's Office |
| Washington | Stillwater | 1.90-2.10 | 2.00 | Washington County Assessor's Office |

Land improvements are included in this cost category. The primary improvements involve landscaping and paving. Estimates obtained from various landscape architectural firms indicate that the unit costs for black-top paving and standard finish landscape are approximately $0.80 per square foot and $0.25 per square foot, respectively. Total land investments for the inspections network derived previously, including improvements, are presented in Table 24.

Equipment Costs--

The major equipment items required to operate a loaded-mode emissions inspection facility were identified based on an analysis of the inspection task requirements, and conversations with individuals currently involved in these types of inspection programs. It is assumed that equipment required to perform the safety aspect of the program will not be purchased until the expansion to include these inspections occurs. This will ensure that the most recent state-of-the-art equipment be purchased.

The equipment cost estimates used in this study were based primarily on interviews with manufacturers' representatives. These interviews focused on identifying the most appropriate type and model for various major items and determining the general level of skill required to operate each. The item of most interest is the emission analyzer itself. There is an extremely wide range of such equipment on the market today. At one end of the spectrum are "garage level" analyzers, generally costing about $3,000 or less; at the other extreme are laboratory grade analyzers, costing in excess of $75,000, that are much more sophisticated than is necessary for application here. The emission analyzers that are suited for centralized lanes have the following general features: (1) to decrease purge-time to a level acceptable for a high volume application, the analyzer has refrigerated bath and filtration capabilities not available in a garage analyzer; (2) to eliminate $CO_2$ and $H_2O$ interference, the centralized lane analyzer has dual detector capabilities; (3) to allow computer tie-in, the analyzer is capable of linearized output; (4) to correct for high and variable ambient concentrations of HC and CO, "flowing reference cells" are included.

Specifications of a typical analyzer for centralized facilities use are presented in Table 25. These specifications are provided for use as a guideline in selecting analyzers and are not intended to be used as "minimum" standards. This information was obtained from Horiba Instruments, Incorporated, Irvine, California.

Outlined in Table 26 are the equipment requirements and associated costs for a loaded-mode emission inspection program.

Equipment costs for any facility configuration, then, can be derived from Table 26. A summary of equipment costs as a function of facility configuration is shown in Table 27.

# TABLE 24. ESTIMATED LAND INVESTMENT REQUIREMENTS, BY COUNTY

| County | Municipality | Facilities required | Configuration | Lot size per facility (ft²) | Land cost per ft² ($) | Cost per facility ($) | Total raw land cost all facilities ($) | Total queue area, all facilities* (ft²) | Total parking area, all facilities+ (ft²) | Total paved area, all facilities (ft²) | Paving cost per ft² ($) | Total paving cost ($) | Landscaped area all facilities (ft²) | Landscaping cost per ft² ($) | Total landscaping cost ($) | Total improvements ($) | Total land investment ($) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anoka | Coon Rapids | 1 | 4-lane | 90,975 | 1.25 | 113,719 | 113,719 | 20,000 | 6,480 | 26,480 | 0.80 | 21,184 | 46,300 | 0.25 | 11,575 | 32,759 | 146,478 |
| Carver | Chaska | 1 | 2-lane | 48,375 | 1.50 | 72,563 | 72,563 | 10,000 | 3,240 | 13,240 | 0.80 | 10,592 | 25,460 | 0.25 | 6,365 | 16,957 | 89,520 |
| Dakota | W. St. Paul | 1 | 5-lane | 114,675 | 0.50 | 57,338 | 57,338 | 25,000 | 8,100 | 33,100 | 0.80 | 26,480 | 58,640 | 0.25 | 14,660 | 41,140 | 98,478 |
| Hennepin | Minnetonka | 1 | 4-lane | 90,975 | 3.50 | 318,413 | 318,413 | 20,000 | 6,480 | 26,480 | 0.80 | 21,184 | 46,300 | 0.25 | 11,575 | 32,759 | 351,172 |
| | Minneapolis | 1 | 6-lane | 139,975 | 4.00 | 559,900 | 559,900 | 30,000 | 9,720 | 39,720 | 0.80 | 31,776 | 72,260 | 0.25 | 18,065 | 49,841 | 609,741 |
| | Brooklyn Park | 1 | 3-lane | 68,925 | 3.50 | 241,238 | 241,238 | 15,000 | 4,860 | 19,860 | 0.80 | 15,888 | 35,280 | 0.25 | 8,820 | 24,708 | 265,946 |
| | Bloomington | 1 | 6-lane | 139,975 | 3.50 | 489,913 | 489,913 | 30,000 | 9,720 | 39,720 | 0.80 | 31,776 | 72,260 | 0.25 | 18,065 | 49,841 | 539,754 |
| Ramsey | St. Paul | 1 | 6-lane | 139,975 | 1.00 | 139,975 | 139,975 | 30,000 | 9,720 | 39,720 | 0.80 | 31,776 | 72,260 | 0.25 | 18,065 | 49,841 | 189,816 |
| | Roseville | 1 | 3-lane | 68,925 | 1.00 | 68,925 | 68,925 | 15,000 | 4,860 | 19,860 | 0.80 | 15,888 | 35,280 | 0.25 | 8,820 | 24,708 | 93,633 |
| Scott | Shakopee | 1 | 2-lane | 48,375 | 2.00 | 96,750 | 96,750 | 10,000 | 3,240 | 13,240 | 0.80 | 10,592 | 25,460 | 0.25 | 6,365 | 16,957 | 113,707 |
| Washington | Stillwater | 1 | 3-lane | 68,925 | 2.00 | 137,850 | 137,850 | 15,000 | 4,860 | 19,860 | 0.80 | 15,888 | 35,280 | 0.25 | 8,820 | 24,708 | 162,558 |
| Total | | 11 | 44 | | | | 2,296,584 | | | | | 233,024 | | | 131,195 | 364,219 | 2,660,803 |

*5,000 ft² per lane

+1,620 ft² per lane.

TABLE 25. GENERAL SPECIFICATIONS OF A TYPICAL I/M CENTRALIZED FACILITY EMISSION ANALYZER

| Item | Specifications/Comments | |
|---|---|---|
| Measuring Method: | NDIR, optical filter, dual source gas-filled capacitive type detector. | |
| Sensitivity: | 0.5% of full-scale analysis range | |
| Repeatability: | ±0.5% of full-scale with successive identical gas samples under the same physical conditions | |
| Zero Drift:* | less than 1% of full-scale/24 hrs | |
| Span Drift:* | less than 1% of full-scale/24 hrs | |
| Response Time (electrical):† | 0.5 to 15.5 seconds to 90% of full-scale in 120 switch selected increments | |
| Ambient Operating Conditions: | temperatures between $0^{o}C$ to $40^{o}C$ humidity - less than 95% RH | |
| Warm-Up Time: | 30 minutes to full accuracy | |
| Power Requirements: | 115 VAC (±10%) 60 Hz ±0.5 Hz | |
| Meter Readout Accuracy: | 5% of full scale | |
| Sample Gas Flow Rate: | 0.5 to 10 liters per minute | |
| Sample Gas Inlet Pressure: | 28.5 psig | |
| Interference From Co-existing Gases: | less than 1% of full scale | |
| Minimum/Maximum Measuring Range:‡ | Minimum | Maximum |
| CO (carbon monoxide) | 50 ppm | 100% |
| $CH_4$ (methane) | 100 ppm | 100% |
| $C_3H_8$ (propane) | 100 ppm | 100% |
| $C_6H_{14}$ (n-hexane) | 100 ppm | 5% |

* Drift performance specifications are based on ambient temperature variation of less than $10^{o}C$ over a 24-hour interval.

† Total analyzer response time is dependent on sample gas flow rate, sample cell length and electrical response time.

‡ Minimum Recommended Measuring Range is the full-scale concentration which may be measured with a 500 mm sample cell, response time of 0.5 seconds full-scale and a noise level of less than 0.5% of full-scale.

TABLE 26. MAJOR EQUIPMENT ITEMS REQUIRED FOR LOADED-MODE EMISSIONS TESTING

| Program element | Item | Remarks | Unit cost ($) |
|---|---|---|---|
| I. Emissions | 1. Chassis dynamometer | Needed for loaded-mode emission test. One unit per test lane required. Cost based on conversations with manufacturers (Clayton, Maxwell). | 14,000 |
| | 2. Emission analyzer | Since loaded-mode is used, analyzer should be capable of measuring CO, HC, and conversion to include $NO_x$. Extremely wide range in analyzer cost; cheaper analyzers found to be inadequate. Analyzers should be capable of being tied into computer data handling system. Costs based on discussions with manufacturers (Horiba Instruments, Hamilton Test Systems). One unit per test lane required. | 26,500 |
| II. Data System | 1. CRT Terminals | Two required per lane. Costs based on literature and discussions with manufacturer's representatives (Honeywell, Digital, Olivetti, Sperry Univac), and experiences of other states. | 2,500 |
| | 2. Minicomputer | One required per facility. Costs based on literature and discussions with manufacturer's representatives. (Honeywell, Digital). Equivalent in capabilities to Digital PDP-11-05. | 40,000 |
| III. Miscellaneous | 1. Facility Furnishings | Exhaust fume collectors, office furniture, miscellaneous furnishings. Cost based on experiences of similar programs in other States. | 40,000 |
| | 2. Miscellaneous tools | As required (per lane) | 1,000 |

TABLE 27. EQUIPMENT COSTS AS A FUNCTION OF FACILITY CONFIGURATION

| Number of lanes | Equipment costs ($) |
|---|---|
| 1 | 126,500 |
| 2 | 173,000 |
| 3 | 219,500 |
| 4 | 266,000 |
| 5 | 312,500 |
| 6 | 359,000 |

The total network cost for inspection equipment can be computed based on the number of facilities, by configuration, developed previously. These costs are presented in Table 28.

In addition to test equipment costs, three additional items must be included in the total network equipment costs: calibration vans and equipment, security systems, investigators' vans, and a central network computer.

One calibration van is required for each maintenance/calibration person. The personnel requirement for this position was previously derived in Section 4. It was determined that five maintenance/calibration persons would be required. Each van is equipped with a spare analyzer enabling a quick replacement of an analyzer which is found to be in need of repairs that cannot be performed at the inspection site. The cost summary is presented below:

| | |
|---|---|
| 1/2 ton light-duty van | $ 5,500 |
| Emission analyzer | 26,500 |
| Tools, gases, etc. | 1,000 |
| Total cost per van | $33,000 |

In addition, the quality assurance investigation would have a van identical to the calibration vans discussed above, costing $33,000. The consumer complaints investigator would have a car, estimated to cost $5,000.

The entire network would be tied into a central computer equivalent in capability to a Digital PDP-11-35. Cost estimates were obtained from several manufacturer's representatives, including Digital, Olivetti, Honeywell, and Sperry Univac, and an average cost of approximately $250,000 was derived.

Each facility should be equipped with security systems to protect against theft and/or vandalism. A contractor has suggested a cost of $1,100 per facility for purchase and installation of security systems. This translates to a total cost of $12,100 for the entire network. The total equipment cost estimate, itemized in Table 28, is $3,391,100.

The capital costs anticipated for the entire program are summarized in Table 29.

## One-Time Startup Costs

Implementation of an I/M program will require the expenditure of monies for noncapital services on a one-time basis prior to the actual commencement of inspections. Costs associated with this category are difficult to define at this point primarily because the elements involve services (planning, design, development, etc.), that are inherently more variable in cost than, for instance, equipment or building. Considerations used in developing cost estimates for each element are presented within the discussion of the individual estimates as follows.

### Land Acquisition--

Costs for land acquisition include expenditures for identifying and locating candidate sites, negotiating purchase price, and completing title transfers. It is estimated that site location and price negotiation would involve approximately 200 man-hours of professional technical time plus 40 man-hours of professional legal time for each site. To translate man-hours to actual cost figures, a $20 per hour and $50 per hour value were assigned to technical and legal hours, respectively; this translates to a total cost of $6,000 per site to cover location and price negotiation. Title transfers involve physical surveys, title searches, preparation of site plans, etc. The cost of these elements is estimated to be approximately 10 percent of the unimproved land value.

For the network being considered here, a total of 11 sites are required, representing a total unimproved land investment of $2,296,584. The cost for land acquisition, then, is calculated as follows:

$$(11\text{ sites})(\$6{,}000\text{ per site}) + (0.10)(\$2{,}296{,}584) = \$295{,}658$$

### Facilities Planning--

This element reflects the costs associated with engineering and design of the inspection facilities, bid review, and construction monitoring. The cost of these services is estimated to be a function of the total building cost. The total building cost for the alternative being evaluated here is estimated at $6,120,450. For building costs of this magnitude, facilities planning costs are estimated to be 10 percent of the total construction cost, or $612,045.

### Program Design--

This element reflects additional planning studies required to establish specific formats for the operation and administration of the inspection program as well as adjunctive programs such as public information, mechanics training, consumer protection, quality assurance, etc. A certain amount of

TABLE 28. EQUIPMENT COSTS FOR THE INSPECTION NETWORK

| County | Municipality | Facility configuration | Equipment cost ($) |
|---|---|---|---|
| Anoka | Coon Rapids | 4-lane | 266,000 |
| Carver | Chaska | 2-lane | 173,000 |
| Dakota | West St. Paul | 5-lane | 312,500 |
| Hennepin | Minnetonka | 4-lane | 266,000 |
| | Minneapolis | 6-lane | 359,000 |
| | Brooklyn Park | 3-lane | 219,500 |
| | Bloomington | 6-lane | 359,000 |
| Ramsey | St. Paul | 6-lane | 359,000 |
| | Roseville | 3-lane | 219,500 |
| Scott | Shakopee | 2-lane | 173,000 |
| Washington | Stillwater | 3-lane | 219,500 |
| Total testing equipment | | | 2,926,000 |
| Calibration vans and equipment (5 at $33,000) | | | 165,000 |
| Central Computer | | | 250,000 |
| Security Systems | | | 12,100 |
| Quality Assurance van and equipment | | | 33,000 |
| Consumer protection car | | | 5,000 |
| Total equipment cost | | | 3,391,100 |

TABLE 29. CAPITAL COST SUMMARY

| Category | Item | Item cost ($) | Category cost ($) |
|---|---|---|---|
| Building Investment | Construction | 6,120,450 | |
| Subtotal | | | 6,120,450 |
| Land Investment | Purchase | 2,296,584 | |
| | Paving | 233,024 | |
| | Landscaping | 131,195 | |
| Subtotal | | | 2,660,803 |
| Equipment Investments | Inspection equipment | 2,926,000 | |
| | Central computer | 250,000 | |
| | Calibration vans | 165,000 | |
| | Security systems | 12,100 | |
| | Investigators' vehicles | 38,000 | |
| Subtotal | | | 3,391,100 |
| Total | | | 12,172,353 |

variability is inherent here as at this time certain factors such as the extent of "in-house" effort that will be undertaken by Minnesota is unknown. In light of this, the estimate derivation focused primarily on the experiences of other states. Based on these experiences and an analysis of the likely requirements specific to Minnesota, an estimate of $100,000 was derived for program design.

Data Handling Software Development--

A comprehensive data handling software development package will be required to provide both basic recordkeeping and program analysis functions. In developing a cost estimate for this item, experiences of other states, conversations with representatives of data processing firms, and an analysis by our own staff were taken into consideration. Based on these discussions, experiences, and our analysis of the likely requirements specific to Minnesota, an estimate of $200,000 was developed for this element.

Personnel Training--

An intensive startup program as well as an ongoing effort will be required to train and certify the entire staff of inspectors, managerial, and maintenance/calibration personnel. A similar effort will be required to provide a mechanics training program to adequately prepare the repair industry for the maintenance phase of the program. This will be discussed separately.

One logical approach to accomplish this task would be to have managers and assistant managers trained as instructors, allowing for a continuation of the training program without the requirement of a full-time instructor. Managers would then be able to train new employees themselves as well as providing the initial training for the inspectors and calibration/maintenance personnel.

Cost estimates for training were developed based on information obtained from the Colorado State University Program. Derivation of the per person cost of training is shown in Table 30.

The operating personnel requirements were previously found to be:

- 11 facility managers
- 11 assistant managers
- 132 inspectors
- 5 maintenance/calibration persons.

Using these personnel requirements and the training costs from Table 5-12, the cost of training operating personnel can be computed as follows:

(11 managers)($74) + (11 assistant managers)($74)

+ (132 inspectors)($16) + (5 maintenance/calibration persons)($16) = $3,820.00

TABLE 30. ESTIMATED INSTRUCTION COST FOR INSTRUCTOR, INVESTIGATOR, AND INSPECTOR/MECHANIC TRAINING*

| Expenditure items | Training level | | | |
|---|---|---|---|---|
| | Central lane inspector‡ ($) | Emissions training instructor† ($) | State investigator† ($) | Private facility inspector/mechanic‡ ($) |
| Rent, insurance, utilities | 12 | 150 | 150 | 45 |
| Equipment | 50 | 150 | 150 | 60 |
| Teaching supplies | 110 | 120 | 120 | 110 |
| Instructor | 100 | 900 | 600 | 180 |
| Clerical | 50 | 160 | 160 | 50 |
| Total | 322 | 1,480 | 1,180 | 445 |
| Cost per person | 16 | 74 | 59 | 22 |

*High Altitude Vehicular Emission Control Program, Volume VIII. Pilot Training Program Results for Motor Vehicle Emission Control, Supplement II. August 1976. Colorado State University and GCA estimates.

†40 hours of training.

‡12 hours of training.

(continued)

TABLE 30. (continued)

ASSUMPTIONS:

- There are 20 students per class.
- There is one instructor per class, except where instructors are teaching instructors. Here, the recommended student/teacher ratio is 12:1; so the indicated cost is for 1.5 instructors.
- A $600.00 maximum figure is used for rent per month (this includes insurance and utilities). When this is broken down into smaller time periods, the rate is considered to be somewhat increased. If a building is owned or rent-free (as private repair stations may be), this figure would change. It is assumed that the contractor already owns the building for the costs undergone in training inspectors for the central lanes.
- The equipment cost given for the private repair stations is a cost-to-rent figure. If the equipment had already been purchased, the cost would change. It is assumed that the contractor has purchased the equipment needed. Therefore, this figure would only encompass electrical costs.
- The instructor cost for the contractor is the cost of a manager's time.
- For the contractor, it is assumed that one lane would be used, and emissions testing would be taught. If necessary, safety testing courses could be added at a later date.
- The teaching supplies are Colorado State University material, and would vary according to what has already been purchased by those in this field in Minnesota.
- The clerical costs will vary according to the extent of records kept as well as to whether an extensive testing system is established.

Personnel Salaries and Overhead--

The wage rates for operating and administrative personnel were derived from: "State of Minnesota Compensation Schedules," Minnesota Department of Personnel, July 5, 1978.

Salaries were matched with position class titles most closely fitting job descriptions of the positions previously defined. From the above source, wage scales (rounded to the nearest $500/year) were found to be:

- Managers, $16,000 per year or $1,333 per month
- Assistant Manager, $14,000 per year or $1,167 per month
- Maintenance/calibration persons, $13,000 per year or $1,083 per month
- Inspectors, $12,000 per year or $1,000 per month.

Based on U.S. Department of Labor and State data and on experiences of a contractor currently involved in a similar program in another state, a 25 percent overhead figure was added to the basic salaries.

Based on the experiences of other states' implementation of similar programs, the following schedule was derived:

- All managerial personnel will start 6 months prior to facilities opening;
- Inspectors will be phased-in 1 month prior to startup;
- Maintenance/calibration personnel will be phased-in 1 month prior to startup.

With these assumptions, the total startup cost for facility personnel can be computed:

$$\begin{aligned}&\Big[(11 \text{ managers})(\$1{,}333/\text{month})(6 \text{ months})\\&+ (11 \text{ assistant managers})(\$1{,}167/\text{month})(1 \text{ month})\\&+ (5 \text{ maintenance/calibration persons})(\$1{,}083/\text{month})(1 \text{ month})\\&+ (132 \text{ inspectors})(\$1{,}000/\text{month})(1 \text{ month})\Big]\ 1.25 \text{ overhead} = \$297{,}788\end{aligned}$$

The administrative personnel costs must also be included in the startup costs. The administrative personnel requirements for the startup phase are presented in Section 4. Based on these requirements and salaries from the Minnesota Department of Personnel, the costs associated with this item were calculated. This computation is shown in Table 31.

The total personnel cost for the startup phase, then, is the total of the operational (facility) personnel and the administrative personnel costs, or:

$$\$297{,}788 + 253{,}125 = 550{,}913$$

TABLE 31. ADMINISTRATIVE SALARIES AND OVERHEAD ASSOCIATED WITH PROGRAM STARTUP

| Job title | Salary Annual ($) | Salary Monthly ($) | Participation during startup (months) | Total salary during startup all positions ($) |
|---|---|---|---|---|
| State Personnel | | | | |
| Administrator | 25,000 | 2,083 | 12 | 25,000 |
| Legal Counsel | 15,500 | 1,292 | 3 | 3,875 |
| Clerical Support (2) | 9,000 | 750 | 12 (each) | 18,000 |
| Mechanics Training Coordinator | 15,000 | 1,250 | 12 | 15,000 |
| Financial Coordinator | 15,500 | 1,292 | 6 | 7,750 |
| Engineer | 15,000 | 1,250 | 6 | 7,500 |
| Information Systems Analyst | 15,500 | 1,292 | 6 | 7,750 |
| Consumer Protection/Quality Assurance Supervisor | 15,500 | 1,292 | 6 | 7,750 |
| Data Analyst | 14,000 | 1,167 | 3 | 3,500 |
| Consumer Protection Investigator | 12,500 | 1,042 | 3 | 3,125 |
| Quality Assurance Investigator | 12,500 | 1,042 | 3 | 3,125 |
| Total State Personnel Salaries | | | | 102,375 |
| Over head @ 25% | | | | 25,594 |
| Total State cost | | | | 127,969 |
| Contractor Personnel | | | | |
| Operations Administrator | 25,000 | 2,083 | 12 | 25,000 |
| Assistant Operations Administrator | 18,750 | 1,563 | 12 | 18,750 |
| Legal Counsel | 15,500 | 1,292 | 3 | 3,875 |
| Clerical Support (2) | 9,000 | 750 | 12 (each) | 18,000 |
| Financial Coordinator | 15,500 | 1,292 | 12 | 15,500 |
| Inspector Training Coordinator | 15,000 | 1,250 | 6 | 7,500 |
| Data Analyst | 14,000 | 1,167 | 3 | 3,500 |
| Maintenance/Calibration Coordinator | 16,000 | 1,333 | 6 | 8,000 |
| *Total Contractor Personnel Salaries* | | | | 100,125 |
| Overhead @ 25% | | | | 25,031 |
| Total Contractor Cost | | | | 125,156 |
| *Total Cost* | | | | 253,125 |

Public Information Program--

An intensive public information program will be required prior to program startup to assure public understanding and acceptance of the I/M concept. Experience thus far indicate that this effort should begin approximately 6 to 12 months prior to the commencement of operation. A preimplementation budget of $0.12 per vehicle to be inspected the first year has been suggested by a contractor from another state. From Section 4, it was found that approximately 1,179,000 vehicles will be required to pass inspection in 1982. This translates to $141,480 for the preimplementation public information program.

Mechanics Training Program--

A comprehensive mechanics training effort, similar to the previously discussed inspector training program, will be required to assure complete understanding of the repair industry regarding their responsibilities in connection with the maintenance aspects of the proposed I/M program. From the data presented in Table 30, a cost for training an individual mechanic was estimated to be $22.

The Minnesota Automotive Council estimates that there are approximately 1,900 repair facilities in the seven-county Minneapolis/St. Paul area. For the purposes of this cost estimate, it is assumed that 75 percent of these stations will send one mechanic to the training program. This translates to 1,425 mechanics at a cost of $31,350 during the startup phase of the program.

A summary of anticipated startup costs is presented in Table 32.

TABLE 32. SUMMARY OF INITIAL STARTUP COSTS

| Item | Cost ($) |
|---|---|
| Land Acquisition | 295,658 |
| Facilities Planning | 612,045 |
| Program Design | 100,000 |
| Data Handling Software Development | 200,000 |
| Personnel Training | 3,820 |
| Personnel Salaries and Overhead | 550,913 |
| Public Information | 141,480 |
| Mechanics Training | 31,350 |
| Total | 1,935,266 |

## Annual Operating Costs

Annual operating costs include all costs associated with the actual operation of the program. For the purposes of this cost analysis, the costs of adjunctive programs such as public information, inspector and mechanics training, etc., are included under "Annual Administrative Costs," which are discussed later.

Facility Personnel--

Annual costs associated with this category are a function of (1) the total number of individuals and relative levels of job responsibility, and (2) the per unit cost of wages and overhead.

The operating personnel requirements and wage scale were previously defined. The unit costs of salaries for each classification were derived from information supplied by the Minnesota Department of Personnel; and overhead estimates were based on U.S. Department of Labor and State data and from experiences of states operating similar programs. The overhead rate was found to be 25 percent of the basic hourly wage-rate.

Applying the facility staffing requirements to the appropriate wage and overhead rates associated with job classification, the annual personnel cost can be computed. This estimate is shown in Table 33.

TABLE 33. ANNUAL PERSONNEL COSTS FOR FACILITY PERSONNEL

| Job title | Total number of positions | Annual salary ($) | Total annual salary for all positions ($) |
|---|---|---|---|
| Manager | 11 | 16,000 | 176,000 |
| Assistant Manager | 11 | 14,000 | 154,000 |
| Maintenance/Calibration | 5 | 13,000 | 65,000 |
| Inspectors | 132 | 12,000 | 1,584,000 |
| Total salaries | | | 1,979,000 |
| Overhead @ 25 percent | | | 494,750 |
| | | | 2,473,750 |

Maintenance--

Costs associated with equipment maintenance reflect equipment repair and preventive maintenance expenditures. This item is best reflected as a function of the total equipment cost. Specifically, this cost is estimated at 20 percent of the original inspection equipment cost. Maintenance costs, then, can be computed as follows:

($2,926,000)(0.20) = $585,200

Utilities/Services/Supplies--

Included in this element are costs associated with electricity, insurance, inspection facility supplies, uniforms, calibration van operation, etc.

Utilities--Electric usage requirements were based on the experiences of other programs, and on discussions with equipment manufacturers' representatives.

For emission testing, in the absence of safety, usage rates were found to be 120 kWh/day for each lane, and 325 kWh/day for each facility. A per kilowatt-hour cost of electricity of $0.03 was obtained from Northern States Power. The annual cost, then, is calculated as follows:

(44 lanes)(120 kWh/day-lane)($0.03/kWh)(250 operating days/year)

+ (11 facilities)(325 kWh/day-lane)($0.03/kWh)(250 operating days/year)

= $66,413 annually.

Insurance--The facilities and associated equipment would most likely be covered by fire, theft, vandalism, and liability insurance. A contractor operating a similar program in another state has suggested an annual insurance cost of $1,500 per lane. This translates to $66,000 annually for insuring 44 lanes.

Computer Operation--Based on discussions with a contractor from another state, and with representatives from several data processing firms, an estimated central computer operating cost of $0.15 per test to be performed was derived. From Section 4 it was found that the average number of inspections to be performed annually will be 1,617,000 for 1982-1987. This translates to an annual cost of $242,550 for computer operation.

Inspection Forms--Inspection forms serve the purpose of reporting test results, providing diagnostic information (should repairs be necessary), and serving as the "certificate of compliance" for registration purposes. A cost of $0.03 per test has been suggested by a contractor from another State. This computes to a total cost of $48,510 annually for inspection forms.

Calibration Costs--The recurring annual cost of equipment calibration, in addition to the personnel salaries previously presented, is defined here as the cost of calibration gases plus the operating cost of the maintenance/calibration vans. The total annual calibration costs, outlined in Table 34, were found to total $53,700.

TABLE 34. ANNUAL CALIBRATION COSTS

| Item | Cost ($) |
|---|---|
| Calibration gases (20 sets/year @ $200/set) | 4,000 |
| Maintenance on equipment | 5,300 |
| Vehicle operations cost ($0.12/mile @ 12,000 miles/yr) | 1,440 |
| Cost per van | 10,740 |
| × vans required | 5 |
| Total | 53,700 |

Taxes--The contractor would be required to pay real estate and personal property taxes on real property. Tax rates were obtained from the Minnesota Department of Revenue. Annual taxes are calculated in Table 35.

Uniforms--Each facility employee is assumed to be furnished with a set of uniforms. From discussions with uniform suppliers, an annual cost per employee of $125.00 was derived. This translates to a total annual cost of $19,875 for a total of 159 uniformed employees.

The total annual costs for utilities/services/supplies are summarized in Table 36.

TABLE 36. ANNUAL COSTS FOR UTILITIES, SERVICES, AND SUPPLIES

| Item | Annual cost ($) |
|---|---|
| Utilities | 66,413 |
| Insurance | 66,000 |
| Computer Operation | 242,550 |
| Inspection Forms | 48,510 |
| Calibration Costs | 53,700 |
| Taxes | 599,219 |
| Uniforms | 19,875 |
| Total | 1,096,267 |

## Annual Administrative Costs

Costs in this category reflect the overall program administration effort. These costs include salaries and overhead of personnel involved in areas such as program administration, consumer protection, quality assurance, public information, etc. Also, the costs associated with operation of investigators vehicles are included in this category.

Program Administrative Salaries and Overhead--

Costs in this category are computed from the personnel requirements, salaries, overhead rate, and level of participation, which were delineated previously. The annual cost computation is shown in Table 37.

Vehicle Operating Costs--

The quality assurance investigator and the consumer protection investigator will each require a vehicle and equipment. Assuming an operating cost of $0.15 per mile and annual travel of 12,000 miles, the yearly operating cost for the two vans may be calculated:

TABLE 35. ANNUAL TAXES

| Location | | Facility configuration | Value of taxable property ($) | Assessment ratio | Tax rate (mills) | Annual taxes ($) |
|---|---|---|---|---|---|---|
| County | Municipality | | | | | |
| Anoka | Coon Rapids | 4-lane | 958,328 | 0.43 | 101.410 | 41,789 |
| Carver | Chaska | 2-lane | 552,770 | 0.43 | 118.830 | 28,245 |
| Dakota | West St. Paul | 5-lane | 1,099,028 | 0.43 | 95.223 | 43,586 |
| Hennepin | Minnetonka | 4-lane | 1,163,022 | 0.43 | 109.088 | 54,555 |
| | Minneapolis | 6-lane | 1,808,591 | 0.43 | 130.092 | 101,172 |
| | Brooklyn Park | 3-lane | 898,996 | 0.43 | 105.301 | 40,706 |
| | Bloomington | 6-lane | 1,738,604 | 0.43 | 105.416 | 78,809 |
| Ramsey | St. Paul | 6-lane | 1,388,666 | 0.43 | 131.026 | 78,239 |
| | Roseville | 3-lane | 726,683 | 0.43 | 109.998 | 34,371 |
| Scott | Shakopee | 2-lane | 576,957 | 0.43 | 125.250 | 31,073 |
| Washington | Stillwater | 3-lane | 795,608 | 0.43 | 118.840 | 40,657 |
| Additional Equipment | | - | 465,100 | 0.43 | 130.092* | 26,017 |
| Total | | | | | | 599,219 |

*Additional equipment assumed housed in Minneapolis.

TABLE 37. ANNUAL ADMINISTRATIVE PERSONNEL COSTS

| Position | Salary Annual ($) | Salary Monthly ($) | Participation annually (months) | Total salary for participation annually ($) |
|---|---|---|---|---|
| State Personnel | | | | |
| Administrator | 25,000 | 2,083 | 12 | 25,000 |
| Legal Counsel | 15,500 | 1,292 | 3 | 3,875 |
| Clerical Support (2) | 9,000 | 750 | 12 (each) | 18,000 |
| Mechanics Training Coordinator | 15,000 | 1,250 | 6 | 7,500 |
| Financial Coordinator | 15,500 | 1,292 | 12 | 15,500 |
| Consumer Protection/Quality Assurance Supervisor | 15,500 | 1,292 | 12 | 15,500 |
| Data Analyst | 14,000 | 1,167 | 12 | 14,000 |
| Consumer Protection Investigator | 12,500 | 1,042 | 12 | 12,500 |
| Quality Assurance Investigator | 12,500 | 1,042 | 12 | 12,500 |
| Hot-Line Operator | 9,000 | 750 | 12 | 9,000 |
| Total State Personnel Salaries | | | | 133,375 |
| Overhead @ 25% | | | | 33,344 |
| Total State Cost | | | | 166,719 |
| Contractor Personnel | | | | |
| Operations Administrator | 25,000 | 2,083 | 12 | 25,000 |
| Assistant Operations Adeministrator | 18,750 | 1,563 | 12 | 18,750 |
| Legal Counsel | 15,500 | 1,292 | 3 | 3,875 |
| Clerical Support (2) | 9,000 | 750 | 12 (each) | 18,000 |
| Financial Coordinator | 15,500 | 1,292 | 12 | 15,500 |
| Inspector Training Coordinator | 15,000 | 1,250 | 3 | 3,750 |
| Personnel Administrator | 15,000 | 1,250 | 12 | 15,000 |
| Data Analyst | 14,000 | 1,167 | 12 | 14,000 |
| Maintenance/Calibration Coordinator | 16,000 | 1,333 | 12 | 16,000 |
| Total Contractor Personnel Salaries | | | | 129,875 |
| Overhead @ 25% | | | | 32,469 |
| Total Contractor Cost | | | | 162,344 |
| Total Cost | | | | 329,063 |

(2 vehicles)(12,000 miles/vehicle)($0.15 per mile) = $3,600

Public Information--
Although the actual annual expenditure for public information can only be determined by State officials on a yearly basis, experiences thus far with I/M indicate that a strong, continuous effort is required. A contractor from another state has suggested $0.12 per test as a reasonable estimate of the anticipated expenditure. Between 1982 and 1987, an average of 1,617,000 inspections will be performed annually. This translates to $194,040 as the annual cost of public information.

Personnel Training--
This element reflects the ongoing requirement to train new operating personnel. The replacement rate, percent of work-force "turned-over" annually, is estimated to be 10 percent annually, based on experiences of other states. This translates to 16 new employees per year or $256 annually.

## Summary

The total cost for the entire program is itemized in Table 38.

## FEE COMPUTATION

### Annualized Costs

In order to derive a "break-even fee," all costs found in Table 38 are converted into annual figures. The steps involved in calculating these annual costs are summarized below.

Initial Capital Costs--
The capital investment in equipment is assumed to yield equal benefits for each of 5 years and be fully depreciated thereafter. The interest rate, i, is the marginal return on capital in the absence of inflation. For the program being assessed here, i is assigned a value of 0.06.

In annualizing equipment costs, the following formulae are employed. The net present value (NPV) of an investment that yields $1 of services for each of n years at a capital growth rate of i is:

$$NPV = \sum_{k=i}^{n} \frac{1}{(1+i)^k} = 1 - \left[(1+i)^{-n}\right] \Big/ i$$

Therefore, an investment of $1 will yield annual benefits of:
$\frac{1}{NPV} = \frac{1}{1-(1+i)^{-r}}$ for each of n years. Therefore, the amortized costs in constant dollars, is represented by $\frac{1}{NPV}$. The amortization factor for equipment, then, is: $\frac{0.06}{1-(1+0.06)^{-5}}$ or 0.2374.

TABLE 38. COST SUMMARY

| | Primary category | | Principal element | Element cost ($) | Total category cost ($) |
|---|---|---|---|---|---|
| I. | Initial Capital Costs | 1. | Building Investment | 6,120,450 | |
| | | 2. | Land Investment | 2,660,803 | |
| | | 3. | Equipment Costs | 3,391,100 | |
| | | | | | 12,172,353 |
| II. | One-Time Startup Costs | 1. | Land Acquisition | 295,658 | |
| | | 2. | Facilities Planning | 612,045 | |
| | | 3. | Program Design | 100,000 | |
| | | 4. | Software Development | 200,000 | |
| | | 5. | Personnel Training | 3,820 | |
| | | 6. | Personnel Salaries and Overhead | 550,913 | |
| | | 7. | Public Information | 141,480 | |
| | | 8. | Mechanics Training | 31,350 | |
| | | | | | 1,935,266 |
| | Total Capital and Startup Costs | | | | 14,107,619 |
| III. | Annual Operating Costs | 1. | Personnel Salaries and Overhead | 2,473,750 | |
| | | 2. | Maintenance | 585,200 | |
| | | 3. | Utilities/Services/Supplies | 1,096,267 | |
| | | | | | 4,155,217 |
| IV. | Annual Administrative | 1. | Personnel Salaries and Overhead | 329,063 | |
| | | 2. | Vehicle Operation | 3,600 | |
| | | 3. | Public Information | 194,040 | |
| | | 4. | Personnel Training | 256 | |
| | | | | | 526,959 |
| | Total Annual Costs | | | | 4,682,176 |

For buildings, the initial investment is assumed to yield a constant flow of capital services for 20 years and be fully depreciated thereafter.

Applying n = 20 to the above formula:

$$\frac{0.06}{1-(1+0.06)^{-20}} = 0.87$$

If structures are liquidated before 20 years, the sale price is assumed to be the capitalized flow of the remaining services. Therefore, a structure sold after j years will sell for:

$$\sum_{k=1}^{20-j} \left( \frac{i}{NPV\ (1+i)} \right)^k$$

for each dollar of initial investment. This assumption enables the use of the above amortization factor, $\frac{1}{NPV}$, without making further adjustments.

Land is assumed to yield a constant level of services in perpetuity ($n = \infty$ in the above formulae). Therefore, \$1 of investment yields i dollars of service per year. That is to say, without inflation, the resale value of land is unchanged from year to year, and the annual benefit (cost of capital services) is i times the original value of the land regardless of when liquidation occurs.

One-Time Startup Costs--

One-time startup costs, like capital costs, occur at the beginning of the project. However, these expenditrues do not yield a flow of services or have a resale value, as do capital investments. Startup costs can, however, be recovered over time. Since the ideal contract length for the program being assessed here is 5 years, a 5-year period of equal annual payments in constant dollars is assumed. Therefore, the annual cost of each dollar of startup cost is:

$$\frac{0.06}{1-(1+0.06)^{-5}} = 0.2374$$

Annual Operating and Administrative Costs--

These costs are presented as annual figures. To obtain total annual cost in constant 1978 dollars, the operating and administrative costs are added directly to the annualized startup and capital costs.

Fee Calculation, $f_c$--

A break-even fee, reflecting constant dollars, is calculated by dividing the total annualized costs by the number of paid inspections per year. This fee is designed to recoup all of the costs presented in Table 38.

Interest Rate and Constant Dollars--

All of the preceding calculations are performed in constant 1978 dollars. To get figures in actual dollars for years other than 1978, all annual costs, amortized costs, and fees must be increased by the amount of inflation since 1978.

The interest rate, i, reflects the real return on capital. Actual interest rates include compensation to offset the diminishing buying power of money as a result of inflation, and thus, are inappropriate here. In this study, we employ a conservative real rate of return on capital, 0.06. The exact rate would depend on the source of financing (i.e., debt, equity, or taxpayers' forgone investment).

Inflation--

The above-mentioned fee is in real (constant) dollars and must be adjusted for inflation. These adjustments will cover increased operating costs, as well as the difference between the market rate of interest and the real return on capital.

A second fee, $f_a$, is also calculated. This fee is uniform in actual dollars over time. In calculating this fee, an inflation rate $\rho$ must be assumed.* In this report, it is assumed that $\rho = 0.07$. For notational convenience, let r = market rate of interest and i = real return on capital ($r = i+\rho$). Then, for investments (capital costs and startup costs) an assumption of uniform capital services in actual dollars allows the use of the previous formulae for $\frac{1}{NPV}$ with r substituted for i.†

Annual operating and administrative costs must be transformed from constant to actual dollars. Actual annual cost is equal to the product of (1) constant annual cost and (2) a transformation factor, T; this transformation factor is determined from:

$$T = \frac{1}{\sum_{k=1}^{n}\left(\frac{1}{1+r}\right)} \sum_{k=1}^{n}\left(\frac{1+\rho}{1+r}\right)^{k} = \frac{r}{1-(1+r)^{-n}} \sum_{k=1}^{n}\left(\frac{1}{1+\frac{1+r}{1+\rho}-1}\right)$$

$$= \frac{r(1+\rho)}{1}\left(1 - \frac{(1+i/1+\rho)^{-n}}{1-(1+r)^{-n}}\right)$$

*It shall be noted that the first fee, $f_c$, was independent of $\rho$.

†Capital investments no longer yield uniform services, but now yield accelerated depreciation.

Therefore, when n, the number of years, equals 5, and i, the real rate of return on capital, = 0.06; then T, the transformation factor, equals 1.210.

Fee Calculation, $f_a$--

The fee, $f_a$, reflecting actual dollars, is calculated in a manner similar to the original fee, $f_c$. Annualized costs are summed and divided by the annual number of paid inspections to arrive at $f_a$. The annualized costs are presented in Tables 39 and 40 for constant 1978 dollars and actual (inflated) dollars, respectively.

Fee Calculation

Utilizing the methodology described above, two fees were calculated for the entire program. The first fee, $f_c$, reflects the annual cost in real (constant 1978) dollars. The second fee, $f_a$, reflects actual (inflated) dollars. Both fees were calculated assuming one free retest is provided for failed vehicles. Fees are shown in Table 41.

It should be emphasized here that the fees shown in Table 41 are break-even fees and therefore do not reflect the profit that the private contractor would make on each inspection. This profit would likely be negotiated between the State and contractor and would range in the area of 10 to 15 percent of the break-even fee.

Derivation of Second Reinspection Fees

Experience thus far with I/M indicates that not all vehicles entering into the maintenance phase of I/M will pass the resultant reinspection. In fact, those jurisdictions that currently have I/M programs are experiencing a re-inspection failure rate of roughly 25 percent.[1] This means that a motorist whose vehicle fails the initial emissions inspection has one chance in four of having to make at least one additional trip back to an inspection lane before his vehicle finally passes the emissions test. This equates to 7.5 percent of the entire motor vehicle population. In order to keep the costs to these motorists as low as possible, certain measures have been proposed by the MPCA. First, one free retest will be allowed for motorists whose vehicles fail the initial test (has been discussed previously). The second, addressed here, is the deviation of a separate fee for third (and subsequent) inspections.

Since 7.5 percent of the total motor vehicle population will fail the emissions test a second time, a reasonable figure to account for these vehicles plus subsequent refailures is assumed here to be 10 percent of the entire motor vehicle population. Based on the average of projected 1982 to 1987 populations (Section 4), this equates to approximately 124,400 additional inspections annually. Rather than assuming additional lanes will be constructed to accommodate these vehicles, a more cost-effective approach would be to assume, rather, that these vehicles will be reinspected within the proposed inspection network; the additional capacity can be gained by extending the hours of operation.

TABLE 39. ANNUALIZED COSTS IN CONSTANT (1978) DOLLARS

| | Cost category | Cost ($) | Amortization factor (i=0.06) | Annualized cost ($) |
|---|---|---|---|---|
| I. | Capital Costs | | | |
| | 1. Land | 2,660,803 | 0.06 | 159,648 |
| | 2. Buildings | 6,120,450 | 0.087 | 532,479 |
| | 3. Equipment | 3,391,100 | 0.2374 | 805,047 |
| II. | Startup Costs | 1,935,266 | 0.2374 | 459,432 |
| III. | Operating Costs | 4,155,217 | 1.0 | 4,155,217 |
| IV. | Administrative Costs | 526,959 | 1.0 | 526,959 |
| | Total | | | 6,638,782 |

TABLE 40. ANNUALIZED COSTS IN ACTUAL (INFLATED) DOLLARS

| | Cost category | Cost ($) | Amortization factor (i=0.06) | Annualized cost ($) |
|---|---|---|---|---|
| I. | Capital Costs | | | |
| | 1. Land | 2,660,803 | 0.13 | 345,904 |
| | 2. Buildings | 6,120,450 | 0.142 | 869,104 |
| | 3. Equipment | 3,391,100 | 0.284 | 963,072 |
| II. | Startup Costs | 1,935,266 | 0.284 | 549,616 |
| III. | Operating Costs | 4,155,217 | 1.210 | 5,027,813 |
| IV. | Administrative Costs | 526,959 | 1.210 | 637,620 |
| | Total | | | 8,393,129 |

TABLE 41. BREAK-EVEN FEES, CONSTANT (1978) AND ACTUAL (INFLATED) DOLLARS

| Fee type | Annualized costs ($) | Average number of paid inspections annually (1982-1987) | Fee ($) |
|---|---|---|---|
| $f_c$ (constant dollars) | 6,638,782 | 1,244,000 | 5.34 |
| $f_a$ (actual dollars) | 8,393,129 | 1,244,000 | 6.75 |

Since this network will already be in place, and the capital and startup costs already accounted for (in the first inspection fee), the additional cost for reinspecting (and re-reinspecting, etc.) these vehicles will appear in annual operating and annual administrative costs accountable to additional inspection hours required. Since the additional inspections concerned here are equal to 10 percent of the total inspections performed, it is reasonable to expect the additional cost needed to perform these inspections will be roughly 10 percent of the annual operating and administrative costs. By dividing the total additional cost by the number of affected vehicles, a subsequent reinspection breakeven fee may be obtained. These breakeven fees, in constant (1978) and actual (inflated) dollars are presented in Table 42.

REFERENCES

1. U.S. DOT. National Highway Traffic Safety Administration. Evaluation of Diagnostic Analysis and Test Equipment for Small Automotive Repair Establishments. A report to Congress. July 1978.

TABLE 42. BREAKEVEN FEES FOR SECOND (AND SUBSEQUENT) REINSPECTIONS IN CONSTANT (1978) AND ACTUAL (INFLATED) DOLLARS

| Fee type | Annual cost of performing second (and subsequent) reinspections, ($) | Average number of second (and subsequent) reinspections annually | Fee ($) | Percent of original breakeven fee |
|---|---|---|---|---|
| $f_c$ (constant dollars) | 474,003 | 124,400 | 3.81 | 70.6 |
| $f_a$ (actual dollars) | 573,544 | 124,400 | 4.61 | 67.6 |

## SECTION 6

## IMPLEMENTATION PLANNING

### INTRODUCTION

Owing to the nature of inspection and maintenance (I/M) programs, the implementation planning phase is extremely crucial with regard to overall program success. Implementation planning can be discussed in terms of coordinating and scheduling various efforts and activities such as securing necessary legislation and funds, selecting the particular operating mode (State-run or Contractor-operated), arranging for the selection of a contractor(s) to run and/or design the inspection facilities, etc.; in other words, coordinating all efforts aimed at getting the program from the conceptual stage to the operational phase. With regard to program success, a distinction can be made between success in terms of (1) accomplishing all those tasks that result in the program being operational by a specified deadline and designed and constructed to operate efficiently, etc.; and (2) the public's acceptance and recognition of the program as an important mechanism for achieving a cleaner environment. The types of planning that will enhance the success of the program in terms of the first definition concern physical planning (e.g., construction planning) while in terms of success from the viewpoint of public acceptance, the critical planning areas consider policy planning (e.g., gradual implementation, gradually increasing stringency factors, planning public information programs; in other words, planning activity that focuses on "selling" the program to the public). Both types of planning are considered in the following paragraphs.

In view of the relative importance of issues concerning scheduling and phase-in, it is appropriate to provide a discussion of these issues; it is not with the intention of deriving a detailed schedule for the implementation of the program, rather the purpose here is to provide an indication of some of the most critical factors in the scheduling and phase-in processes.

In this connection, three general types of issues can be considered. First, the U.S. Environmental Protection Agency has set policy guidelines that directly affect the schedule and phase-in requirements of the program. These concern primarily the dates when the program has to be implemented and operating fully. Second, there exists a general sequence to the efforts that will be undertaken in connection with implementing the program that, even though quite logical and perhaps very obvious, will be mentioned here for completeness. Third, there are several issues relating to either scheduling or phase-in that are quite subtle and have a potential impact on the program. These types of issues have been identified through discussions with individuals who have been involved in the implementation and/or operation of I/M programs and have the insights that are obviously gained through such experience.

IMMEDIATE ISSUES

The most immediate issues are those that require action of some sort by EPA, either in connection with the revised State Implementation Plan (SIP) or as a matter concerning the I/M program specifically. In that the I/M program is an element in the SIP, there is obviously a strong connection between SIP requirements and the tasks that must be accomplished immediately as part of the I/M effort. With regard to scheduling, EPA guidance defines several requirements concerning I/M that must be fulfilled prior to submitting the revised SIP; these can be seen in the following excerpt from an EPA policy memorandum dated 17 July 1978:

> "<u>The I/M Implementation Schedule</u>
>
> The specific items listed below must be included as a part of the States' I/M implementation schedules with specified dates for implementation of each item. The stringency planned for the program and other factors affecting the potential for emission reductions should also be indicated. Additional items if necessary because of local factors may be required by U.S. EPA Regional Offices.
>
> 1. Initiation (or continuation) of public information program including publicizing the I/M program in the media, meeting and speaking with affected interest groups, etc.
>
> 2. Preparation of a draft legislative package and submittal of legislation package to legislature if additional legislative authority is needed.
>
> 3. Certification of adequate legal authority by appropriate state official.
>
> 4. Initial notification of garages explaining program and schedule of implementation.*
>
> 5. Development and issuance of RFPs.*
>
> 6. Award to contractor(s).*
>
> 7. Initiation of construction of facilities.*
>
> 8. Completion of construction of facilities.*
>
> 9. Adoption of procedures and guidelines for testing and quality control including emission analyzer requirements (and licensing requirements for private garages, if applicable).*

*Indicates that items may apply to some I/M programs and not to others.

10. Notification of and explanation to garages of actions in Step 9.*

11. Completion of equipment specification, and purchase and delivery of equipment.

12. Development and adoption of cutpoints.

13. Initiation of hiring and training of inspectors <u>or</u> licensing of garages.*

14. Initiation of introductory program (voluntary maintenance with either voluntary or mandatory inspection) if not previously initiated.

15. Initiation of mechanics training and/or information program.

16. Initiation of mandatory inspection.

17. Initiation of mandatory repair for failed vehicles.

If certification of adequate legal authority occurs after January 1979, the States may modify previous commitments to implement and enforce the elements of the schedule to conform to the legal authority.* These modifications will be approved by the EPA Regional Offices and must be consistent with the Administrator's February 24, 1978, policy memorandum. The documents should be submitted by January 1, 1979. Any necessary adjustments to the schedule may be made at this time but must be approved by the EPA Regional Offices."

The requirement is that an I/M implementation schedule be prepared as part of the SIP revision, and that the schedule consider the items listed above (if applicable). The development of this section considers the above list of schedule elements as well as several additional elements, and these are discussed below. The discussion of each element should provide some insight as to how the I/M schedule requirement (defined above) should be addressed. However, the basic task is:

- formulate tentative plans for the format, scope, design operation and implementation of the items listed in the I/M Schedule requirements; this has been accomplished.

which is followed by a second task involving:

*Indicates that items may apply to some I/M programs and not to others.

- develop an I/M implementation schedule that will address (at least) the relevant issues defined above for submittal as part of the revised SIP; this should have been completed prior to 31 December 1978.

A good starting point in this discussion concerns the legislative requirements indicated by items 2 and 3 in the implementation scheduling requirements.

At this point, the general I/M scenario that will be implemented in Minnesota has been tentatively defined although certain issues are at this point undecided. This report will serve as an aid in making these decisions.

As a general comment, the implementation requirements are such that a significant planning effort should be underway even at this point in time to ensure that the schedule requirements (discussed later) can be met.

That the State recognizes this requirement is obvious in that draft legislation has been prepared and will be submitted to the legislature early in 1979. This is of considerable importance, as the EPA deadline for securing the legal authority to implement and enforce the program is 30 June 1979, therefore, enabling legislation must be ratified during this session.

In a very similar connection, a program budget must be derived in order to secure the funds necessary to implement and operate the program. This establishment of the required funds is also a legislative process and, therefore, must also occur during the early 1979 State Legislative Session. This obviously requires the preparation of a budget estimate and substantiating documentation, probably by the MPCA. The specific task then is:

- Prepare and <u>approve</u> a program budget request including actual estimates and substantiating data; this should be accomplished in early to mid-1979.

It is unfortunate that there are no checklists that can be followed or procedures that can be recommended to guarantee rapid approval of the proposed legislation and budget by the State Legislature. EPA guidance, however, is rather specific with regard to the scheduling requirements for securing the proper authority to implement I/M, as can be seen in the following excerpt from an EPA policy memorandum dated 17 July 1978:

> "<u>Authority to Implement I/M</u>
>
> Normally, adequate legal authority to implement a SIP revision must exist for a revision to be approved. Where a legislature has had adequate opportunity to adopt enabling legislation before January 1, 1979, the Regional Administrator should require certification that adequate legal authority exists for I/M implementation by January 1, 1979. However, for many states there will be insufficient opportunity to obtain adequate legal authority before their legislatures meet in early 1979. Therefore, a certification of legal authority for the implementation of I/M in these states must be made no

later than June 30, 1979. An extension to July 1, 1980, is possible, but only when the state can demonstrate that (a) there was insufficient opportunity to conduct necessary technical analyses and/or (b) the legislature has had no opportunity to consider any necessary enabling legislation for inspection/maintenance between enactment of the 1977 Amendments to the Act and June 30, 1979. Certification of adequate legal authority, or other evidence that legal authority has been adopted, must be submitted to the EPA Regional Offices to be included in the SIP revision already submitted. Failure to submit evidence of legal authority by the appropriate deadline will constitute a failure to submit an essential element of the SIP, under Sections 110(a)(2)(I) and 176(a) of the Act."

It is entirely likely (and logical) that during discussion regarding the I/M legislation the question will arise as to: what will happen if we do not approve I/M legislation by the 30 June 1979 deadline? The answer to this is that the State would not be able to submit an essential element of the SIP, and that Sections 110(a)(2)(I) and 176(a) of the Act would apply. Of particular interest are the provisions of Section 176(a), which deal with sanctions that may be placed against states for noncompliance; this Section is excerpted below:

"Sec. 176. (a) The Administrator shall not approve any projects or award any grants authorized by this Act and the Secretary of Transportation shall not approve any projects or award any grants under title 23, United States Code, other than for safety, mass transit, or transportation improvement projects related to air quality improvement or maintenance, in any air quality control region –

(1) in which any national primary ambient air quality standard has not been attained.
(2) where transportation control measures are necessary for the attainment of such standard, and
(3) where the Administrator finds after July 1, 1979, that the Governor has not submitted an implementation plan which considers each of the elements required by section 172 or that reasonable efforts toward submitting such an implementation plan are not being made (or, after July 1, 1982, in the case of an implementation plan revision required under section 172 to be submitted before July 1, 1982).

(b) In any area in which the State or, as the case may be, the general purpose local government or governments or any regional agency designated by such general purpose local governments for such purpose, is not implementing any requirement of an approved or promulgated plan under section 110, including any requirement for a revised implementation plan under this part, the Administrator shall not make any grants under this Act.

(c) No department, agency, or instrumentality of the Federal Government shall (1) engage in, (2) support in any way or provide financial assistance for, (3) license or permit, or (4) approve, any activity which does not conform to a plan after it has been approved or promulgated under section 110. No metropolitan planning organization designated under section 134 of title 23, United States Code, shall give its approval to any project program, or plan which does not conform to a plan approved or promulgated under section 110. The assurance of conformity to such a plan shall be an affirmative responsibility of the head of such department, agency, or instrumentality.

(d) Each department, agency, or instrumentality of the Federal Government having authority to conduct or support any program with air-quality related transportation consequences shall give priority in the exercise of such authority, consistent with statutory requirements for allocation among States or other jurisdictions, to the implementation of those portions of plans prepared under this section to achieve and maintain the national primary ambient air quality standard. This paragraph extends to, but is not limited to, authority exercised under the Urban Mass Transportation Act, title 23 of the United States Code, and the Housing and Urban Development Act."

The implications of not approving I/M legislation are quite severe, as can be seen from Section 176(a), and therefore should be considered in legislative discussions on the proposed legislation.

The basic task, then, is:

- approve I/M legislation and corresponding funding; this in general should be accomplished prior to 30 June 1979.

The second element to be discussed concerns the initiation of a public information program regarding I/M. In deciding on the particular program details, several points should be considered. First, there are three basic stages in the public information effort and the activity and timing of each should be treated carefully. The first stage occurs during the period prior to introducing the legislation to the Legislature, and extends through the time that the legislation is approved. The intent is to inform the public about the basic concepts of the program primarily to develop support from those individuals whose representatives will be acting on the legislation in the State Legislature. The effort may be directed more toward organized groups who have both a recognized lobbying power and an inherent interest in promoting air pollution reduction. The second phase occurs approximately 6 months to a year prior to the startup of the program and extends through the first year of operation. This entails a very strong, visible effort to inform the public about the details of the I/M program, particularly concerning the benefits that the individual motorist is likely to derive from the program. Also, the intent should be to ensure that the requirements for each motorist to obtain an inspection are defined in detail so that essentially everyone knows what to expect with regard to how he is notified as to when and where he will be inspected, eliminate uncertainty regarding repair liability (repair cost ceiling), where he can take his vehicle for repairs if required, etc. The final phase is a continued effort after the I/M program is operating smoothly.

The intent would be to inform the public of the program's effectiveness in reducing pollution. This would require a somewhat lower level of effort than would the second stage.

The tasks associated with public information programs, then, can be described as follows:

- develop program strategy including who will operate the program (State franchise or private firm), level of activity associated with each phase, implementation dates (approximate) of each phase, etc.; this planning effort should be completed prior to 31 March 1979.

- define details of the first phase of the public information program and implement and conduct same; this should occur during the period from approximately 1 April 1979 to 31 August 1979.

- define details of the second phase of the public information program and implement and conduct same; this should begin 6 to 12 months prior to program startup and extend through the first year of full operation.

- define details of the third phase of the public information program and implement and conduct same; this should follow the completion of the second phase and continue as required.

The next items from the list of I/M Implementation Schedule elements that will be discussed are items 5 through 8. Items 5 and 6 concern developing and issuing requests for proposals (RFP's), and subsequent award of a contract(s) to a private firm(s), while items 7 and 8 concern the actual construction of facilities.

Assuming first that contractor-operated inspection facilities are selected, the first task would be to develop a detailed plan of what the program is to include, and specifically, what the requirements for and responsibilities of the contractor would be. These would be published as an RFP and distributed to interested contractors, who would respond with proposals to establish and operate the inspection facilities. The State would review and evaluate the proposals and select a particular contractor from those submitting proposals.

The next items deal with the initiation and completion of facilities construction.

If Minnesota decides to run the program "in-house," an additional task can be identified; this involves the formal processes that the State must use in negotiating for a design consultant, soliciting bids from a construction contractor, and finally selecting a construction contractor. Certain other steps are also as critical as construction start and completion dates; these include site selection, land purchase, etc.

The individual tasks associated with the items discussed above can be defined as follows:

- prepare request for proposal; this would likely take 2 months to prepare and would not be started until after the legislature and budget were approved; this task would occur, say, during April through July 1979;

- assuming that the RFP's were issued by August 1, 1979, and proposals due in late November 1979, the proposals could be evaluated and a contractor selected by late January 1980;

- contractor begins site search and purchases required land; occurs during the period February 1980 through July 1980;

- contractor begins construction of facilities; construction period August 1980 through March 1981.

Selection, purchase, and delivery of equipment is listed next in the I/M Implementation Schedule. It could be expected that a fairly substantial lead time would be required between ordering and delivery of certain equipment items. The intent, however, would be to stage equipment delivery over the latter portion of the facilities construction period, so that equipment could be installed as it arrives. This is the usual procedure used in construction practice and should not be of extraordinary concern.

Should a state-run option be selected, additional time would be needed as a competitive bidding procedure would be required. The specific tasks, then, are:

- Select equipment in accordance with State specifications, purchase same; this would be done, say, during the period August 1980 through March 1981.

- Equipment delivery; occurs as required August 1980 through March 1981.

Item 12 in the Implementation Schedule concerns the development and adoption of cutpoints. Initial cutpoints can be selected based on vehicle emissions data compiled by other states, and these can be refined during the early stages of inspection once a sufficient cross-section of the vehicle population has been tested. The initial cutpoints should be defined after some initial study of existing data. Specific tasks include:

- review data from other programs, define initial cutpoints; this can take place during the period 6 to 9 months prior to startup;

- refine cutpoints to account for Minnesota-specific data and changing vehicle emissions characteristics; this occurs approximately 6 months after initiation of testing and continues throughout program.

Items 13 and 15 on the Implementation Schedule deal with hiring and training inspectors and other personnel, and initiation of training programs for both inspection personnel and the auto repair industry. A distinction can be made with regard to operating personnel and administrative personnel phase-in. Administrative personnel would be phased into the program 12 months prior to beginning the testing while operating personnel, managers and inspectors, would be phased in 6 months and 1 month prior to startup, respectively. Training courses for inspection personnel would begin approximately 6 months prior to startup to train all new personnel, and the training would continue throughout the program to train additional personnel approximately 6 months prior to mandatory maintenance. A task that must be carried out prior to implementing mechanics training is to define the nature of the training program in terms of who will do the testing, what will be taught, etc. The specific tasks involved include:

- hire administrative personnel; this would be accomplished 12 months prior to program startup;
- hire inspection facility managers and assistant managers; this would be accomplished 6 months prior to start;
- determine training program details including scope, who will conduct training, where training is to be held, etc.; this would be accomplished 1 year prior to startup.
- begin mechanics/inspector training program; this would begin 6 months prior to beginning any testing (inspector training phase would begin 1 month prior to startup).

The last items on the Implementation Schedule concern phasing in mandatory inspections and mandatory maintenance. The MPCA has indicated that the general procedure would be to have voluntary maintenance but mandatory inspections during the first full year of operation. EPA guidance on deadlines is provided below:

"D. <u>I/M Implementation Deadlines</u>

Implementation of I/M "as expeditiously as practicable" shall be defined as implementation of mandatory repair for failed vehicles no later than two and a half years after passage of needed legislation or certification of adequate legal authority for new centralized systems and one and a half years after legislation or certififation for decentralized systems or for centralized systems which are adding emission inspections to safety inspections. For the normal legislation deadline of June 30, 1979, new centralized programs must start by December 31, 1981, and all others must start by December 31, 1980. For the case of the latest possible legislation date, July 1, 1980, this means that a new centralized program must start by December 31, 1982, while all other programs must start by December 31, 1981. Where I/M can be implemented more expeditiously, it must be. Each state implementation schedule must be looked at individually to determine if it is as expeditious as practicable. Implementation dates ordered by courts, if earlier than these dates, take precedence."

New policy guidance from Region V administrator, John McGuire, however, states:

> "Regardless of whether legal authority for I/M is obtained during the 1979 or the 1980 legislative session, the I/M program must be implemented in its mandatory phase no later than December 31, 1982, in the case of a centralized I/M program, in order to insure equity among the States."

It appears, then, that a full year of mandatory inspection, voluntary maintenance will be possible for the proposed program.

The tasks that can be identified here regarding phase-in are:

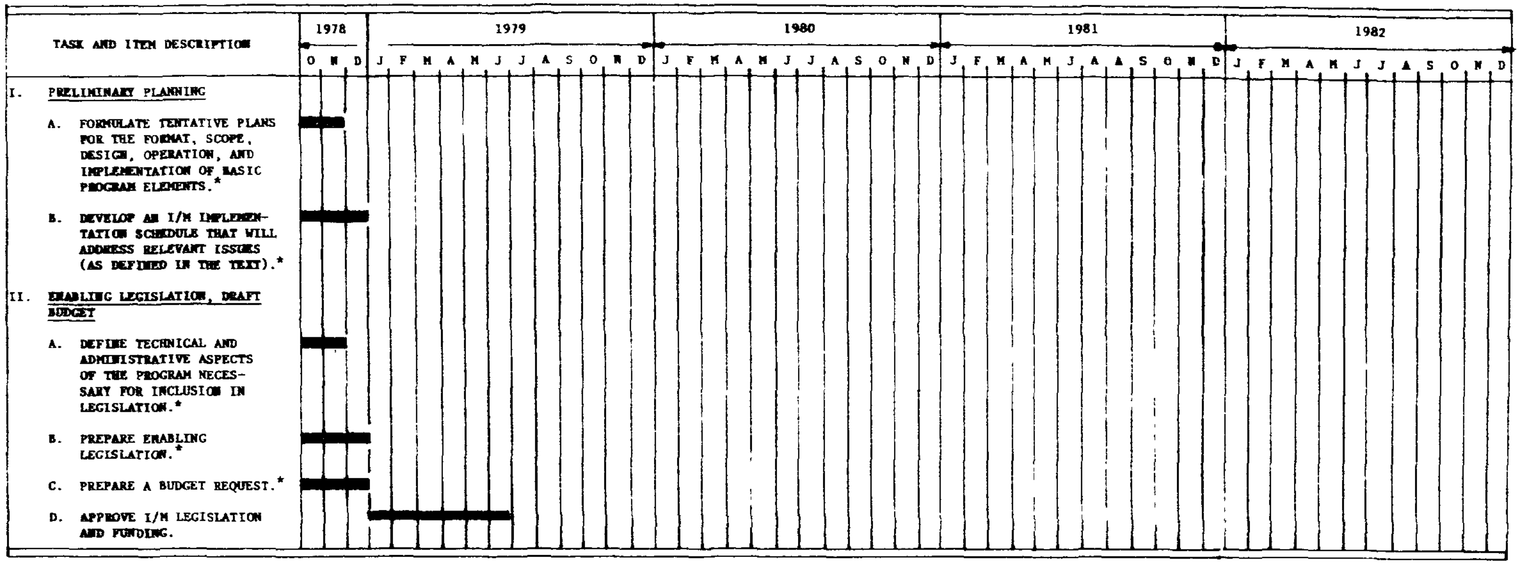
- implement mandatory inspection, voluntary maintenance; this will occur approximately 1 July 1981 and run through 30 June 1982.
- implement mandatory inspection, mandatory maintenance; this would begin 1 July 1982 and extend throughout the program*.

The issues discussed above, again, must be defined in terms of the schedule for implementation in the revised SIP. As a summary of the above discussion, Table 43 is presented showing each task identified above and its approximate implementation dat .

Legislation now being considered by the State of Minnesota has called for opening of inspection stations by November 1, 1981, mandatory inspection by January 1, 1982, and mandatory repair by January 1, 1983, which would comply with the Region V implementation requirements mentioned above. The schedule shown in Table 43 indicates implementation may be possible approximately 6 months prior to the legislative deadline of mandatory inspections (January 1, 1982). One alternative to beginning mandatory inspections on July 1, 1981, would be the inclusion of a six month voluntary inspection period from July 1, 1981, through January 1, 1982, when mandatory inspections could be initiated.

*The actual duration of the program beyond 1987 is open to speculation at this time. Should the program not be needed as an air quality improvement measure beyond 1987, the State would have the option of continuing, modifying, or terminating it.

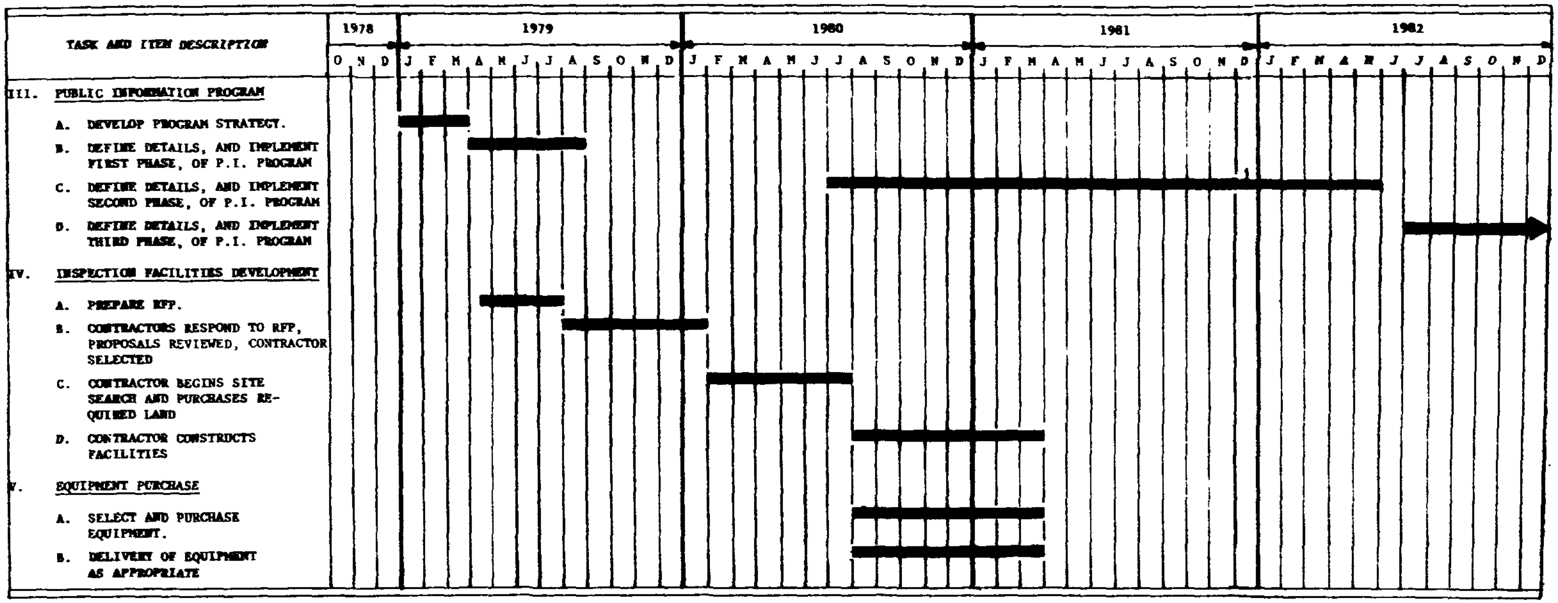
TABLE 43. IMPLEMENTATION SCHEDULE




*Has already been accomplished by Minnesota.

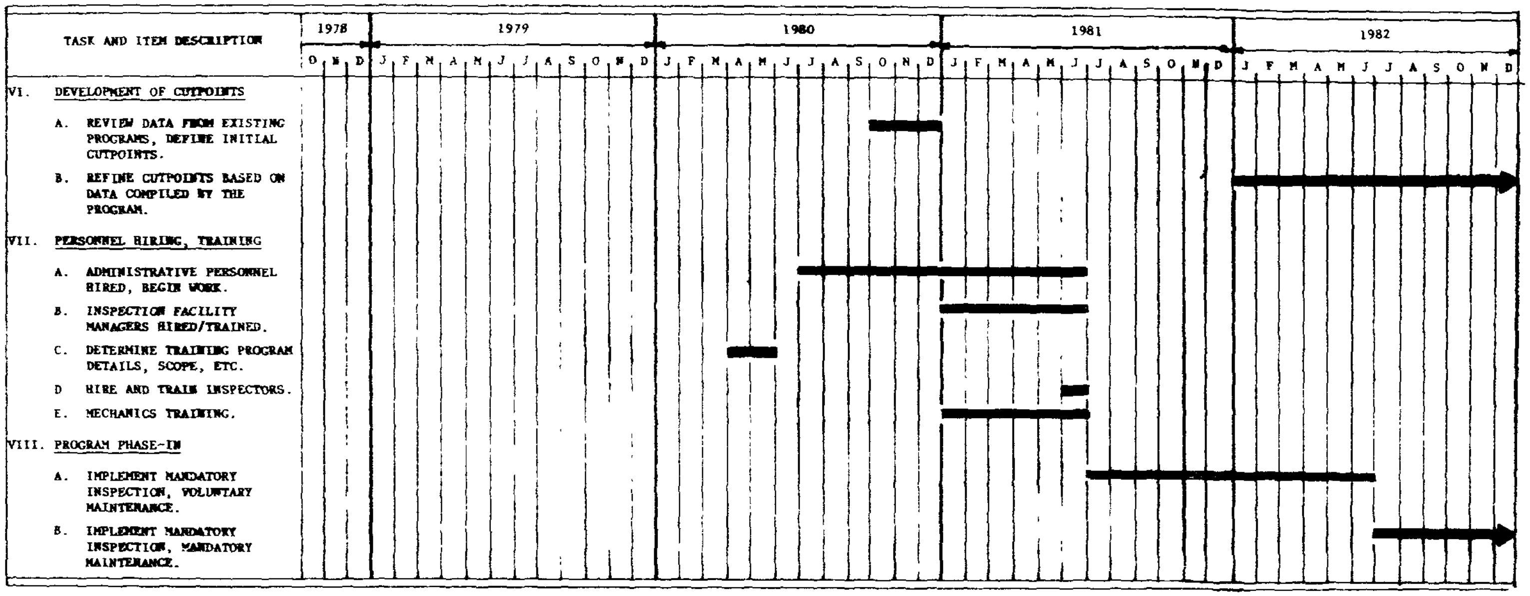
(continued)

TABLE 43. (continued)




(continued)

TABLE 43. (continued)



## SECTION 7

## COLD CLIMATE CONSIDERATIONS

### INTRODUCTION

Numerous statistics do not have to be presented here to substantiate the statement that winters in Minnesota tend to be quite severe. The question, however, as to how severe winter weather affects emissions testing is quite important.

Winter conditions would be expected to affect the emissions testing program in three specific areas; viz.:

- individual vehicle emissions
- analyzer performance
- general station operation

Each of these areas is discussed in the following paragraphs.

### EFFECTS OF COLD OPERATION ON INDIVIDUAL VEHICLES

The primary impact of cold ambient temperatures on automotive emissions occurs during the initial stages of operation. Cold-mode operation is the term that, in the very general sense, is defined as the first several minutes of operation. The purpose of this discussion is to define the causes and implications of cold-mode operation as it affects (or potentially may affect) the proposed I/M program for Minnesota. Additionally, the issue of seasonal differences in motor fuel composition, and the possible impacts on emissions is also discussed.

#### Cold Mode Characterization*

As was indicated above, cold mode operation is defined in general terms as the first several minutes that a vehicle is operated after having not been operated for several hours. The primary manifestation of cold-mode operation is an extraordinarily high emission rate of both carbon monoxide and hydrocarbons.

The excess emissions associated with cold operation occur as a result of a temporary imbalance in the combustion system parameters. In order for

*Based on: Midurski, Theodore P., and Alan Castaline. Determination of Percentage of Vehicles Operating in the Cold-Start Mode. GCA Corporation, GCA/Technology Division, Bedford, Massachusetts. Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning Standards, Research Triangle Park, North Carolina. EPA Report No. EPA-450/3-77-023. August 1977.

ignition to occur in a gasoline engine, the fuel introduced into the cylinder must be vaporized and there must be present an appropriate balance or ratio* between the quantities of air and vaporized fuel. Gasoline does not vaporize as well at lower temperatures as it does in the relatively high temperature ranges that are typical of stabilized engine operation. Therefore, when a "cold" engine is being started, the rate of gasoline vaporization that occurs in the combustion area is much less than when the engine is operating at normal temperature. As a result, an imbalance occurs in the air-to-fuel ratio; this imbalance can be so severe that ignition will not occur. To compensate for this temporary imbalance in the air-to-fuel ratio, the fuel delivery system is equipped with a choke mechanism, which, when activated, restricts the flow of incoming air to the point where a vacuum occurs in the intake manifold. The vacuum causes additional fuel to be drawn into the manifold resulting in extra fuel being delivered to the combustion areas. The increase in the total amount of fuel delivered to the cylinder compensates for the reduction in the rate of vaporization, so that the net result is an air-to-vaporized fuel ratio that is suitable for ignition. Although the ratio of air-to-vaporized fuel becomes balanced when the choke is functioning, the ratio of air to total fuel becomes imbalanced owing to an insufficient quantity of combustion air being present. This imbalance results in incomplete fuel combustion; two major products of incomplete combustion are carbon monoxide and various unburned hydrocarbon compounds.

The choke mechanism on most vehicles is actuated automatically by a heat sensor incorporated into a temperature-sensitive engine component such as the intake manifold. The rise-time from ambient to stabilized temperature for the heat sensitive components generally lags the rise-time in the entering fuel temperature and combustion chamber temperature by various amounts of time, thereby assuring adequate choke-on time. Studies have shown the choke-on time to be a function of ambient temperature. Figure 5 provides an indication of choke-on time as a function of ambient temperature.[1]

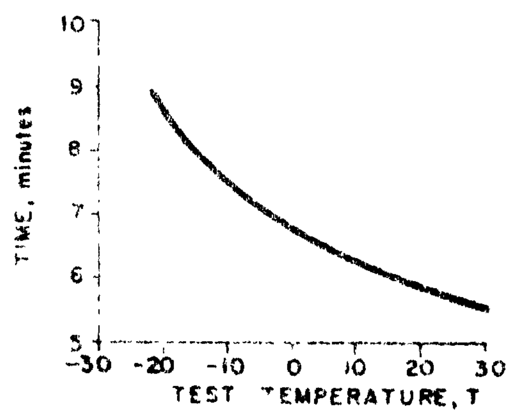



Figure 5. Representation of choke-on time as a function of ambient temperature.

*This ratio is commonly referred to as the air-to-fuel ratio.

Production of excess emissions during the cold stages of vehicle operation occurs also as a result of a phenomenon known as wall quenching. Wall quenching is a combustion phenomenon that occurs when a flame moves towards a relatively cool cylinder wall. The cool cylinder wall slows and effectively stops combustion in the vicinity, thus a layer of unburned and partially burned fuel remains at the wall surface at the end of the combustion stroke. The thickness of the layer is a function of several parameters including the cylinder temperature and pressure, the presence of cylinder deposits, and the wall temperature itself. Obviously, the cylinder and wall temperatures are much lower during initial operation than after warm-up. These lower temperatures result in a thicker layer of unburned or partially burned fuel during each stroke, which contributes to the total excess emissions associated with cold-mode operation.

Emissions from newer vehicles equipped with catalytic converters are affected by cold operation because of an additional factor. The converter, which functions as the primary emission control device, does not begin to operate efficiently until it reaches a certain temperature. The time required to reach the most efficient operating range is generally around 200 to 300 seconds, regardless of the ambient temperature.[2] Therefore, during the several minutes that it takes for the converter to reach optimum operating temperature, carbon monoxide and hydrocarbons emission rates are somewhat higher than during warmed-up operation.

Temperature obviously has a considerable effect on cold-mode emission characteristics. The relative impact that ambient temperature has on emission rates has been analyzed in the laboratory during several studies. Of particular importance is the fact that these studies conclude that the effects of varying ambient temperatures are apparent only during the first several minutes of operation. In one set of tests,[2] the effect of ambient temperature on carbon monoxide and hydrocarbon emission rates for three configurations of standard 1970 production cars, and three 1970 production cars equipped with advanced (with respect to the 1970 model year) emission control devices, was analyzed. The testing involved measuring the emissions produced by each vehicle as it was operated from a cold condition* through the Urban Dynamometer Driving Schedule, which is included in the Federal Test Procedure. Tests were performed at several different ambient temperature conditions for each vehicle. Cumulative emissions were then identified as a function of elapsed operating time and temperature; test results are illustrated in Figures 6 through 11.

These figures show quite vividly that the emission rates of both hydrocarbons and carbon monoxide for the test cars† are generally not sensitive to changes in ambient temperature beyond, say, the first 200 to 300 seconds of operation, but within the first 200 to 300 seconds, temperature has a marked effect on emission rates.

---

*Cold condition implies that the vehicles had not been operated for at least 12 hours prior to testing.

†HC emissions for Test Cars G, I, and J (Figures 9 through 11) were conducted but are not reported here.

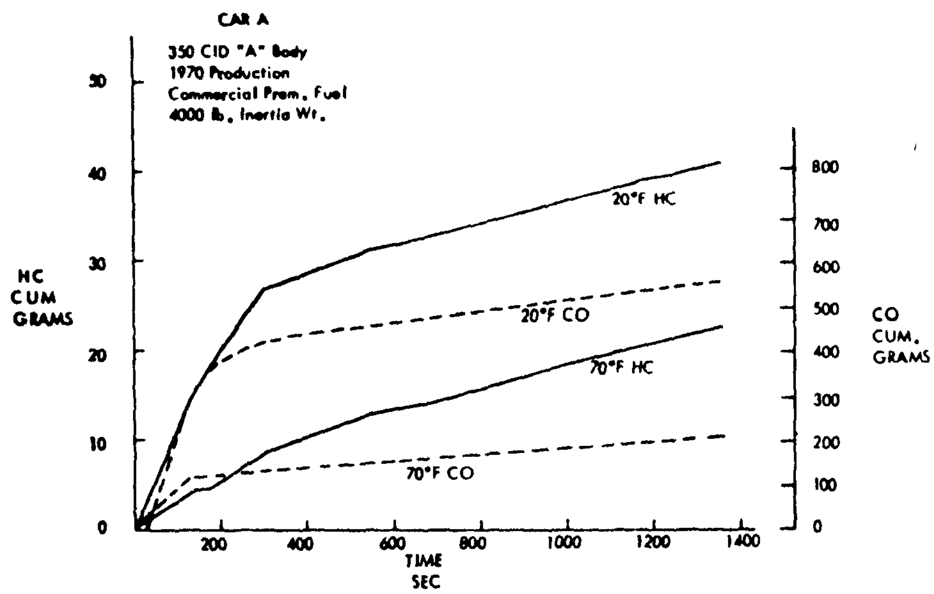



Figure 6. Cumulative HC and CO emissions during FTP driving cycle - Car A.

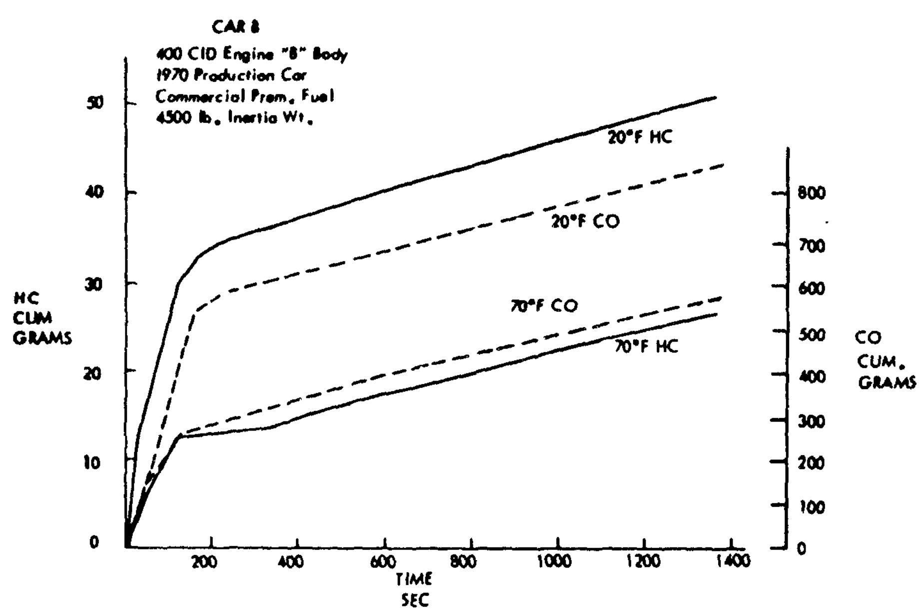



Figure 7. Cumulative HC and CO emissions during FTP driving cycle - Car B.

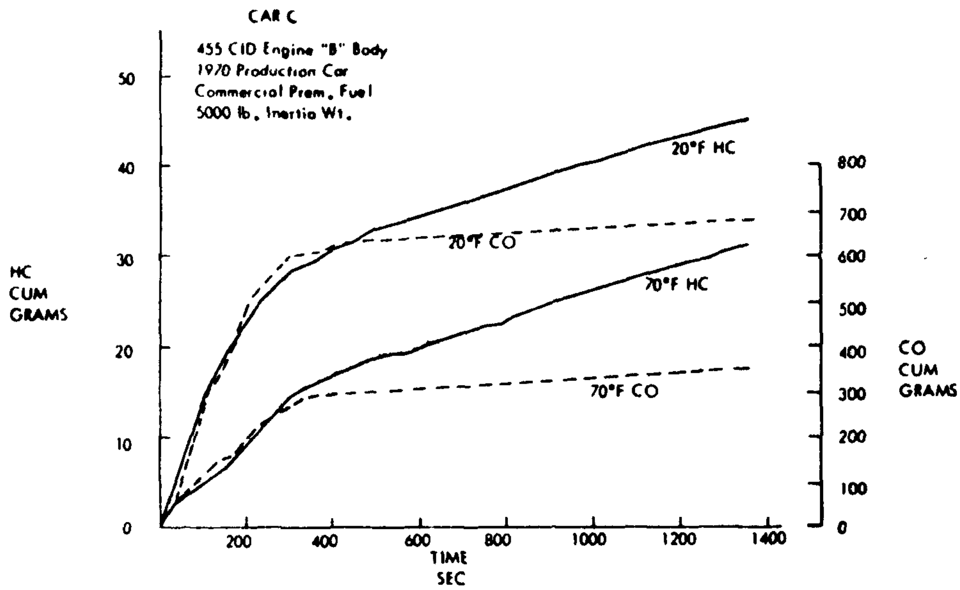



Figure 8. Cumulative HC and CO emissions during FTP driving cycle - Car C.

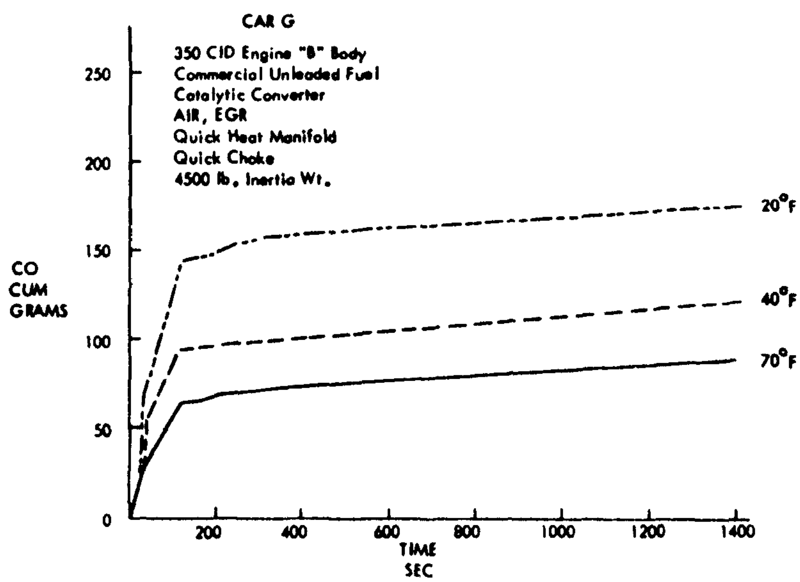



Figure 9. Cumulative CO emissions during FTP driving cycle - Car G.

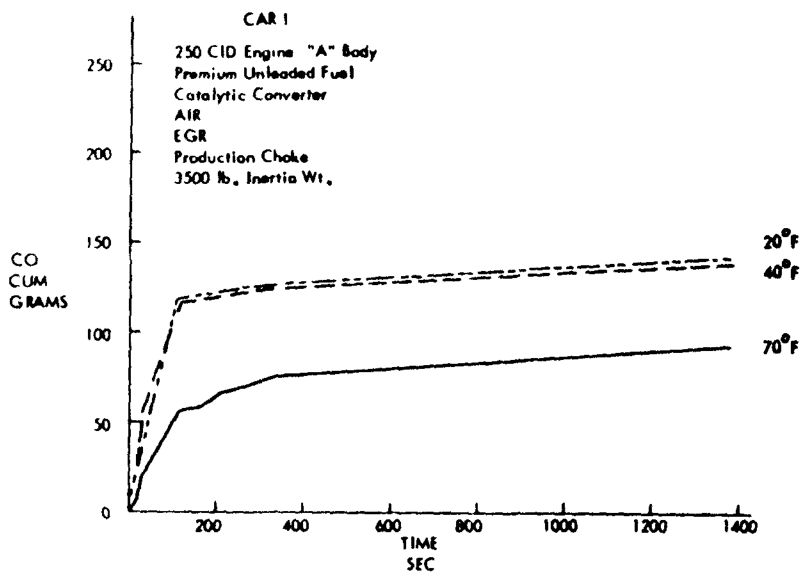



Figure 10. Cumulative CO emissions during FTP driving cycle - Car I.

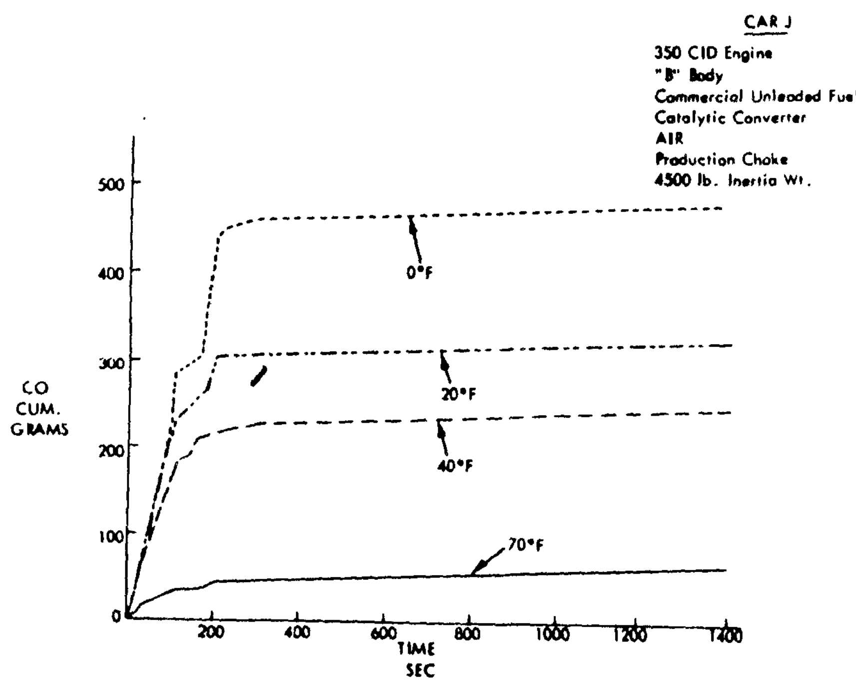



Figure 11. Cumulative CO emissions during FTP driving cycle - Car J.

In another series of investigations[3] on the effects of cold ambient temperatures on light-duty vehicle emissions, nine 1973 vehicles were considered. These tests involved a standard 23-minute FTP driving schedule during which exhaust samples were collected for three cycles of operation. The first cycle included the first 505 seconds of the schedule representing the "cold" operating phase. The second cycle involved the stabilized phase, which represents the remainder of the 23-minute cycle. The third cycle represents a "hot start" condition, which involves repeating the first 505 seconds of the driving schedule after a 10-minute engine-off period. For this series of tests, an ambient temperature of 60°F was established as a baseline condition. Comparisons were made of carbon monoxide emissions for each mode at ambient temperatures ranging from 0°F to 80°F.

The results of the tests are shown in Figure 12. This figure shows the relative effect of temperature differences (with respect to an ambient temperature of 60°F) for each of the three test phases and the composite.* Figure 12 shows, again, that the relative effect of various ambient temperatures is insignificant beyond the first few minutes of operation; this is shown by comparing temperature effect on Bag 1 emissions (the first 505 seconds of operation) to the Bag 2 emissions.

The results of a third study[4] also indicated the significance of the first few minutes of cold operation. In this study, 26 production vehicles of various model years and configurations were tested using the FTP driving cycle. The testing was conducted at ambient temperatures of 20°F, 50°F, 75°F and 110°F. The average emission rates for each phase of the FTP driving cycle and a composite emission rate were defined for various groupings of vehicles; these are shown in Figure 13.

Figure 13 provides a good indication of the magnitude of the effect that cold-mode operation has on emission rates. The effect is best illustrated by directly comparing the Bag 1 and Bag 2 emission rates. The curves for catalyst vehicles operating at 20°F indicate that during the first 505 seconds of operation, the emission rate is about 130 grams per mile while the Bag 2 rate is about 3 or 4 grams per mile. The importance, then, of accouting for cold-mode operation in any analysis of carbon monoxide is obvious. As an illustration, if emissions were computed for a specific location first assuming (1) an ambient temperature of 20°F, (2) a vehicle mix whose emission characteristics were similar to those for 1973 - 1974 model year vehicles shown in Figure 13, and (3) all vehicles operating in the warmed-up (stabilized) mode, the result might yield the quantity X, which would represent the product of an average emission rate (in this instance, about 60 grams per mile based on Figure 13 and a travel factor defining the quantity of travel (in vehicle-miles). If a second analysis were performed using the same assumptions except that all vehicles were operating in the cold mode (obviously an extreme assumption), the results would be the quantity 3.8X; this reflects the difference in emission rates for cold and stabilized operating modes for the representative vehicle population. If it were assumed that the vehicle population was comprised of all catalyst vehicles, the difference would be much greater (again, based on Figure 13).

*The composite is computed using the sum of 43 percent of Cycle 1 emissions, 100 percent of Cycle 2 emissions, and 57 percent of Cycle 3 emissions.

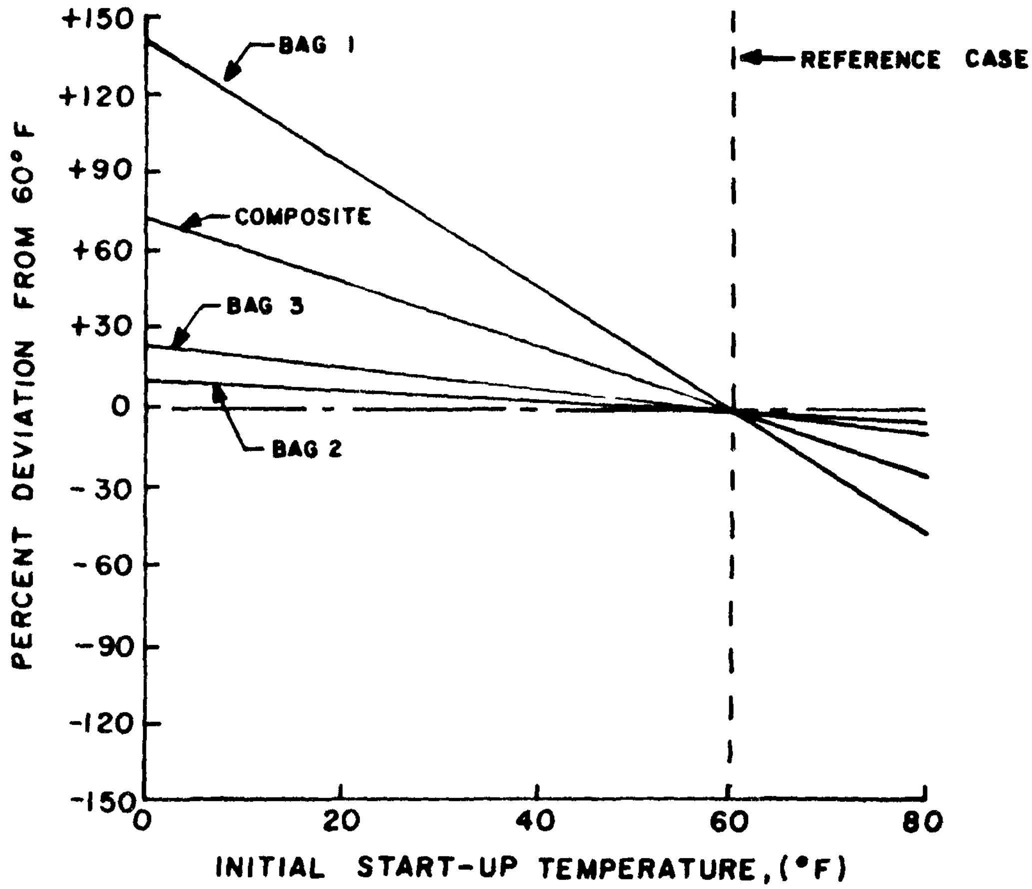



Figure 12. Average vehicle CO percent deviation versus start-up temperature.

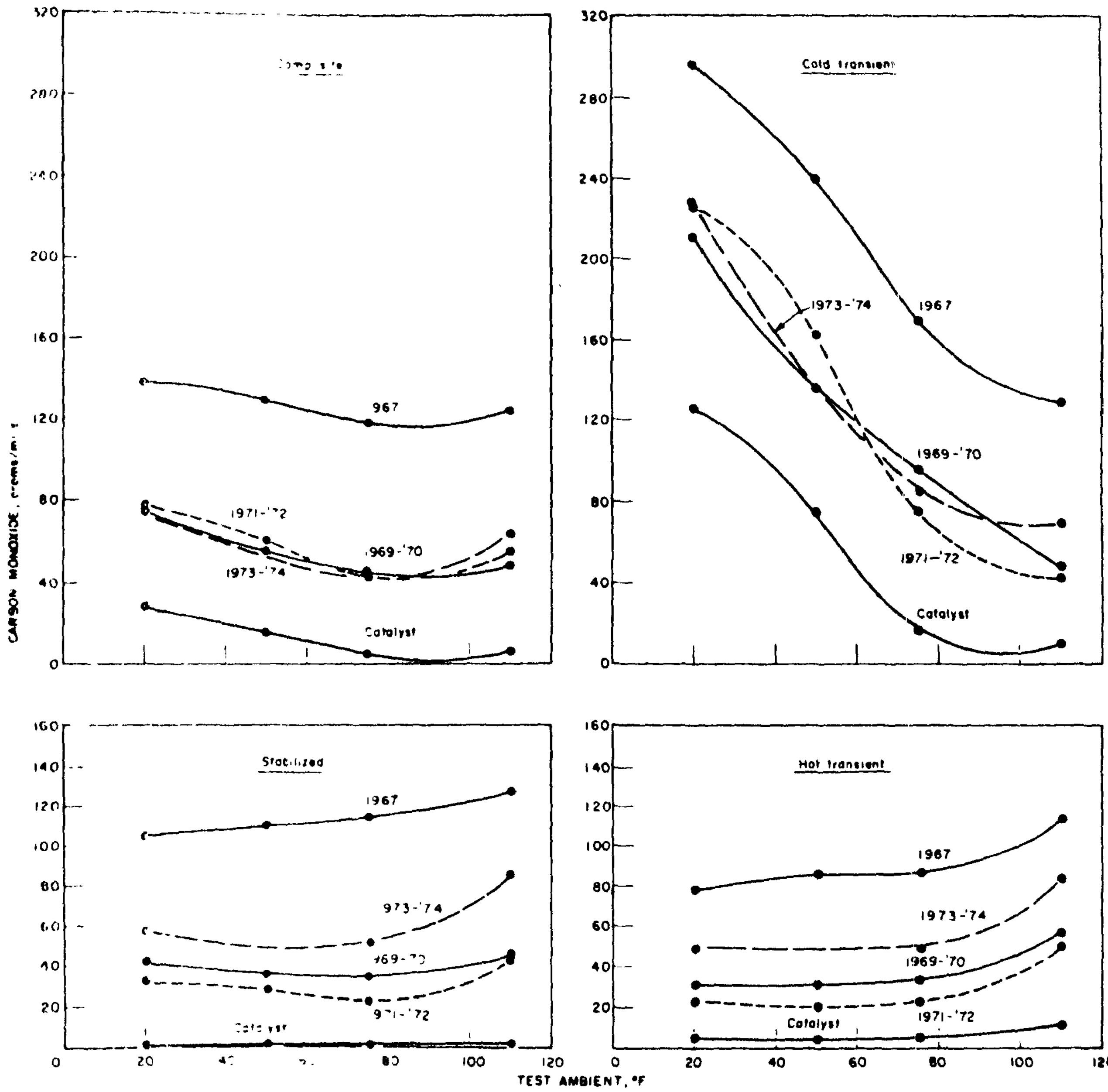



Figure 13. Temperature dependency of carbon monoxide emissions - varied categories of vehicles.

Technical Definition of Cold-Mode Operation

It can be concluded from the previous discussion that cold-mode operation is a time-dependent function. The standard definition of cold-mode operation is that it represents *the first 505 seconds of vehicle operation following a 4-hour (minimum) engine-off period.*[5] This definition implies that a discrete function exists between cold-mode operation and the cold-soak period.* Recall, however, that in the previous discussion it was indicated that both ambient and engine temperatures appear to be critical determinants of cold-mode operation. The figures presented in that section indicate that ambient temperature does not have a large effect on the time required to stabilize (ambient temperature does have a very significant effect on the rate of emissions, however). Apparently, then, the rise-time to stabilized operating temperature is not affected to a large extent by a differential in ambient temperature of, say, 50°F (20°F to 70°F). However, the temperature within an engine ranges from ambient up to about 2000°F in the combustion area (cylinder walls) and over 200°F for fuel delivery components. Obviously, when an engine is shut down, these components begin to cool down to the ambient temperature. If the engine is restarted before the components reach ambient temperature, the amount of time required to again reach the hot stabilized condition would be reduced. Limited testing[6] by the U.S. Environmental Protection Agency, Office of Mobile Source Air Pollution Control, has indicated that the time required to reach the hot stabilized mode is indeed a continuous function of the engine starting temperature. In these analyses, the starting temperature is considered implicitly to be a function of the soak time. In this connection, equations were developed describing the required time to reach the stabilized mode as a function of cold soak period; one of these equations is

$$t = 3.11\ S^{0.36} \qquad (1)^{\dagger}$$

where $t$ = time in minutes to reach the stabilized mode and

$S$ = soak time in hours.

The time $t$ defined in equation (1) represents the time to stabilize when the ambient temperature is about 75°F. Testing was also performed at temperatures of about 20°F and an equation was derived representing the time required to stabilize ($t'$) again as a function of the cold-soak duration; this equation is

$$t' = 2.61\ S^{0.36} + 1.32 \qquad (2)$$

where $t'$ = time in minutes to reach the stabilized mode at an ambient temperature of 20°F, and

$S$ = soak time in hours.

---

*Cold soak is defined at the time interval that a vehicle's engine is not operated.

†This equation has been normalized to reflect assumptions in AP-42; for analyses not associated with the emission factors presented in AP-42, a slightly different equation applies.

The effect of ambient temperature on the cold-mode cycle length can be seen by comparing the results of equations (1) and (2) applied to a set of arbitrary cold-soak durations; this is presented in Table 44, below.

TABLE 44. COMPARISON OF COLD-MODE CYCLE LENGTH IN MINUTES AS A FUNCTION OF SOAK DURATION FOR AMBIENT TEMPERATURES OF 75°F AND 20°F

| Ambient temperature, °F | Cold soak duration, hours | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 1.5 | 2.5 | 3.5 | 4.5 | 5.5 | 6.5 | 7.5 | 8.5 |
| 75 | 2.4 | 3.6 | 4.3 | 4.9 | 5.3 | 5.8 | 6.1 | 6.4 | 6.7 |
| 20 | 3.3 | 4.4 | 5.0 | 5.4 | 5.8 | 6.1 | 6.4 | 6.8 | 7.0 |

Table 44 clearly shows that the effect of ambient temperature on the cold-mode cycle length is not nearly as severe as is the cold-soak duration.

## Emissions Levels Associated with Cold-Mode Operation

From the previous discussion, it is obvious that the impact of cold-mode operation on total emissions produced is highly dependent on ambient temperature. This can be illustrated even more dramatically by plotting both total emissions and the cold-start portion of the total emissions produced during the FTP urban driving cycle, as a function of ambient temperature; such a plot is shown in Figure 14, below. This figure indicates that at temperatures below approximately 0°F, the cold-start mode contributes 70 to almost 85 percent of the total emissions produced.

This becomes even more significant when considering carbon monoxide levels in areas where large concentrations of cold-mode operation are likely to occur (in urban core areas during evening rush hours, for example). It has been suggested that current methods for analyzing cold-mode operation--such as that used to derive Figure 14--underestimate the cold-mode emissions at 0°F by a factor of about 2.[7] The obvious point of interest concerns whether or not control strategies developed to reduce CO emissions adequately reflect the impact that cold-mode operation has on total emissions produced*.

## Implications Regarding I/M Effectiveness

The basic question that surfaces at this point concerns the effectiveness of I/M in reducing cold start emissions. Unfortunately, there are no data that would provide the basis for a quantitative assessment of the emissions reductions achievable through an I/M program for the cold-operating mode only. To date, the composite emissions reductions only have been quantified.

---

*Since photochemical oxidants are associated more with warm seasons, it has been shown that relatively warm ambient temperatures do not significantly affect cold-start emissions, the emphasis here is on CO, only.

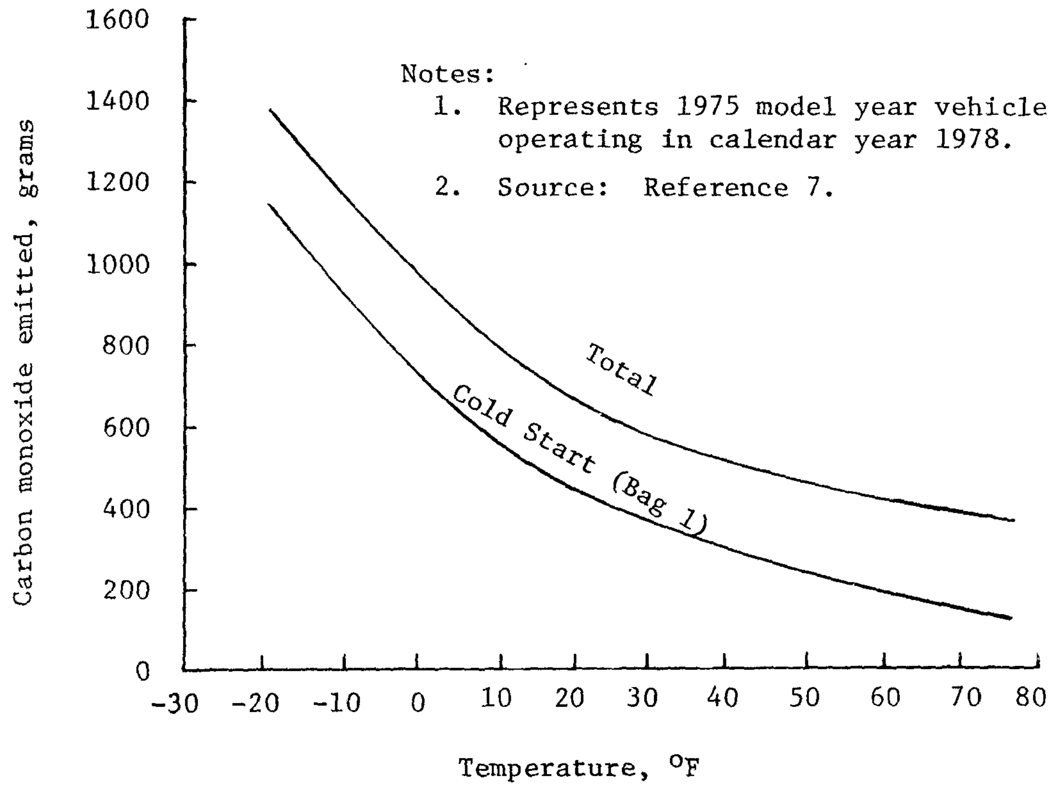



Figure 14. Cold-start emissions and total emissions produced during FTP driving cycle as a function of ambient temperature.

Intuitively, however, it would be expected that repairs or adjustments of the types associated with I/M would necessarily have a positive impact on cold-mode emissions reductions. Further, if additional emphasis were placed on inspecting and/or repairing or adjusting components that are particularly critical with respect to cold-mode emissions generation, such as the choke, spark plugs, PVC value, etc., one would expect that additional benefits (i.e., reductions in cold-mode emissions) would accrue from an I/M program.

Again, it is stressed here that the uncertainty of how I/M affects cold-start emissions is almost entirely related to conditions where ambient temperatures are generally below about the 30 to 40°F range. This means that the uncertainty is relevant primarily to the effectiveness of I/M as a CO control measure.

Implications Regarding Emissions Testing

A further question concerns how cold operations can be expected to affect emissions testing. First, the previous discussion indicated that the primary effect of ambient temperature occurs during the warm-up period, which is generally less than 8 minutes in duration. Beyond this initial period, temperature apparently has very little impact on the acutal emissions rates for CO and HC. The implication here is that during the emissions testing, the only requirement is to ensure that the vehicle being tested is fully warmed prior to measuring CO and HC levels. It sould be safe to assume that most vehicles will be in the stabilized mode by the time they reach the test site and have been processed at the reception area. If there is a question of whether or not a specific vehicle is in the stabilized mode, the owner can be advised to wait several minutes with the vehicle running prior to entering the station. It would not be practical to do this in the inspection lane, although the cruise portions of a loaded mode test do offer some preconditioning time.

SEASONAL VARIATIONS IN FUEL COMPOSITION

In order to maintain relatively uniform performance from motor fuel throughout the year, its composition is altered according to the season. During colder periods, the vaporization rate of motor fuel (as measured by its Reid Vapor Pressure) must be enhanced to offset the effects of temperature. As part of the special blending process, the proportions of various hydrocarbon categories may change from season to season. The result is that there may be measurable differences in the emission characteristics of a particular vehicle from season to season primarily because of the difference in fuel that is used.

While these differences in emissions characteristics may be small, it may be of value to analyze the results of the actual tests performed during the first year of program operation to determine whether or not distinct differences can be detected as a function of season. If in fact significant differences are identified, the cutpoints used to determine pass-fail may have to be adjusted for the particular season, as well.

COLD TEMPERATURE EFFECTS ON ANALYZERS

Another problem concerning winter temperatures has to do with the steep temperature differential between ambient conditions within the test and the outside air. Even the more sophisticated emission analyzers, undergoing frequent quality control checks to minimize analyzer, sampling system, and calibration error, while performing vehicle replication tests, can show under varying ambient conditions total variability many times greater than the equipment test variability[8]. Frequent opening of inspection facility doors will result in temperature variations within the inspection lane over time. A common energy saving measure of lowering the thermostat at night might also result in problems, especially if the analyzer is only calibrated daily. Vehicles tested later in the day when the lane has been heated up to more comfortable temperatures may not be tested accurately.

It is likely that at certain times, especially at the end of the month if strict inspection schedules are adopted, vehicles may encounter delays at the inspection facilities and thus be forced to idle for lengthy periods in the cold. The result of such a waiting period is a significant increase in tailpipe moisture. Again, if not properly planned for, this will affect test results. Moisture from the tailpipe can find its way into the sampling line and cuase "hydrocarbon hangup," which results in serious inaccuracies in the emissions measurements.

Aside from reducing waiting times by the availability of additional lanes, one solution to the tailpipe moisture problems is to heat sample lines, thus minimizing hydrocarbon hangup problems. Also, to alleviate problems with temperature fluctuations, test facilities should be equipped with analyzers that are self-contained in well-insulated, heated/air-conditioned cabinets. During winter and summer months, the analyzers should be recalibrated every few hours.

COLD CLIMATE IMPACTS ON FACILITY OPERATION

Several potential problems can be anticipated in the operation of an inspection facility in a cold climate. Snow, for instance, can have an impact on safety, facility capacity, and inspection demand. Snow-laden vehicles will result in wet, slippery floors in the inspection area. Also, it is likely that some motorists may arrive at the inspection facility with tire chains or studded snow tires. A vehicle cannot be run on a dynamometer with chains; same discussion has occurred regarding the testing of vehicles with studded tires on a dynamometer. General conclusions are that vehicles with studded tires ought not to be tested on the dynamometer because there is the danger of studs becoming loose and also since the dynamometer rollers would be subjected to severe wear.

Since vehicles registered in Minnesota are currently prohibited from using studded snow tires, the associated safety and equipment problems will be avoided. Motorists should be advised, however, that chains must be removed before the vehicle can be tested. Should the state rescind prohibition of studded tires, dynamometers with specially treated rolls are capable of withstanding studded tires, but are, of course, more expensive.

Snow may cause slowdowns in inspection demand, resulting in a much larger demand than can be easily handled, at a later point in time. This may require some flexibility in establishing operating hours. For example, additional operating hours may be required after prolonged periods of unusually cold or snowy weather.

One obvious safety problem associated with cold weather operation is the possibility that in a test lane, when doors are closed, the ambient concentration of carbon monoxide could reach unsafe levels making working conditions dangerous. To insure against unsafe carbon monoxide levels in the test lanes, fresh air circulatory systems should be utilized, and ambient CO monitors provided as warning devices.

## SUMMARY

As can be seen from the previous discussion, the rather severe winter weather associated with the State of Minnesota can have a significant impact on the proposed I/M program, but only if the program is planned, implemented, and operated without regard to the special requirements imposed by the climate of the region. Various measures can be incorporated that will mitigate the impacts for the most part. It is noted that the experience to date with I/M programs of the type being considered here, has been in states where winters tend to be much less severe as compared with Minnesota. There is obviously a possibility that impacts beyond those delineated above will be discovered once Minnesota and other similar states have gained experience with winter operations. The conclusion at this point, however, is that there appear to be no obstacles that cannot overcome rather easily in operating an I/M program in areas that are subjected to severe winter weather.

The more important issue of just how effective I/M will be as a control measure, given the rather cold climate in Minnesota must be considered also. While it is wholly reasonable to expect I/M to be very effective in reducing HC emissions during the mild seasons, there appears to be some question as to how it will affect emissions during the colder periods during the year, particularly with regard to CO emissions. While a definitive answer to the effectiveness question cannot be provided at this time, it is noted that substantial interest in this issue exists, and there apparently will be research conducted in the very near future in this connection.

## REFERENCES


1. Robertson, J. E. The Impact of Vehicle Emissions on Air Quality at Low Ambient Temperatures. SAE Paper No. 741054. October 1974.

2. Miles, Donald L. and Max Homfeld. The Effect of Ambient Temperature on Exhaust Emissions on Cars With Experimental Emission Controls. SAE Paper No. 451052. October 1974.

3. Polak, J. C. Cold Ambient Temperature Effects on Emissions From Light-Duty Motor Vehicles. SAE Paper No. 741051. October 1974.

4. Ashby, H. A., et al. Vehicle Emissions - Summer to Winter. SAE Paper No. 741053. October 1974.

5. Compilation of Air Pollutant Emission Factors, Second Edition. U.S. Environmental Protection Agency, Research Triangle Park, N.C. 27711. Supplement No. 5 to Publication No. AP-42. February 1976.

6. Williams, Marcia. Definition of Vehicle Cold Start Operation. Unpublished paper. U.S. Environmental Protection Agency, Office of Mobile Sources. May 1977.

7. A Review of Carbon Monoxide Emissions from Motor Vehicles During Cold Temperature Operation--the Importance of Cold Start Emissions for Attainment of Ambient Air Quality Standards. Working Draft. Alaska Department of Environmental Conservation. November 1978.

8. Elston, J. Auto Emission Inspection Test Variability. (Presented at the 70th Annual Meeting of the Air Pollution Control Association.) Toronto, Canada. June 1977.

## TECHNICAL REPORT DATA

*(Please read Instructions on the reverse before completing)*

| 1. REPORT NO. | 2. | 3. RECIPIENT'S ACCESSION NO. |
|---|---|---|
| EPA-905/2-79-001 | | |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| Evaluation of Motor Vehicle Emissions Inspection and Maintenance Programs in Minnesota | February 1979 |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT NO. |
| Theodore P. Midurski, Frederick M. Sellars, Nancy K. Roy, Donna L. Vlasak | GCA-TR-79-03-G |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT NO. |
| GCA Corporation<br>GCA/Technology Division<br>Burlington Road<br>Bedford, Massachusetts 01730 | 11. CONTRACT/GRANT NO.<br>68-02-2887, WA No. 6 |
| 12. SPONSORING AGENCY NAME AND ADDRESS | 13. TYPE OF REPORT AND PERIOD COVERED |
| U.S. Environmental Protection Agency<br>Region V Office<br>Chicago, Illinois | 14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Recent data for the State of Minnesota indicate that the National Ambient Air Quality Standards for CO and $O_x$ will not be attained in all areas of the State by 1982, even if all reasonable available control technologies are applied. In view of this, it is likely that the State will request from U.S. EPA an extension of the compliance date beyond 1982. In order for this request to be considered, the state must, among other things, have adopted a firm schedule for implementing a motor vehicle inspection and maintenance (I/M) program in the highly urbanized non-attainment areas. In this connection, the State of Minnesota is currently planning for the implementation of an I/M program. As a part of this effort, detailed analyses have been performed of the costs, personnel requirements, rationale for selecting the particular option, scheduling requirements, and effects that the cold climate in Minnesota might have on emission testing associated with the particular program option being considered. This document reports these analyses.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Automobile engines | Automobile emissions | |
| Exhaust detection | Inspection/Maintenance | |
| Exhaust emissions | Mobile source control | |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS (This Report) | 21. NO. OF PAGES |
|---|---|---|
| Unlimited distribution | UNCLASSIFIED | 150 |
| | 20. SECURITY CLASS (This page)<br>UNCLASSIFIED | 22. PRICE |

EPA Form 2220-1 (9-73)