EPA-905/2-79-006

DATA PROCESSING PROCEDURES AND EQUIPMENT FOR THE WISCONSIN INSPECTION AND MAINTENANCE PROGRAM

Final Report

Contract No. 68-02-2887
Work Assignment No. 8

January 1980

GCA/TECHNOLOGY DIVISION
BEDFORD, MASSACHUSETTS 01730

EPA-905/2-79-006

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION V
CHICAGO, ILLINOIS

Contract No. 68-02-2887
Task Order No. 8

EPA Project Officer
Carlton Nash

DATA PROCESSING PROCEDURES AND EQUIPMENT FOR THE WISCONSIN INSPECTION AND MAINTENANCE PROGRAM

Final Report

January 1980

Prepared by

Frederick M. Sellars
Michael W. Kozenko
Dominic Caracciolo Jr.

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, Task Order No. 8. 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

The Wisconsin Department of Transportation (WDOT) and Department of Natural Resources (WDNR) are currently involved in planning for the implementation of a motor vehicle emissions inspection and maintenance program. Once operational, the program will be generating a considerable amount of data. In addition to the obvious problem of handling and analyzing this data, any system developed must be easily integrated with existing computer systems in WDOT and WDNR.

This document defines the computer hardware specifications for emission testing installations so that needed data can be readily collected, stored, and transferred to WDOT systems. In addition, the required software systems and specifications that will enable manipulation and analysis of data either on the selected I/M contractor's central computer or the State's system are identified. Finally, a model data processing portion of an I/M Request for Proposals (RFP) is provided.

CONTENTS

FIGURES

Number		Page
1	Conceptual layout of a loaded-mode emissions inspection lane	23
2	Generalized data processing flow plan	25
3	State of Arizona vehicle inspection report, obverse side . . .	32
4	State of Arizona vehicle inspection report, reverse side . . .	33
5	Facility computer data links	41

TABLES

Number		Page
1	Operator-Entered or System-Generated Data for each Inspection File	6
2	Inspection Report Data Provided to the State	7
3	Proposed Vehicle Inspection Report Requirements	34
4	Proposed Dynamometer Loadings as a Function of Vehicle Curb Weight and Engine Displacement	37
5	Response Time for Various Processing Modes	53

SECTION 1

INTRODUCTION

The 1977 Amendments to the Clean Air Act require that all areas of the U. S. attain the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO) and photochemical oxidants (O_x) by 31 December 1982. Each state containing an area currently in violation of the NAAQS was required to submit a revision of its State Implementation Plan (SIP) during January 1979, demonstrating compliance by 31 December 1982. Recognizing that all states could not demonstrate compliance by 1982, provisions were made for extending the compliance date to 31 December 1987. To be granted an extension, the SIP revisions must have included (among other things) a specific schedule for the implementation of a motor vehicle emissions inspection and maintenance (I/M) program for those nonattainment areas with urbanized populations greater than 200,000. Failure to submit an acceptable I/M implementation schedule could result in the imposition of sanctions including refusal to grant industrial permits and loss of certain transportation funding aids.

Seven counties of southeast Wisconsin are not expected to be in compliance with the NAAQS for CO and/or O_x. Therefore, an ad hoc legislative committee, working with the Wisconsin Departments of Transportation (WDOT) and Natural Resources (WDNR), had drafted legislation (A.B. 500) requiring these agencies to design, implement and conduct an I/M program in the required areas. WDOT and WDNR are currently planning for the required I/M program. Once operational, the program will be generating a considerable amount of data. In addition to the obvious problem of handling and analyzing this data, any system developed must enable data transfer to the existing computer system now utilized by WDOT and WDNR.

The objective of the effort undertaken in connection with this project, was to define the data processing requirements and computer hardware specifications for emission testing installations so that needed data can be readily collected, stored, and transferred to WDOT and WDNR systems. In addition, required software systems and specifications were defined to enable manipulation and analysis of data either on the selected I/M contractor's central computer, the State's system, or by an independent data processing subcontractor.

The principal objective in defining any data processing plan is to maximize the quantity and quality of necessary information, while minimizing the cost. With regard to Wisconsin's proposed I/M program, the ideal data processing system will gather and store enough data to enable the State to:

- Administer the program
- Evaluate its effectiveness
- Monitor the performance of the contractor(s)
- Monitor the practices of the repair industry

In fulfilling this objective, the State must, of course, keep the cost of the program as low as possible, but do so without sacrificing accuracy, program effectiveness, consumer protection, etc.

The specific data items collected and analyses performed must be defined through a careful analysis of a series of trade-offs. While a few states have undertaken these analyses, giving Wisconsin the advantage of their experiences, the ideal solution is quite state specific. In other words, what may have been deemed well worth a few additional cents per test in one state, may clearly be a waste of money in another state. For example, portions of California and Arizona have centralized, contractor-run I/M test lanes. Both are very much interested in identification of repair shops that are not successfully repairing vehicles. Unlike Arizona, California has state licensing of repair shops. California has determined that the importance of monitoring repair shops is great enough to justify coding of repair information directly onto the data file for all vehicles seeking reinspection following failure of the initial test and receiving repairs. Arizona, on the other hand, requires the information be filled out on the back of the initial inspection form but not entered into the computer. Arizona then periodically selects a small random sample of repair reports and codes and analyzes them. While the Arizona approach involves keypunching costs, the California approach necessitates storage of twice as much information per vehicle on computer tape (about 250 bytes of information per test in California, only 120 bytes of information per test in Arizona). Additionally, the inspector who enters the data at the inspection lane in California must enter more data, spend more time, and risk more errors than the Arizona counterpart.

This report has attempted to present the trade-offs Wisconsin faces in defining the I/M program data processing plan and, when appropriate, provides our recommendations. It remains the state's responsibility, however, to determine what information it feels necessary to have and what price it is willing to pay for this information.

This report consists of six principal sections including this introduction. Section 2 presents a brief summary of the entire report. A definition of the data processing requirements in terms of the specific data items that should be collected, the statistical analyses that will be required to administer the program, and the analyses necessary to monitor the program effectiveness are provided in Section 3. Also included in Section 3, is a discussion of the central computer system now being utilized by WDOT and WDNR, and the data input requirements. Data processing flow plans are provided for data collection, storage, transfer, and analysis. Section 4 discusses data processing hardware requirements in terms of equipment needed, availability, cost, and performance specifications. An analysis of the data processing software requirements is provided in Section 5. Section 6 provides a discussion of considerations regarding data processing procedures in drafting the Request for Proposals (RFP).

SECTION 2

SUMMARY

The objective of the effort undertaken for this project was to define the data processing procedures and equipment required for successful operation of Wisconsin's motor vehicle emissions inspection/maintenance program.

DATA PROCESSING REQUIREMENTS

The principal objective of any data processing plan is to secure the maximum quality and quantity of information while minimizing the cost. The ideal I/M data processing system will collect and store sufficient data to enable the State to:

- Administer the program
- Evaluate its effectiveness
- Monitor the performance of the contractor(s)
- Monitor the effectiveness of the repair industry

To define the data collection requirements it was first necessary to identify the following analyses which must be performed by the State to fulfill the above defined objectives:

- Data editing and correction
- Facility operation information (volume, failure rates, etc.)
- Emission standards evaluation
- Overall program evaluation
- Repair industry evaluation

Following definition of the analysis requirements, it was possible to determine the data input requirements. Data in this category includes both operator-entered and system-generated data. The determining factors regarding the necessity of a particular data element are listed as follows:

- Is the item necessary for conducting the inspection?
- Is the item necessary for the vehicle inspection report?

- Is the item necessary for administrative recordkeeping?
- Is the item necessary for performance of the statistical analyses?

An analysis was made of the inspection scenario, report requirements, recordkeeping demands, and statistical analysis requirements. The resulting data elements are provided in Table 1.

The data elements which will be necessary to include on the data tape provided to WDOT by the contractor were defined. This list is provided in Table 2.

An analysis of the Hill Farm's Regional Computer was undertaken to determine the format requirements of the data tapes transferred to WDOT by the contractor. The Hill Farms system consists of an Amdahl 470 V/6 mainframe which presents no problems in accepting tapes that most minicomputer systems are capable of generating. The tape requirements are outlined below.

- Parity — Odd, 9-track tapes
- Density — can easily handle 800 or 1600 BPI tapes
- Character Code — extended binary-coded decimal interchange code (EBCDIC)
- Data should be labeled as specified by the Hill Farms Regional Computing Center
- One inspection report per record
- Data should be blocked (approximately 10 records per block)

HARDWARE REQUIREMENTS

The general types of computer hardware required for the I/M program data processing include:

- Central processor
- Magnetic tape unit
- Communications interfaces (modems)
- Remote processors
- Flexible diskette storage
- Peripheral interfaces

TABLE 1. OPERATOR-ENTERED OR SYSTEM-GENERATED DATA FOR EACH INSPECTION FILE

Data item	Source	Purpose	Remains on State's file
Queue number	S.G.	T	No
Test or retest (number)	O.E.	R,Q,I,A	Yes
License number	O.E.	R,E,I	Yes
Inspection mode (auto, semiauto)	O.E.	R,T,Q,A	Yes
Vehicle indentification number	O.E.	R,E,I,A	Yes
Model year	O.E.	T,R,Q,I,A,E	Yes
Vehicle make	O.E.	R,E,Q,I,A	Yes
Vehicle style	O.E.	R,E,Q,I,A	Yes
Vehicle classification[a]	O.E.	T,R,Q,I,A	Yes
Mileage	O.E.	R,Q,I,A	Yes
Emission standards	S.G.	T,R,Q,I,A,E	Yes
Emissions measurements	S.G.	T,R,Q,I,A,E	Yes
Pass/Fail/Waiver	S.G.	T,R,E,Q,I,A	Yes
Analyzer I.D.	S.G.	R,Q,I	Yes
Date, time	S.G.	R,E,I,A	Yes
Serial number of report	S.G.	R,E,Q,I	Yes
Serial number of previous report	O.E.	R,Q,I,A	Yes
Station and lane number	S.G.	R,Q,I,A	Yes
Inspector number	S.G. or O.E.	R,Q,I,A	Yes
Test modes performed	O.E.	T,R,Q,A	Yes
Inspection abort, reason	O.E.	T,R,Q,A	Yes
$CO + CO_2$ sum/std/decision	S.G.	T,R,Q,A	Yes
Special case code	O.E.	T.R,E,Q,I,A	Yes
Contractor management data	S.G. or O.E.		No (unless given to public)

Key: S.G. = System generated

O.E. = Operator entered

T = Test performance

R = Recordkeeping

E = Enforcement

Q = Quality assurance

I = Inspection report

A = Statistical analyses

[a]Includes number of cylinders and weight class.

TABLE 2. INSPECTION REPORT DATA PROVIDED TO THE STATE

Data item	Size (bytes)
Test or retest(s)[a]	2
Inspection mode (manual, automatic, semiautomatic	1
License number	6
Vehicle Identification Number (VIN)	13
Model Year	2
Vehicle make	5
Vehicle style	4
Vehicle classification	1
Mileage[b]	3
Emission standards:	
high cruise CO	4
high cruise HC	4
low cruise CO	4
low cruise HC	4
idle CO	4
idle HC	4
Emissions measurements:	
high cruise CO	4
high cruise HC	4
low cruise CO	4
low cruise HC	4
idle CO	4
idle HC	4

Data item	Size (bytes)
Pass/Fail:	
high cruise CO	1
high cruise HC	1
low cruise CO	1
low cruise HC	1
idle CO	1
idle HC	1
Analyzer i.d.	3
Date: day/month/year	6
Time: hour/minute	4
Serial number of report	7
Serial number of previous report[c]	7
Station number	2
Lane number	1
Inspector number	3
Test modes performed	1
Inspection abort/reason	2
$CO + CO_2$ sum (measured)	2
$CO + CO_2$ sum (standard)	2
$CO + CO_2$ sum (valid/not valid)	1
Special case i.d. and code	2
Waiver yes/no	1
TOTAL	135

[a] 1 for test or retest identification, 1 for numbering additional retest(s)

[b] thousands only

[c] for retest

- CRT display/data entry terminals
- Teleprinters, report printers
- High-speed (line) printer

The general specifications of suitable equipment for each type of hardware are outlined below.

Central and Facility Processors

- Minicomputer central processing units
- 16-bit word length
- 24-32 kilowords of memory (24 for facility processors, 32 for the central processor)
- Metallic oxide semiconductor (MOS) memory
- RS-232C interfacing with peripherals

The facility Processors should be capable of performing the following:

- Control progress of vehicles through the test lane
- Process vehicle identification data
- Accept emission measurement data
- Correlate vehicle data and select failure standards
- Compare measured values to limits separately for each input
- Output test data for report printout
- Output test data onto bulk storage devices

The Central Processor should be capable of performing the following:

- Communication with each facility processor
- Data collection and data entry for inspection information
- Data validation and compilation for periodic submission to the Department of Transportation
- Data analysis and summarization for network operation management
- Data management reporting

- Network software maintenance

- Preparation of magnetic tape file of inspection data for submission to the Department of Transportation on a periodic basis

Communication Interfaces

- Normal voice grade telephone line communication modems
- RS-232C interfaces
- Asynchronous, full-duplex (bidirectional) communication
- 1200 baud
- Automatic "dial-up" from headquarters computer
- Automatic answer at facility computers

Mass Data Storage Devices

- Flexible magnetic disk (diskette or floppy disk)
- 250,000 byte storage
- RS-232C interface

Magnetic Tape Unit

- 9-track, ½-inch industry standard tapes
- 800 or 1600 bpi
- EBCDIC character code

CRT Display/Data Entry Terminals

- Cathode Ray Tube (CRT) display
- Standard keyboard
- Full-duplex communication
- ASCII character code
- RS-232C interface
- 12-inch (diagonal) screen
- 64 displayable characters, at least 0.19 inch high by 0.125 inch wide
- 5 x 7 dot matrix characters
- 80 characters per line

- 12 lines displayable on full screen
- Nondestructive cursor
- Fields protection
- Tab to unprotected field

Teleprinters and Report Printers

- Inspection report printer should use 8½- by 11-inch report size forms (one original and two copies)
- ASCII transmission code
- RS-232C interface
- 80 characters per line
- 30 characters per second (300 baud)
- 64 character set, (0.19 by 0.11 inch)
- 7 x 7 dot matrix characters

High-Speed Printer

- ~300 lines per minute
- 132 columns per line
- RS-232C interface

Exhaust Measurement Subsystems (EMS)

The EMS should be capable of controlling either automatically (in conjunction with the System Controller) or manually all emissions measurement and test control functions. The EMS should contain its own control processor, the EMSCP, which should meet the following specifications:

- 8-bit microprocessor
- Interfaced with, but functionally independent of the System Controller
- Capable of outputting results through the Inspection Report Printer during System Controller downtime.

The EMS should also contain a Control Pendant, which consists of a small keyboard device enabling the inspector to start, stop, and control the test process. A Test Display Panel is used in conjunction with the Control Pendant to prompt the inspector with instructions and display test information such as road speed, operation mode, etc.

Equipment Costs

Estimates were obtained for suitable equipment meeting the above specifications, these estimates are outlined below:

Facility System Controllers	$ 7,000 - 9,000 each
- communications interface	$ 6,000 - 7,000
Headquarters Control Processor	$13,000 - up
- communications interface	$ 6,000 - 7,000
Modems	$ 800 - 1,000 each
Flexible disk units	$ 3,500 - 4,500 each
Magnetic tape unit	$ 8,000 - 18,000
CRT Terminals	$ 1,500 - 2,000 each
EMS's	Contractor fabricated
Teleprinters and inspection report printers	$ 900 - 1,600 each
Line printer	$ 6,000 - up
Graphics CRT	$ 3,500 - 7,500

SOFTWARE REQUIREMENTS

The software requirements were divided into three major categories:

- SYSTEM software
- Data transfer software
- Analysis software

SYSTEM Software

SYSTEM software consists of all programs necessary to enable the SYSTEM (all hardware and software used in the inspection process) to fulfill the following functions:

- Prompt for, accept, and verify vehicle identification data from the Vehicle Identification Terminals (VIT)
- Coordinate the emissions inspection through the EMS
- Correlate vehicle emissions data, select appropriate standards and dynamometer loadings, make pass/fail determinations
- Output test data for report printout and to bulk storage
- Perform and keep records of emissions analyzer calibration checks as well as all other SYSTEM maintenance data

Related to the SYSTEM software is the EMS software, which consists of programs necessary to enable the EMS to perform the following:

- Prompt and cue the inspector during the inspection
- Convert raw analog measurements into digital format
- Perform all necessary calculations
- Monitor and correct dynamometer loadings, instrument drift, etc.
- Collect and analyze emissions, make pass/fail determinations
- Display appropriate information during the inspection (road speed, horsepower load, mode of test, test complete, warning messages, etc)

The SYSTEM and EMS software should consists of real-time application programs written in an Assembly or Macro-level language. Assembly is the preferred language for real-time applications as it can be much more efficient than higher level languages such as FORTRAN or PL/I.

Data Transfer Software

Software in this category consist of all programs necessary to enable transfer of data from facility computers to the central computer system. This software controls the modems and telecommunication links and like the SYSTEM and EMS software, should be programmed in an Assembly-level language.

Data Analysis Software

Two subcategories of software exist under this heading, that developed by the contractor (recordkeeping, reporting, etc) and that used by the State (program evaluation, cutpoint selection, etc). These "batch-processing" programs can be written in higher level languages such as FORTRAN or PL/I.

General Software Requirements

All software should be developed under the general programming approach known as "Structured Programming." Structured programming involves breaking the program "problem" into smaller, more manageable components. This involves a technique known as modularization which essentially means the program will consist of a number of independent modules (or subroutines). A program developed under this technique will achieve four basic goals (listed in order of importance):

- Reliability – Does the program consistantly give dependable results that are accurate?
- Modifiability - Can the program be modified easily to respond to changing standards, requirements or devices?

- Understandability – Since the State will likely reserve the option to purchase the SYSTEM, including all software, will the State programmers be able to understand the program logic well enough to use, update, and modify it?

- Efficiency – Does the program operate as efficiently and inexpensively as possible?

Software Documentation

Although there is some overlap between them, four general types of documentation were defined:

- Design documentation
- Construction documentation
- User documentation
- Maintenance documentation

Design documentation is a "blueprint" for developing the data processing system. This would constitute the overall plan for designing and implementing the software and should be a proposal requirement. Construction documentation includes precise formats, data layouts, algorithms, program names, etc. and should be developed concurrently with the software. This type of documentation should be a contractor requirement for the regular progress meetings with the State during software development. User documentation includes user's manuals and operator's guides concerning all functions of the system and how to use them. Maintenance documentation consists of complete descriptions of the system in its final format including information on the limitations of the system, procedures to be followed in updating or modifying the system, and complete listings of all program statements for all developed software.

State Developed Software

The State will be required to develop software enabling performance of the program analyses described previously. There are three options open to the State in fulfilling this requirement:

- Develop specific software "in-house"

- Use preexisting software packages

- Obtain the services of a software firm to develop software and/or conduct the analyses.

The preferred solution would be in-house development of software, provided that the State programming staff has sufficient time and expertise. Some existing software packages may be suitable for the statistical applications required. If an analysis is to be performed on a one or two time basis, use of preexisting packages is encouraged. If a particular set of analyses will be performed periodically, however, application-specific programs should be developed as they can be made more efficient and therefore, cheaper to run. This is because most software packages are designed to handle a number of different situations, whereas a program developed for a specific application can eliminate a lot of unnecessary capability.

Another alternative would be to hire a "software house" to develop the application-specific programs needed. If the State's in-house staff lacks the time and/or expertise to develop the required software, contracting the work out is the most logical alternative.

SOFTWARE DEVELOPMENT COSTS

Software development costs were estimated based on discussions with software houses, experiences of other states, and an analysis by the GCA data processing staff. Based on these sources the following estimates were developed:

	Man-hours		Man-hours
Contractor's software	3,500	State's software	1,000
Contractor's documentation	1,000	State's documentation	200
	4,500		1,200

A standard $30 per hour figure was used to translate hours into a dollar cost, equalling $135,000 for the contractor and $36,000 for the state.

RFP CONSIDERATIONS

The quality of proposals submitted is somewhat directly proportional to the quality of RFP issued by the State. It is important that the RFP be free from ambiguities and outlined in very specific terms the functional requirements of the program. There is a risk, on the other hand, of developing an RFP that is too specific. While the bidders must be made well aware of what must be accomplished, the RFP should be left somewhat open concerning how it is accomplished. By being overly specific, the bidders could be prohibited, or at least discouraged, from proposing what could be a higher quality or more cost effective system than that specified within the RFP. A model data processing portion of an I/M RFP is provided in Section 6.

SECTION 3

DATA PROCESSING REQUIREMENTS

As discussed in Section 1, the primary objective of any data gathering and processing system is to maximize the quality and quantity of information obtained, while minimizing the cost. In order to meet this objective in defining the data processing requirements for Wisconsin's proposed I/M program, it is important that all essential data is collected and retained, but no duplication of data exists. For example, the State may, at some point want to determine if temperature variation within the test lane is affecting test results. It would then be necessary to keep a record of the lane temperature. Only one log of temperatures need be kept for each facility, however. Recording temperature on each inspection record would be an unnecessary duplication of effort.

In order to define the specific data elements that should be collected and stored, it is first necessary to determine how this data is to be utilized. The data generated, gathered, and stored from the I/M program will be used for two primary purposes; first, to perform analyses to administer the program, and second, to evaluate the program's effectiveness and the performances of the I/M contractor, subcontractors, and the repair industry. Related to identification of these required data elements is the issue of the division of analysis responsibilities between the contractor(s) and the state.

ANALYSIS REQUIREMENTS

There are a number of analyses that should be performed periodically to properly administer and evaluate the program. Some of these analyses can be regularly provided by the I/M contractor, some are more appropriate for the State to undertake, some may be best handled by an outside data processing contractor. The important administrative and evaluative analyses are defined below, along with rationale for conducting them and our recommendations concerning where the responsibility for each should lie. The software requirements for these analyses are discussed in greater detail in Section 5.

Data Editing

One of the most important sets of analyses involves verification and correction, if necessary, of all collected data. The importance of edit checks cannot be overemphasized as all decisions and actions based on other analyses are dependent on the accuracy of the data used. Without reasonably accurate data, all other program analyses become meaningless. Discussions with individuals currently involved in I/M data processing indicated that most data errors occur during the initial entry at the inspection facility. This seems logical since the inspector who enters the data at the "rapid throughput" inspection lane is performing under strict time constraints as the cost effectiveness of centralized programs is quite time dependent.

In a previous analysis,[1] it was determined that even a 1-minute increase in throughput time would result in a 29 percent increase in the "breakeven" fee charged to the motorist. While some quality assurance procedures should be performed during data entry, the time dependence of the centralized approach to I/M will limit the extent of edit checking at the data entry point itself. As a result, additional data processing of computerized edit checks will be required. There are two principal edit procedures that should be included in the editing sequence: identification of errors and their correction, each of which is described below.

Identification of "Bad" Records--

The first step toward correction of errors is, quite logically, their identification. Data collected from the I/M program will exist in two formats, numeric and alphanumeric. The procedure used in the identification of errors will, of course, be dependent on the data format. Data in numeric format can be compared against reasonable upper and lower limits to detect possible errors. Pollutant concentrations exceeding the maximum measurement range of the emission analyzer, for example, may be assumed incorrect. Similarly, a numeric entry can also be verified by other means dependent on the specific variable in question. The number of cylinders in an engine is, in most instances, an even number. Odd numbers for this parameter, though not errors in all instances, can be identified and their validity checked individually.

Alphanumeric fields must be validated by comparing the field against an array of possible "correct" entries. The manufacturer, for example, can be checked against a list of all manufacturers. This will uncover misspelling or improper entries, for example, FODD for FORD or OMNI instead of DODGE.

Error Correction--

After identification of an error, a decision as to what action to take must be made. In some instances, the error will be such that the intended entry will be obvious, the misspelling for FORD, for example, or the entry of a model name common to only one manufacturer in place of the manufacturer code. In other instances different data within the same record can be used; say, for instance, the manufacturer code was not identifiable but the VIN was properly entered and recognizable. In yet other instances, the error will be such that the correct entry cannot be determined. These records should simply be excluded from analyses dependent on that particular field.

The responsibilities for error correction should be divided as follows. The contractor should be responsible for providing limit checks and checks for missing data, etc., at the time of the inspection. The state should retain responsibility for data verification (i.e., matching VIN to registration numbers, etc.)

Facility Operation Information

Analyses in this category include basic administrative recordkeeping tasks concerning the actual operation of the inspection facilities. The State will want to keep track of statistics on the number of vehicles handled, how many passed/failed, etc. These analyses are described in detail below.

Volume Information--

Analyses should be made periodically on the inspection volumes at each facility. Additionally, the volumes should be broken down by day of the week/ month and the time of day. Information gained from these analyses will be helpful in assessing the operating hours of each individual facility for seasonal adjustment and in determining the effectiveness of the public information program's advertising of hours. If one facility is handling considerably more vehicles per month than a nearby facility, perhaps the location of the less-utilized facility should be advertised more. If registrations are staggered on a monthly basis, the end of each month will likely be bringing greater demand for inspection. Analyses regarding inspection demand as a function of day of the month can be utilized to determine both the extent of the problem as well as the effectiveness of the solutions (public information, etc.). The inspections should also be categorized as initial inspections, reinspections, second or subsequent reinspections, special tests, idle-mode-only tests, and refused inspections for safety reasons or no registration.

Failure Rates--

The inspection results should be categorized and summed. Statistics such as failure rates should be broken down by facility and lane and be analyzed periodically for consistency, or to determine seasonal effects. Failure rates should also be broken down by pollutant, vehicle type, make, model, engine configuration, year of manufacture, etc. to determine possible inspection requirement biases for or against a particular type of vehicle and to determine if the selected cutpoints are appropriate.

The same analyses of the distribution and nature of failures should be performed for reinspections as well to evaluate the success of the repair industry and effectiveness of the diagnostic information provided. Before and after reinspection, pollutant concentrations should be compared to detect whether or not motorists are seeking repairs at all. Analyses should also be made regarding how many vehicles would have failed the cruise portions of the inspection, particularly for retests. This will give an indication as to whether the repair shops are fixing vehicles completely or just readjusting them to pass the idle test.

Many of the analyses in this category can be performed by the I/M contractor, who should be required to submit monthly (or biweekly) reports on facility operations. The contractor's report should be limited to the following volume information.

- Total number of inspections
  - How many were initial inspections?
  - How many were reinspections?
- Pass/Fail rates
  - For initial inspections
  - For reinspections
- Number of inspections refused
  - Safety reasons
  - No registration
  - Other reasons
- Number of exemptions and waivers issued
- Equipment calibration information

The report should, of course, be backed up with data tapes containing all of the test records to verify the report information, and to enable the State to perform the remaining analyses discussed under this category.

Cutpoint Evaluation

Theoretically, the existence of an I/M program will gradually improve the condition of the inspectable fleet. Since failure rates are set to fulfill a number of criteria beyond emission reduction considerations (public acceptance, etc.), the emission level cutpoints can periodically (usually on an annual basis) be adjusted to gain further emissions reductions while maintaining approximately the same failure rate. The procedure to accomplish this adjustment is relatively straightforward. Raw test scores from initial inspections are rank ordered from the greatest concentration to the lowest and the cutpoint is defined as the percentile value equivalent to the desired failure rate. This analysis must be performed for both CO and HC concentrations for as many vehicle classes as there are standards. According to the current draft emissions inspection rules, this would entail at least 9 classifications based on model year, number of cylinders, and vehicle type. Additionally, the process would have to be repeated for high cruise (approximately 50 mph), low cruise (approximately 30 mph), and idle standards.

After derivation of the cutpoints, the rank ordering used in their calculation should be broken out by manufacturer and model to verify that the standards are not biased for or against any specific vehicle make or model.

The responsibility for these analyses should be assumed by the State, although assistance could be obtained from the I/M contractor.

Program Evaluation

WDOT and WDNR will likely be asked to periodically report to the State Legislature on the status and effectiveness of the program. WDOT will probably be requested to report on the status of the contractor's operations and the emission reduction effectiveness of the I/M program which is the difference, over time, of the average tailpipe pollutant concentrations for each inspection class.

Additionally, this data can be integrated with air quality data collected by WDNR, to determine if the program is actually meeting its objectives.

Program evaluation should clearly be the State's responsibility, however, assistance can be sought from the I/M contractor.

Repair Industry Evaluation

A number of analyses regarding the repair industry will be useful as a measure of the effectiveness of mechanic's training programs as well as for consumer protection purposes. The State will certainly want to keep track of how much money motorists are spending on repairs. Repair information from motorists applying for retests should be evaluated, and average and median repair costs calculated. Statistics such as how many repair cost waivers were issued can be used to assess the appropriateness of the repair cost ceiling.

The market distribution of repair work should also be evaluated to determine where repairs are being performed (garages, dealers, tune-up specialists, etc.). This information is helpful in determining where and to whom mechanics training should be focused. Similarly, reinspection failures should be examined to identify what shops are doing poor repair work; "bad" shops can then be encouraged to participate in training classes. Repair information can be compared to inspection results to determine the appropriateness of the repair work performed. Analyses such as these will also enable identification of unscrupulous mechanics who perform inappropriate or excessive repairs. The repairs performed can also be compared to repair costs to identify shops that are overcharging.

Emission reductions from test to retest can be analyzed to determine the effectiveness of the repairs. This information can also be compared between shops that have had mechanics attend training programs and shops that have not, to evaluate the training programs. This data, along with reinspection success rates, can be used to encourage more mechanics to seek training.

Repair industry evaluations should be the State's responsibility, although these analyses could be contracted out to an independent data processing firm.

Currently, the draft inspection rules mandate that the inspection report provide space for the following:

- Itemization of the repairs performed
- Cost of repairs (or cost estimate of repairs required if such repairs will exceed the maximum specified repair cost)

- Name and address of the business firm (or person) making the repairs

- Signature of person certifying repairs

In addition, to be considered for a waiver due to excessive repair cost, the following information must also be recorded:

- Idle emissions concentration of HC and CO upon completion of repair if an NDIR analyzer is used

- Serial number or identification number of emission analyzer if used by the individual in measuring the emission concentrations concentrations

- For vehicles greater than 10 years old, or requiring repairs that will exceed the maximum repair costs, evidence of receiving a "low emission tuneup," as defined in the proposed rules, will be a waiver prerequisite.

One question that arises here is whether this data should be routinely entered into a computer file when the vehicle arrives for reinspection, or will it be sufficient to simply keep the inspection form and periodically select a random sample, code the information, and then analyze the data? Two states' approaches to this problem were briefly discussed in Section 1. California codes this information upon reinspection at the test facility; Arizona uses the random sample approach. The justification for coding all of the repair information in California, and thus, greatly increasing the size of each inspection report file, is that unlike Arizona, California has formal licensing of repair shops. This information would be very helpful in determining which mechanics are unsuccessful at correcting problems, and which shops are reporting emission levels quite different than those measured at the inspection facility. This extra information, of course, comes at an extra cost. The repair information described above will affect data processing costs in four areas:

1. Data storage costs
2. Data processing costs
3. Data transmission costs
4. Data entry time.

By coding all repair information at the inspection facility each inspection data file will nearly double in size. As a result, the cost of storing data will increase since more tape space will be required. Processing the data will be more costly as the larger record size will occupy more disk and memory space during analysis. The data transmission time (time required to transfer data from each inspection facility to the contractor's central computer) will also increase. The additional cost to the consumer will not be significant as a result of the increases in these three areas. Increases in the fourth area, however, will be significantly more costly. As previously mentioned, the time requirements of each task in a centralized I/M facility are very crucial. A

1-minute increase in throughput time would result in an approximate fee increase of 29 percent. The exact throughput time increase will depend on the failure rate, thus, the number of times the inspector will be required to enter repair information. A 1-minute increase would not be unreasonable to expect. An alternative approach would be to add another inspector to each test lane. The additional inspector could drive the vehicle to the second position while the first inspector begins entering information on the next vehicle. One additional inspector per test lane would add at least another 10 percent to the inspection fee.* Unlike California, Wisconsin does not have formal licensing of mechanics and repair establishments. Further, the Wisconsin I/M Task Force has indicated that it is reluctant to endorse further State regulation of the repair industry; therefore, a repair shop certification program is currently not being considered.[2] As a result, the random sample approach used in Arizona may be adequate for Wisconsin. It should be noted that the Arizona approach has been effective at identifying poor repair industry practices.

Other Analyses

It is reasonable to assume that the State will wish to perform additional analyses when situations arise. For example, routine analyses of repair and retest data may indicate that some motorists have not sought repairs at all. An analysis of the time span between initial test and retest can easily be undertaken to determine the frequency of motorists trying to "beat the system." Periodically, the State may wish to take advantage of the "captive audience" provided by mandatory inspections for surveys or questionnaires. Simple response questions can be coded on the form to relate opinions about the program to the success of the motorist in passing inspection, age of the vehicle, etc. To allow for these extra analyses, without subsequent software modification, input records should contain some reserved space to accommodate additional data, should it become necessary. This is discussed in greater detail in the following subsection on Input Requirements.

INPUT REQUIREMENTS

Data items included in this category consist of both inspector-entered items and system-generated items. In order to minimize the inspection time, as much data as possible should be system generated. This includes both items that are totally independent of the inspection process (date, time, lane number, etc.) and items derived from inspector-entered data (cutpoints based on vehicle model year and class). Certain input or generated data items are necessary only during the inspection process and should not be permanently transferred to computer tape; for example, a queuing number may be assigned to each vehicle to identify it during the inspection process. This is an important variable since in a six-lane facility as many as 18 vehicles may be undergoing inspection at the same time. After completion of the test, however, the queuing number is of little importance and should be deleted from the permanent inspection report file.

---

*Based on cost assumptions utilized in reference 2.

The determining factors regarding the necessity of a particular data input item are listed below:

- Is the item necessary for conducting the inspection?
- Is the item necessary for the vehicle inspection report?
- Is the item necessary for administrative recordkeeping?
- Is the item necessary for performance of the statistical analyses?

In addition to State-required items, the contractor may desire certain information for management purposes. For example, the time differential between logon and logoff for each test by lane would be useful to check the efficiency of certain inspector "teams" to see what combinations are most effective. This data is probably of little importance to the State, so, it should not be included in the final tape file of each inspection report. The tape that is finally turned over to the State, then, will be a subset of all information collected. The contractor should be free to collect as much management information as necessary and turn over to the State only the information the State wants. However, any information that is provided to the public should be supplied to the State as well. These issues are discussed in greater detail in Section 5, RFP Considerations.

Emission Inspection Scenario

Since data entry, generation and alteration can occur at several points during the inspection process, a brief review of the actual inspection scenario is presented here for reference. As shown in Figure 1, a loaded-mode emissions testing lane consists of three positions. Each of the three positions has essentially one principal function: data entry, emissions testing, results reporting, respectively.

Position 1--

Most of the data entry occurs at the first position. Upon arrival at the facility, the vehicle owner presents registration information to an inspector who enters the appropriate data items into the computer. The computer creates a unique file for this vehicle and, based on the entered data determines whether the vehicle should be subjected to all three testing modes (high cruise, low cruise, and idle) or if elimination of one or more of these tests is appropriate. The computer then determines what standards the vehicle must meet, selects the proper dynamometer loadings to apply, and signals the inspector to move the vehicle to position 2.

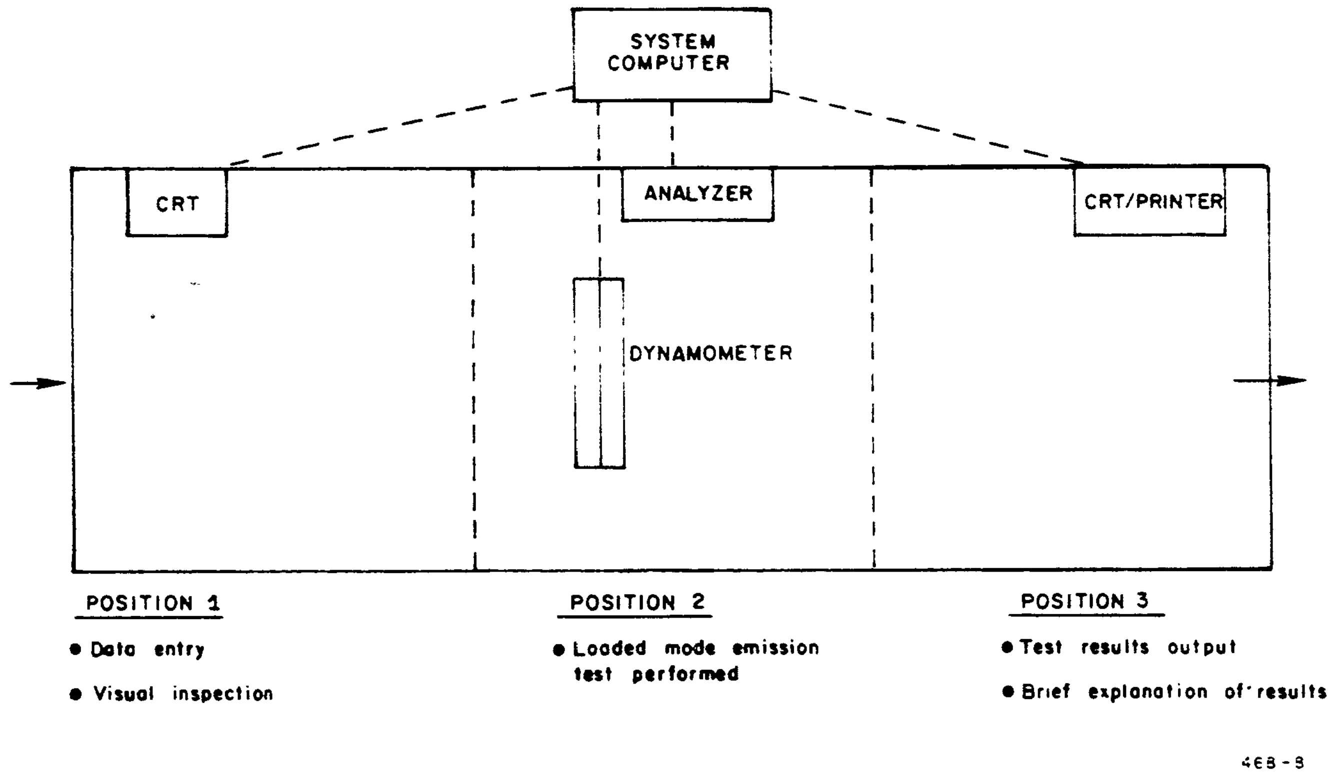


Figure 1. Conceptual layout of a loaded-mode emissions inspection lane.

Position 2--

The actual emission inspection occurs at this position. If the vehicle is subject to the high cruise test, the computer instructs the operator to increase the driving speed to approximately 50 mph* (on the dynamometer). When the vehicle has reached a stable speed within a specified tolerance, the analyzer will be instructed by the computer to begin sampling. For quality assurance purposes, several samples are taken, the number of which is predetermined. After collection and measurement of the samples, an average is calculated and the result stored. The computer then instructs the inspector to change speed to approximately 30 mph and the process is repeated. After completion of the low cruise test the vehicle is tested at idle. When the three tests have been completed, the computer determines whether the vehicle has passed or failed each portion for both CO and HC. The computer then informs the inspector that the test is complete and to move the vehicle to position 3.

Position 3--

At the third position, the vehicle inspection report is printed out. The computer, at this time, finalizes the inspection file and stores it on disk. The final report file is "protected," prohibiting any alteration to its contents.

A generalized data flow plan for the inspection process is provided in Figure 2.

Data Items

To determine the data input requirements, an examination must be made into the specific demands for each of the categories listed previously; conducting the inspection, the inspection report, recordkeeping, and analysis requirements. Since considerable overlap will exist among these categories, the first classification presented here will be the vehicle inspection report, which includes the most items.

Vehicle Inspection Report

In the draft of proposed rules for the inspection process, specifications for the vehicle inspection report information are provided. These requirements are summarized in Table 3. Items A through G in Table 3 are inspector-entered data, items H through N can be generated by the computer system, item O, inspector number, can either be entered or generated depending on how frequently inspectors change positions.

The vehicle inspection report is generated by the computer and printed at the third position of the inspection lane, where an inspector can briefly explain the results to the vehicle owner. An example of a typical report, from Arizona, is provided in Figures 3 and 4. This report form will differ somewhat

---

*The actual speed and horsepower loading will vary depending on the vehicle classification (weight and number of cylinders), as determined by the computer. For simplification the high cruise will be referred to as 50 mph, the low cruise as 30 mph.

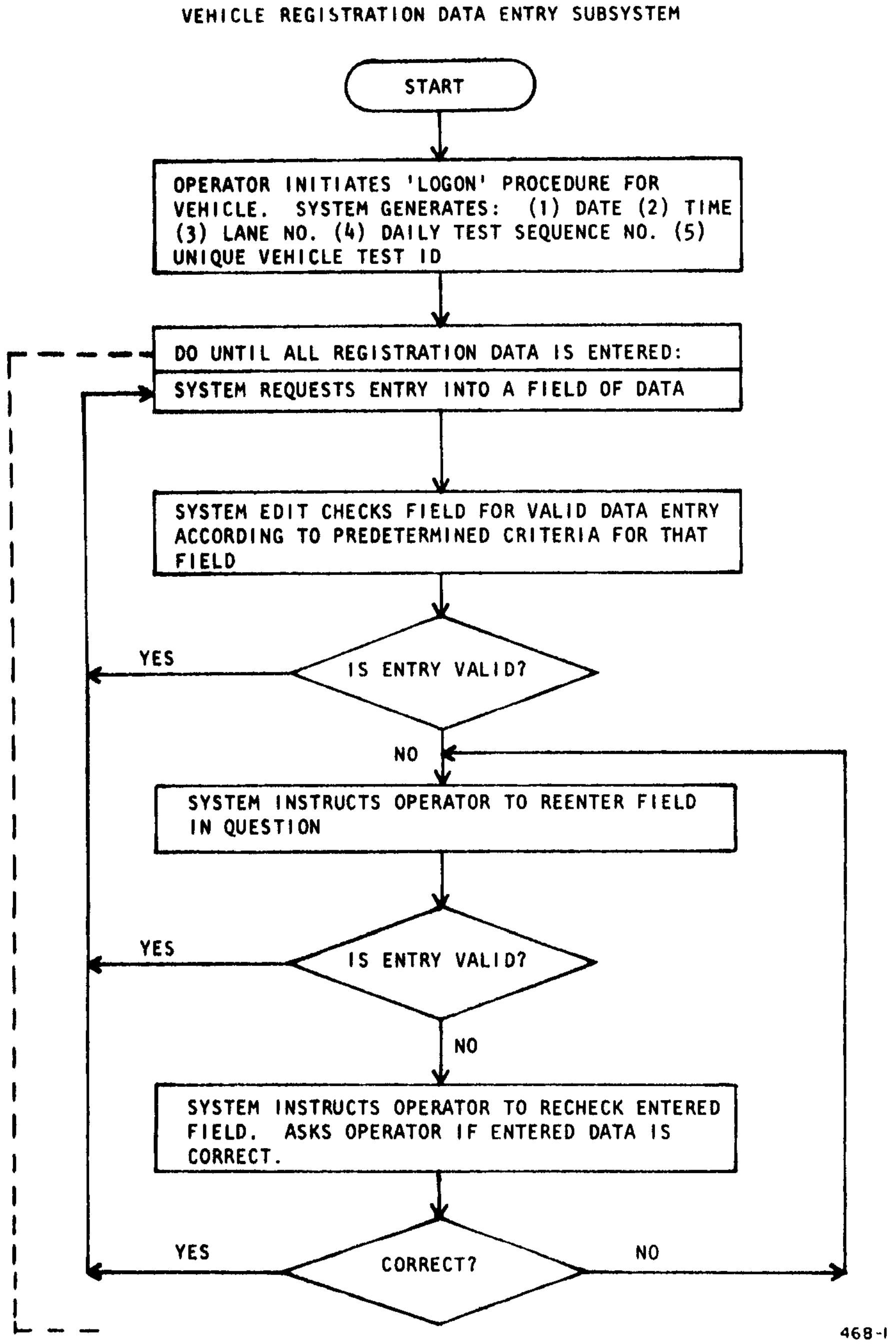


Figure 2. Generalized data processing flow plan.

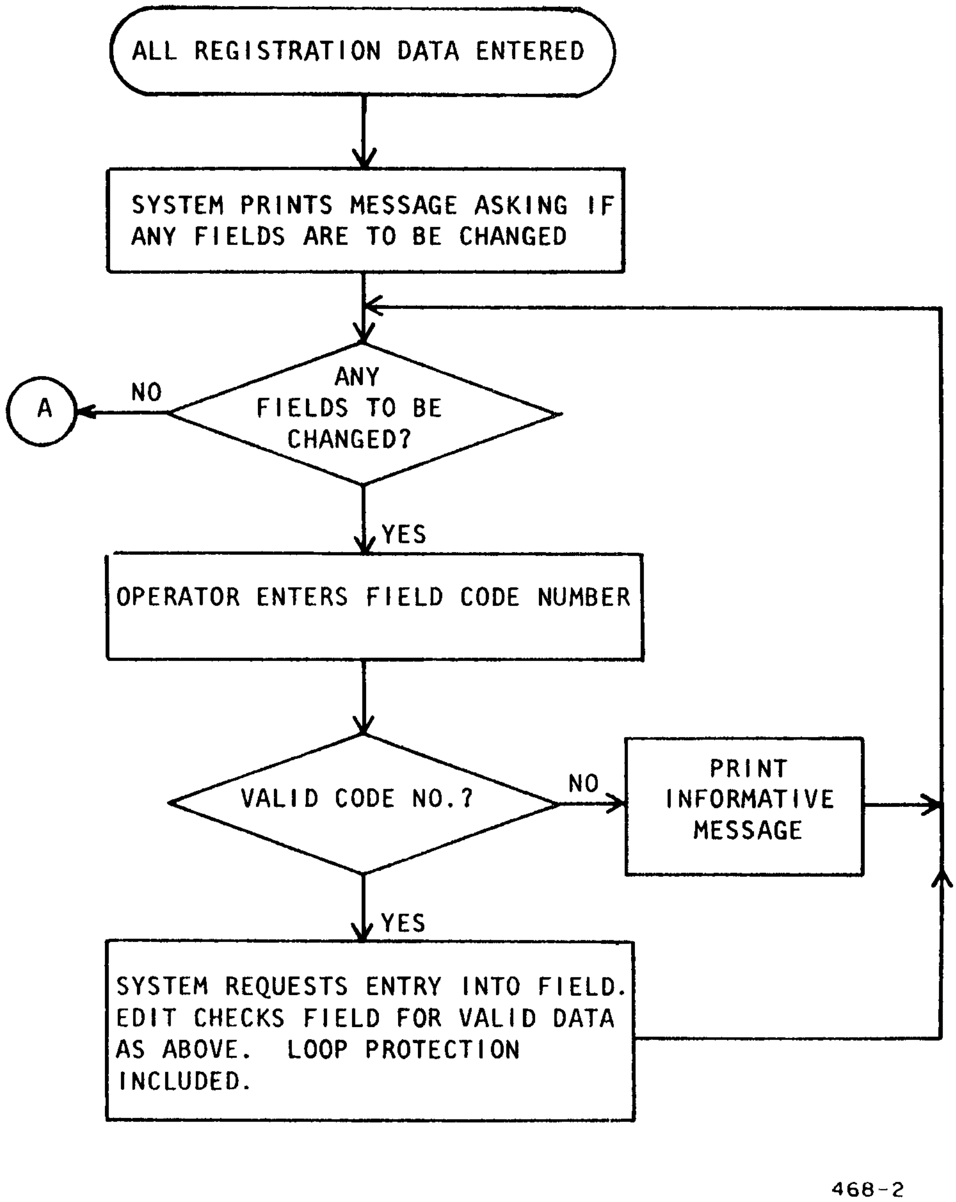


Figure 2 (continued).

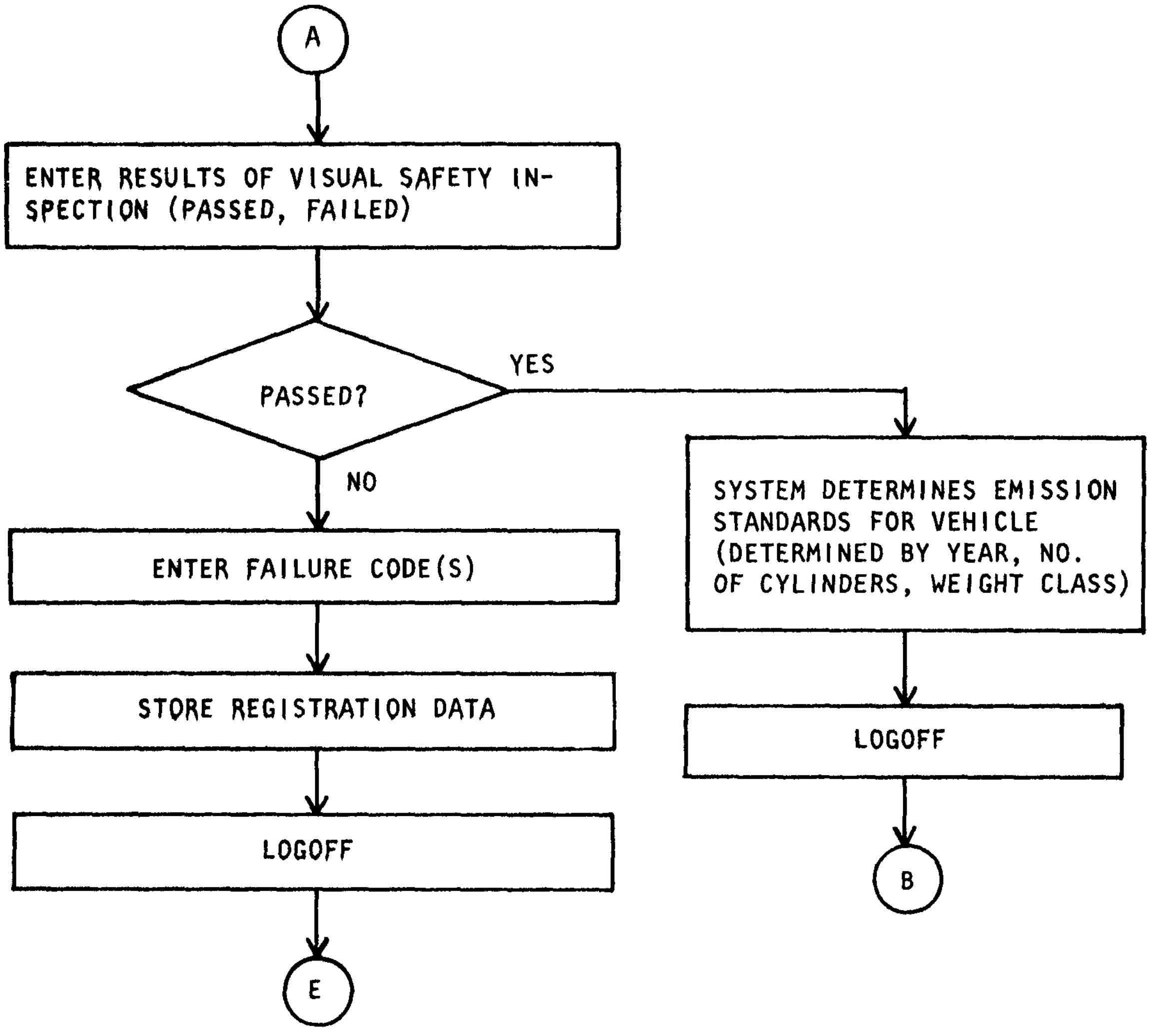


Figure 2 (continued).

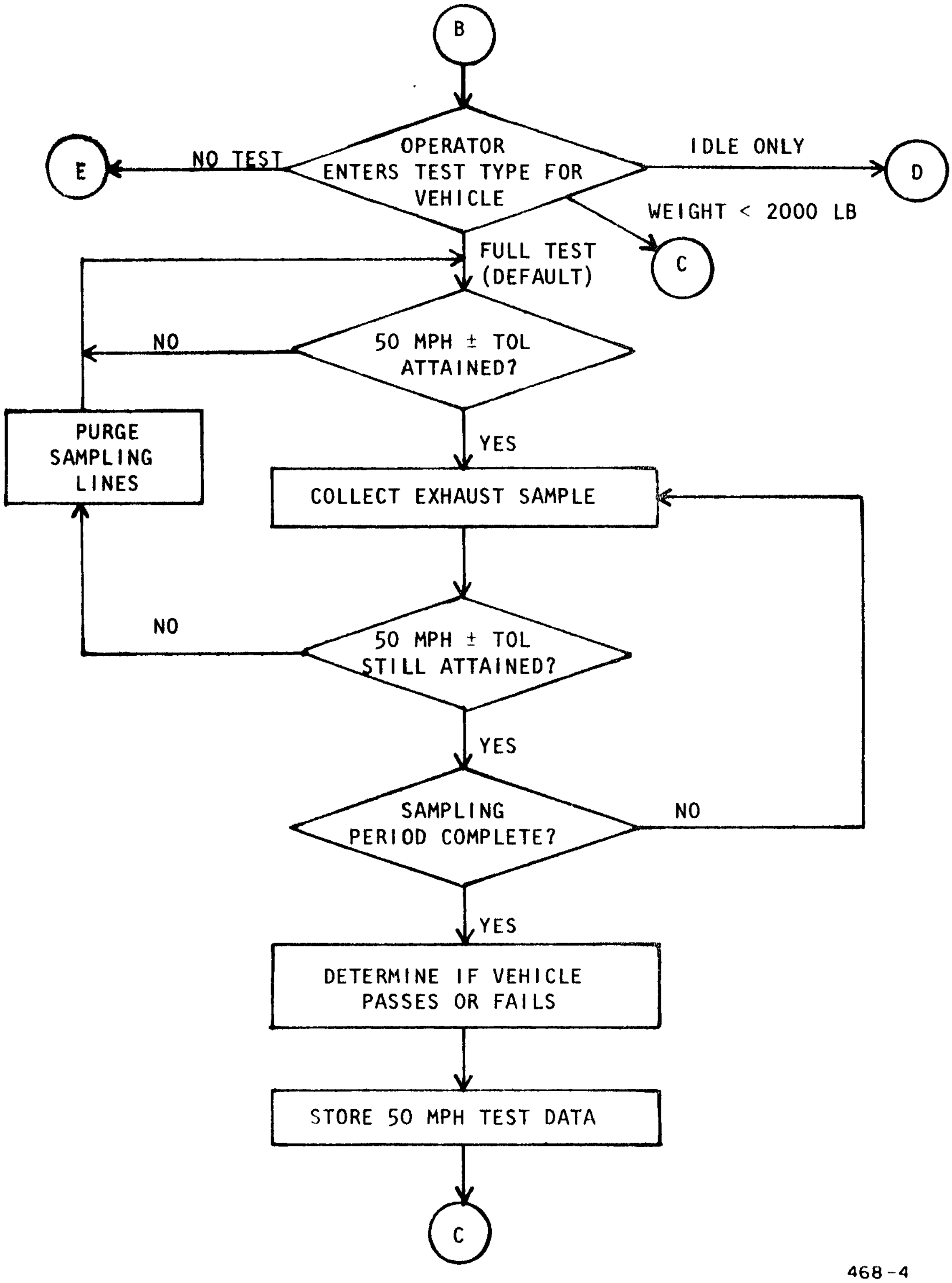


Figure 2 (continued).

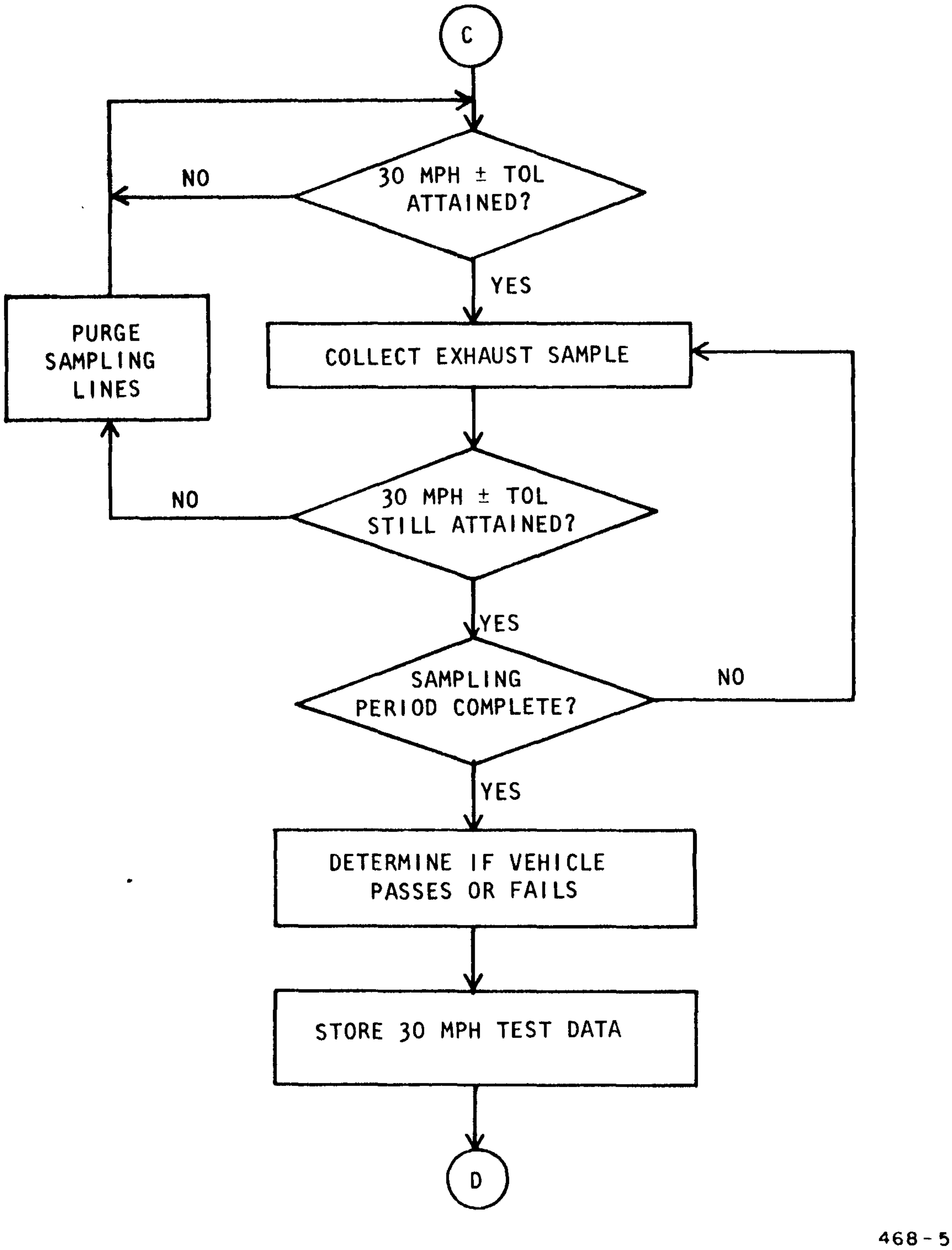


Figure 2 (continued).

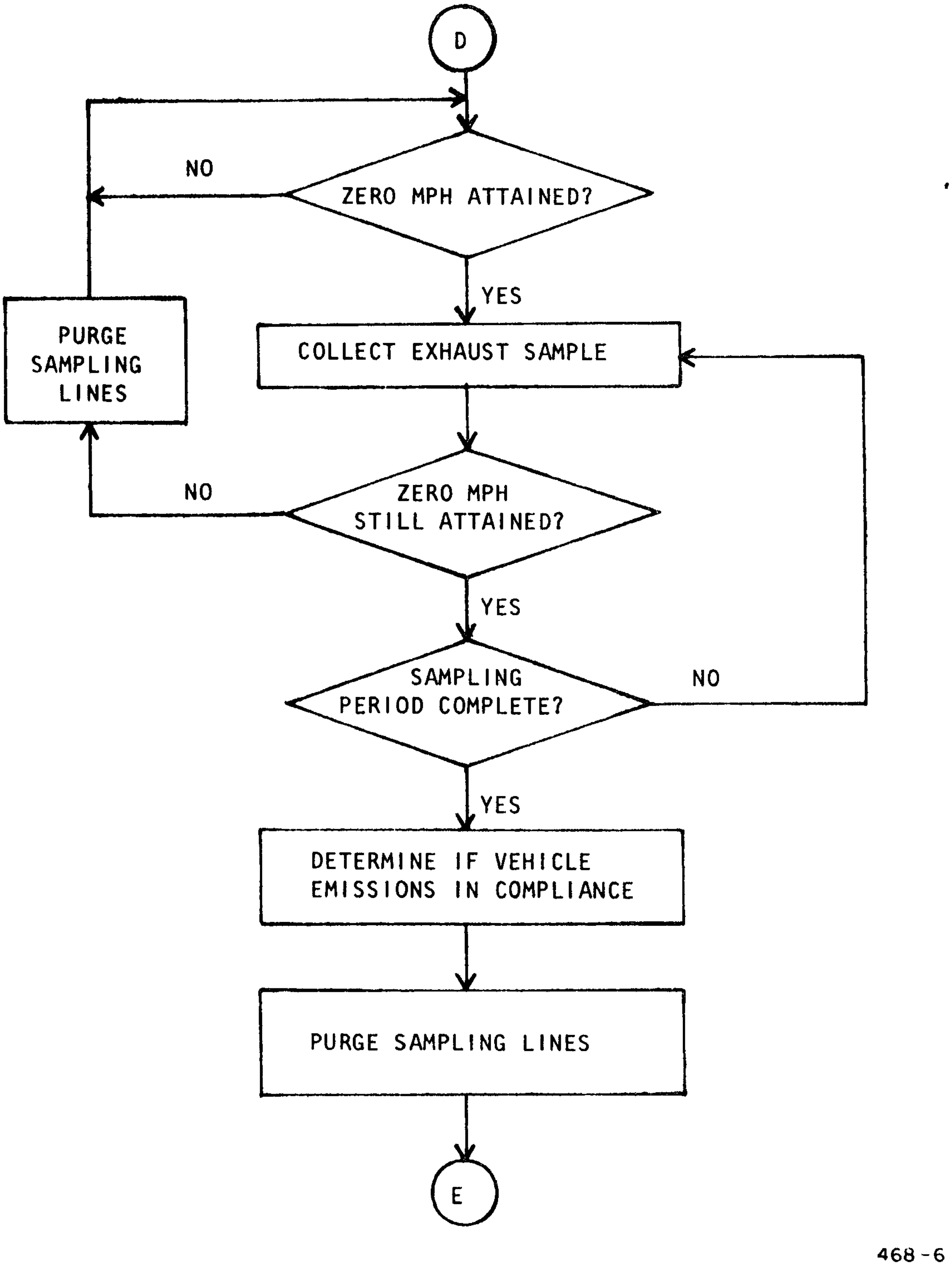


Figure 2 (continued).

TEST REPORT SUBSYSTEM

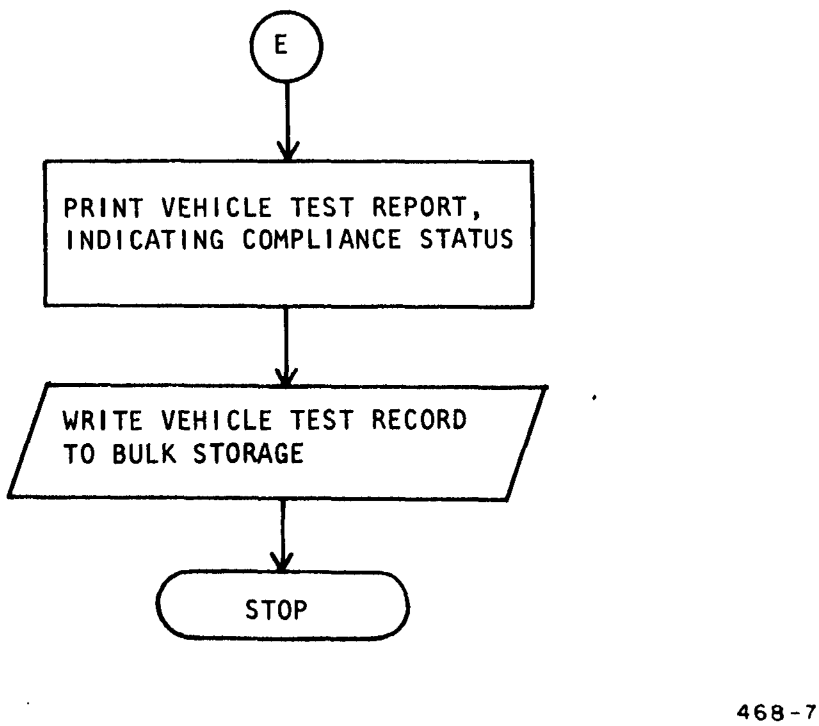


Figure 2 (continued).

VEHICLE INSPECTION REPORT

STATE OF ARIZONA 0000000

OFFICIAL VEHICULAR INSPECTION STATION

CERTIFICATE BELOW NEEDED FOR REGISTRATION
(CANNOT BE REPLACED IF LOST OR STOLEN)

Your vehicle's test results are shown below. If your vehicle uses gasoline fuel, the exhaust emissions were tested for hydrocarbons (HC) and carbon monoxide (CO); pass or fail in the "Final Result" space is based on results of the idle portion of the test. If it uses diesel fuel, it was tested for smoke emissions. If the "Final Result" space shows your vehicle failed, you are entitled to one free retest after repairs or adjustments have been made. To get the free retest, you must return within 60 days with this report*, signed on the reverse side, signifying that emission-related repairs or adjustments have been made.

***NOTICE: The free retest period does not change your registration deadline. An $8 late registration fee is charged if registration is processed after deadline.**

For registration instructions, see below.

STATION NO.	LANE NO.	TEST MODE	TEST NO.	DATE	TIME

VEHICLE INFORMATION

LICENSE PLATE	VEHICLE IDENTIFICATION NO.	YEAR	MAKE				

LOADED TEST EMISSION RESULTS

	HIGH CRUISE HC (PPM)	HIGH CRUISE CO	LOW CRUISE HC (PPM)	LOW CRUISE CO
STATE STANDARD				
TEST READING				

PASS/FAIL EMISSION RESULTS

	IDLE HC (PPM)	IDLE CO (%)	DIESEL SMOKE OPACITY
STATE STANDARD			
TEST READING			

FINAL RESULT

FOR OFFICIAL USE ONLY

ARIZONA VEHICULAR EMISSION INSPECTION CERTIFICATE

PLATE VIN YEAR MAKE

The above vehicle was emission inspected at station

on and the emission standards as established by regulation

This certificate may only be used for registration purposes when either the word COMPLIANCE or WAIVER is printed in this block → [ ]

If the word TEST appears, see inspection report supplement

THIS CERTIFICATE CANNOT BE REPLACED IF LOST OR STOLEN AND IS VOID WHEN ALTERED. 0000000

IF THE WORD **COMPLIANCE** OR **WAIVER** APPEARS IN THE BLUE BLOCK ON THE CERTIFICATE, **TEAR ALONG** THE PERFORATED LINES AND TAKE IT OR MAIL IT WITH YOUR REGISTRATION CARD TO THE COUNTY ASSESSOR. KEEP TOP PART CONTAINING THE TEST RESULTS UNTIL YOU RECEIVE LICENSE TAGS

IF THE WORD **TEST** APPEARS, THE VEHICLE DESCRIBED HAS FAILED THE INSPECTION AND MUST BE REPAIRED ACCORDING TO INSTRUCTIONS IN THE INSPECTION REPORT SUPPLEMENT

Figure 3. State of Arizona vehicle inspection report, obverse side.

DIAGNOSTIC INFORMATION

GENERAL:
1. A RESTRICTED OR DIRTY AIR CLEANER WILL CAUSE HIGH CO
2. MALFUNCTIONING CHOKE WILL CAUSE HIGH CO
3. DISCONNECTED OR INOPERATIVE EMISSIONS CONTROL DEVICES MAY CAUSE HIGH CO AND/OR HIGH HC, PARTICULARLY IN LATE MODEL CARS

CO - CARBON MONOXIDE

IF EMISSION READING IS	PROBABLE CAUSES ARE
1 HIGH AT IDLE ONLY, OR 2 HIGH AT IDLE AND LOW CRUISE	IMPROPER CARBURETOR IDLE SPEED AND/OR AIR/FUEL MIXTURE ADJUSTMENT
1 HIGH AT LOW CRUISE ONLY, OR 2 HIGH AT HIGH CRUISE ONLY, OR 3. HIGH AT LOW AND HIGH CRUISE	CARBURETOR MAIN SYSTEM MALFUNCTION NOTE, THIS PROBLEM CANNOT BE CORRECTED BY IDLE ADJUSTMENT ONLY
1 HIGH AT IDLE AND HIGH CRUISE OR 2. HIGH AT IDLE, LOW AND HIGH CRUISE	A COMBINATION OF MALFUNCTIONING CARBURETOR MAIN SYSTEM AND A MALADJUSTED IDLE AIR/FUEL RATIO

HC - HYDROCARBON

IF EMISSION READING IS	PROBABLE CAUSES ARE
1 HIGH AT IDLE ONLY OR 2 HIGH AT IDLE AND LOW CRUISE	1 IDLE SPEED ADJUSTMENT 2 EXCESSIVELY HIGH CO AT IDLE CAN CAUSE MODERATELY HIGH HC AT IDLE 3 INTERMITTENT IGNITION MISFIRE IS POSSIBLE BUT NOT PROBABLE 4 IDLE CIRCUITS ON 2 AND 4 BARREL CARBURETORS HIGHLY IMBALANCED OR ADJUSTED IMPROPERLY 5 GROSSLY ADVANCED BASIC IGNITION TIMING 6 VACUUM LEAKS INTO THE INTAKE MANIFOLD CAUSING A LEAN MIXTURE AND SUBSEQUENT MISFIRE IN SOME CYLINDERS 7 COMPRESSION LEAK THROUGH ONE OR MORE VALVES
1 HIGH AT LOW CRUISE ONLY OR 2 HIGH AT HIGH CRUISE ONLY OR 3 HIGH AT LOW AND HIGH CRUISE OR 4 HIGH AT IDLE AND HIGH CRUISE OR 5 HIGH AT IDLE, LOW AND HIGH CRUISE	IGNITION MISFIRE UNDER HIGHER COMPRESSION PRESSURE OF POWER OPERATION DUE TO A FAILURE OF AN IGNITION SYSTEM COMPONENT

IF YOUR VEHICLE FAILS THE INITIAL EMISSIONS INSPECTION, YOU MUST HAVE IT REPAIRED AND EITHER PASS REINSPECTION OR QUALIFY FOR A WAIVER AS SPECIFIED IN THE INSPECTION REPORT SUPPLEMENT. IN EITHER CASE, TO QUALIFY FOR A REINSPECTION OR BE GRANTED A WAIVER, REPAIR INFORMATION MUST BE PROVIDED BELOW:

TO BE FILLED OUT BY REPAIR FACILITY OR VEHICLE OWNER

Person or Facility Performing Repairs ______

Address ______ Date of Repairs ______

Check the appropriate items below indicating the repairs and adjustments performed

1
- ☐ A/F Mixture - per mfgr's spec
- ☐ Idle Speed - per mfgr's spec
- ☐ Dwell/Timing - per mfgr's spec
- ☐ Air Cleaner - clean/replaced
- ☐ Choke - free & open
- ☐ PCV - operating
- ☐ Vacuum hoses - connected & not leaking

2
- ☐ Carburetor - adjusted/repaired/replaced

3
- ☐ Spark plugs - cleaned/replaced
- ☐ Plug wires - replaced
- ☐ Distributor components repaired/replaced
- ☐ Other (Specify) ______

TOTAL REPAIR COST $ ______

ANALYZER REG NO ______

If an NDIR analyzer was used during the repairs record the following		HC	CO
	Initial Reading	ppm	%
	Final Reading	ppm	%

I HEREBY CERTIFY THAT THE REPAIRS REQUIRED PER THE INSTRUCTIONS CONTAINED IN THE INSPECTION REPORT SUPPLEMENT WERE PERFORMED ON THIS VEHICLE AND IF THE VEHICLE FAILS REINSPECTION, A WAIVER IS REQUESTED.

NAME: ______ PRINT ______ SIGNATURE

IMPORTANT

INSPECTORS ARE PROHIBITED BY REGULATION FROM MAKING ANY RECOMMENDATIONS OR ESTIMATES RELATIVE TO REPAIRS.

FOR REPAIR INSTRUCTIONS REFER TO THE INSPECTION REPORT SUPPLEMENT.

FOR REGISTRATION INFORMATION SEE REVERSE SIDE

☐ **I HEREBY REQUEST** THE SPECIAL WAIVER WITHOUT REINSPECTION AS DESCRIBED UNDER "CO FAILURES ONLY" IN THE INSPECTION REPORT SUPPLEMENT (FOLLOW INSTRUCTIONS CAREFULLY IF REQUESTING THIS WAIVER ---- DO NOT MAIL THIS REQUEST WITH REGISTRATION FEES TO COUNTY ASSESSOR.)

PLEASE PRINT

Name ______

Street Address ______

City, State, Zip ______

Signature ______

[illegible] MVI

Figure 4. State of Arizona vehicle inspection report, reverse side.

from the Wisconsin form. Arizona's report form, for example, has a detachable compliance certificate in the lower left corner. This compliance certificate must be presented upon obtaining or renewing motor vehicle registration. Wisconsin will be utilizing a slightly different approach to proof of compliance. Rather than issuing certificates of compliance, the inspectors will "stamp" the inspection application forms at the inspection lane.

TABLE 3. PROPOSED VEHICLE INSPECTION REPORT REQUIREMENTS

Item	Description
A	License plate number.
B	Vehicle identification number.
C	Model year of vehicle.
D	Make of vehicle.
E	Style of vehicle.
F	Vehicle classification.
G	Mileage.
H	Emissions standards.
I	Emissions Measurements.
J	Statement of pass/fail, comply/noncomply, or waiver, if applicable.
K	Serial number or identification number of emissions analyzer used in making the test.
L	Date and time of inspection.
M	Serial number of report.
N	Inspection number by station and lane.
O	Inspector number.

One important item not appearing on the proposed report list concerns whether the inspection is an original test or a retest. This information will be important in conducting statistical analyses on emission reductions from the original test to the retest. Additionally, according to the draft legislation, vehicles requiring mandatory inspection are entitled to one free retest without charge, provided:

- The motorist returns within 30 consecutive calendar days of the initial inspection.

- The specified emission-related repairs and adjustments have been made.

- The vehicle is accompanied by the initial inspection report with the specified repair information filled out.

Unless there is an indication on the inspection report as to whether the test was an initial inspection or a reinspection, motorists could fail retests, fill out this form, and qualify for additional retests at no charge. This possibility will be avoided if the inspection report identifies the test as a retest or initial test.

Conducting the Inspection

There are certain operator-entered or system-generated data elements not included on the inspection report necessary for properly conducting the inspection. First, as previously mentioned, as many as 18 vehicles may be undergoing inspection at the same time (in a six-lane facility). While each of these vehicles will have unique license or VIN numbers, an easier solution would be for the system to generate a "queuing number" to identify the vehicle during the inspection, tieing all inspection information to the proper vehicle. Since as many as six inspectors may be entering registration data simultaneously on vehicles in the first position of their respective lanes, identification of vehicles may have to occur before the VIN is entered; therefore, a queuing number should be assigned to each vehicle at "Logon," and prior to entry or generation of any other data.

In some instances, the idle mode test may be performed in lieu of the loaded mode test. For these cases, the inspector must enter an idle-mode-only code which notifies the system to forego the high and low cruise portions of the test. The draft rules have made provisions for eliminating the cruise portions of the examination in the following instances:

- The vehicle has a tire or a driving wheel with less than 2/32-inch tread with metal protuberances, or with obviously low tire pressure (as determined by superficial visual inspection) or any other condition that in the opinion of the vehicular emissions inspector precludes loaded testing for reason of safety to personnel, equipment, or vehicle.

- The vehicle is driven by a person who, because of physical incapacity, is unable to yield the driver's set to the emissions inspector.

- The vehicle is driven by a person who refuses to yield the driver's seat to the emissions inspector.

- The vehicle is equipped with constant four-wheel drive

It should also be noted that one other condition enables elimination of one or both cruise tests.

- The vehicle is unable to be tested according to the dynamometer loading table because of the vehicle's inability to attain the speeds specified.

It is unlikely that the inspector will be able to determine this during data entry. Provisions must be made, then, to enable the inspector to change the "test mode" field after the initial data entry. This can be accomplished by allowing data entry at the second position of the inspection lane, where the vehicle will undergo the actual emissions measurement portion of the inspection.

There are certain conditions that permit inspectors to refuse to perform the emissions test. The draft rules have identified four such conditions:

1. The vehicle's exhaust system has an obvious leakage or other condition that could affect the validity of the exhaust sample readings as determined by the stations vehicular emissions inspector.

2. The vehicle is smoking, and in the judgment of the vehicular emissions inspector, the vehicle is incapable of passing the exhaust emission inspection.

3. Gasoline or oil leaks are apparent and deemed a safety hazard.

4. The vehicle is carrying, loaded with, or towing a trailer* loaded with explosives or any other hazardous material not used as fuel for the vehicle.

It is likely that discovery of these items will occur after the initial data entry. A provision must be made to allow the inspector to cancel the test. The inspection file should not be deleted, however. Rather, a code should be entered identifying the reason for inspection refusal.

To enable proper selection of emission standards for each vehicle, two items are needed: model year and number of cylinders. Model year is input as item C in Table 3. Item F., vehicle classification, should include the number of cylinders. Though not required to select emission standards, two additional variables should be identifiable by item F, vehicle curb weight an engine displacement. The items are necessary to enable the system to select the proper

---

*Though not necessarily a safety hazard in all instances, trailers could be a nuisance in a test lane. Wisconsin should consider not permitting any trailers in the facility.

dynamometer loadings for the cruise portions of the test, as shown in Table 4. As also shown in Table 4, no displacement information is required for vehicles with curb weights greater than 2,000 lb.

TABLE 4. PROPOSED DYNAMOMETER LOADINGS AS A FUNCTION OF VEHICLE CURB WEIGHT AND ENGINE DISPLACEMENT

Vehicle curb weight (pounds)	High cruise mode		Low cruise mode	
	hp	mph	hp	mph
Less than 2000	Idle test only		Idle test only	
2000 - 2800	11.8-13.6	36-38	2.8-4.1	22-25
2801 - 3800	20.8-23.7	44-46	6.4-8.4	29-32
Greater than 3800	26.8-30.0	48-50	8.4-10.8	32-35

Since the dynamometer loadings are divided into eight specific categories, it is actually only necessary to identify the loading class rather than the variables this class is dependent on, curb weight and engine displacement.

In addition to collecting and storing HC and CO levels on each vehicle, the CO_2 level must also be collected, despite the fact that no standard exists for CO_2. The CO_2 level must be added to the measured CO level to validate the inspection. As indicated in the proposed rules, "the test will not be considered valid if the exhaust gas is diluted to such an extent that the sum of the carbon monoxide and carbon dioxide concentrations recorded for the idle speed reading from an exhaust gas outlet is 8 percent or less, and on 1975 and later vehicles with air injection systems 7 percent or less." A total of three additional data items must therefore be collected: CO_2 level, the system calculated sum of CO and CO_2, and the system-generated valid/not valid decision.

Statistical Analyses and Administrative Recordkeeping

There are a few additional items not previously accounted for that may be important for analysis and recordkeeping. The importance of differentiating initial inspections from reinspections has been previously discussed. For recordkeeping purposes it becomes important, in the case of retests, to also determine how many retests were undertaken by a specific vehicle. If the State uncovers considerable "ping-ponging" of vehicles from the inspection lane to the repair industry and back, it may indicate that the repair process is not being adequately explained to the motorists at the inspection facility.

For each vehicle a record will be kept on both the emission levels measured and the standards used to determine if the vehicle passes or fails. For quality assurance purposes, the standards used should periodically be checked to make sure they are appropriate for the vehicle inspected. To accomplish this, the standards are compared with the criteria determining them (model year, number of cylinders). In some instances, this information will be misleading as the proper standards will not be those generally assigned to the model year and number of cylinders appearing on the inspection report. For example, a 1968 motor vehicle which has had an engine replacement may have had a 1970 engine installed. The standards should be based on the engine. However, the vehicle should be recorded as the model year corresponding to the VIN for registration recordkeeping. In these cases, the vehicle's model year should be recorded but a code should be recorded indicating that different standards were applied and why.

Some vehicles will not fit into any of the emission standards classifications, but will be tested according to the most appropriate classification for which standards have been derived. Two such examples have been mentioned in the proposed rules.

- All rotary piston engines shall be treated in the same manner as four-stroke engines with four cylinders or less.

- All turbine engines shall be treated as four-stroke engines having more than four cylinders.

Identification of these cases is important for two reasons. When emissions level cutpoints are determined, these vehicles should probably be eliminated from the analyses. After cutpoints are determined, previous test results should be compared with the new cutpoints to determine if they are still appropriate for these vehicles.

In summary, when a vehicle does not match the classification description associated with the standards it is treated against, a notification should be made enabling identification of this occurrence and the reason for it. Elaborate descriptions need not be entered for this purpose, rather a "flag" enabling quick determination of a special case should be activated and a code indicating the general reason should be recorded, (e.g., replaced engine, turbine vehicle, rotary piston, etc.)

A summary listing of the input requirements for operator-entered or system-generated data is provided in Table 1. Only computer file data is presented in Table 1. As previously mentioned, repair information, if required, should be recorded on the initial test report and should include:

- Itemization of the repairs performed

- Cost of repairs or cost of estimated repairs required if such repairs exceed the maximum specified repair cost

- Name and address of the business firm or person making the repairs or the estimate

- Signature of person certifying repairs or the estimate

Other data the contractor should supply include information on equipment calibration. Specifically, the time of each calibration check, the results, and what adjustments were made. The equipment calibration process should be performed periodically by the computer system. A frequency of 1-hour is reasonable for a centralized lane. Calibration checks should include analyzer zero and span calibration checks. These functions can actually be performed using microprocessors within the analyzer itself. In fact, equipping the analyzer with its own "microcomputer" can reduce much of the burden on the facility's minicomputer. In the California system, for example, the analyzer's microprocessors perform the following function:

- Analyzer zero/span check
- Exhaust gas sample purge after each test
- Health check of analyzers/sample system blockage
- Exhaust gas dilution limits
- Analyze test results, select state standards
- Forwards data to system controller and printers

One advantage of delegating the above task responsibilities to the emission analyzer is that in the event of a computer malfunction, operations at the inspection facility can continue. When a facility's minicomputer is "down," semiautomatic operation is put into effect. The analyzer system can forward data directly to the printer in this instance. A copy of the inspection report can be kept at the lane, and this data can be entered into the computer at a later time. If both the computer and the analyzers are "down," the inspections will have to be performed manually. Under manual operation, a backup (garage level) analyzer is used for emission measurement and all data is recorded manually. Automatic, semiautomatic, and manual operation is discussed in greater detail in Section 4.

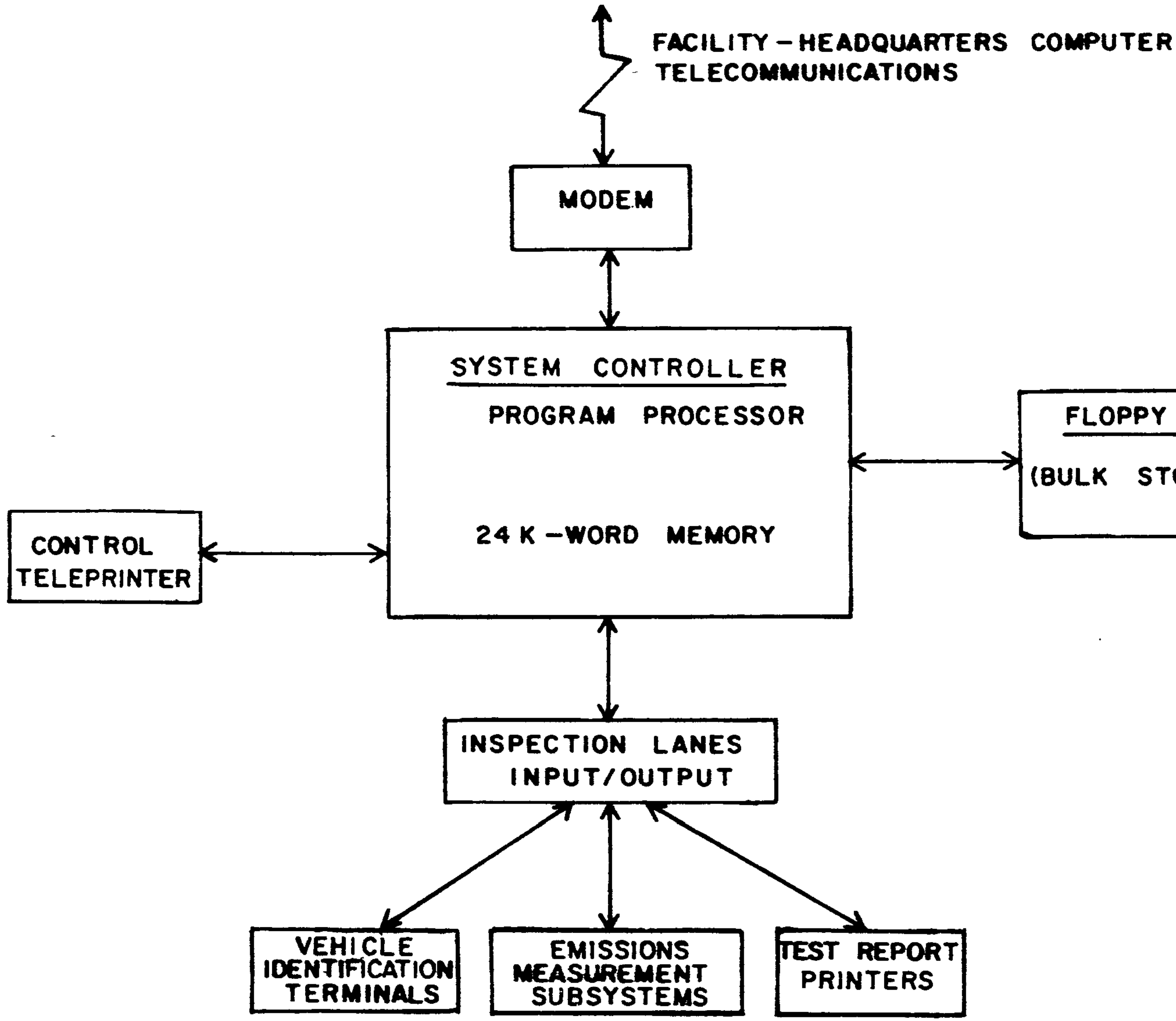
The data files from each inspection should be included on a magnetic tape and all information filed should be included with the contractors periodic reports. Items from Table 1 that were identified as being provided to the State, will be the contents of this tape. Further definition of these items is provided in Table 2.

Data Transfer

Data files for each inspection can be temporarily stored at the facility's minicomputer on floppy disk. The minicomputer should be equipped for bidirectional telecommunications to the contractor's central (headquarters) computer. The telecommunications link should be set for automatic transfer of a day's data each evening (during off-hours). This enables each individual facility to remain independent and relatively unaffected by outages in the network telecommunications systems. The telecommunications operations are controlled by the central headquarters computer. The data processing telecommunications links are depicted in Figure 5. At the end of each report period, the contractor will, along with the periodic report, submit to the State a magnetic tape containing all of the information in Table 2 for every inspection performed during that month. The format and parity of the data tapes are dependent on the State's computer.

WDOT utilizes the State of Wisconsin's Hill Farms Regional Computing Center. Since 1977, the Hill Farms Center has been using an Amdahl 470 V/6 Model II CPU. The Amdahl system is very similar to an IBM system and is compatible with most minicomputer-generated tapes. The tape requirements are outlined below:

- Parity — Odd, 9-track tapes
- Density — 800 or 1600 bpi tapes
- Character Code — Extended binary coded decimal interchange code (EBCDIC)
- Data should be labeled
- One inspection report per record
- Data should be blocked (approximately 10 records per block)



468-9

Figure 5. Facility computer data links.

SECTION 4

DATA PROCESSING HARDWARE REQUIREMENTS

The ultimate success of Wisconsin's automated Inspection and Maintenance program will rest on the adequacy and success with which the contractor interprets and accomplishes the data processing functions of the program. Central to this concern is the contractor's system hardware specifications and "hands on" experience with any proposed equipment. The general types of computer hardware devices that will be required for the Wisconsin program are:

- Central processor
- Magnetic tape unit
- Communications interfaces (modems)
- Remote processors
- Flexible diskette storage
- Peripheral interfaces
- CRT display/data entry terminals
- Teleprinters, report printers
- High-speed printer

The specification of exact make and model configurations will be a central item in the contractor's response to the data collection and processing requirements of the program. In this report, however, only general hardware specifications will be discussed as an aid to Wisconsin in evaluating the proposed configurations in responses to the subject RFP.

The central processor, magnetic tape unit, a control terminal, the high-speed printer, interfaces, and one modem will be located at the contractor's headquarters office. This central system will "dial up" the remote inspection facilities each night and receive from their processors the vehicle inspection data that was collected during their normal operations that day. Each remote site will consist of a processor, modem, control terminal, and a flexible diskette storage unit; along with interfaces, a CRT data entry terminal, an emissions measurement subsystem (EMS), and a teleprinter for each operating inspection lane as illustrated in Figure 5.

PROCESSORS

The processors used should be minicomputer central processing units (CPU) which consist of arithmetic and decision circuitry, for computations and executing programs; and a memory section for the storage of program instructions and intermediate test results and computations. The processor should have a 16-bit word length to ensure sufficient accuracy in computations and possess at least 24 and 32 kilowords of memory for facility and central processors, respectively. Most currently available minicomputers use MOS (metallic oxide semiconductor) memory due to its fast cycle time, low power requirements, and inherent reliability. The exact memory specified by the contractor must be of sufficient capacity to support the necessary programming to control the maximum number of vehicles undergoing testing at the site in question. The processors specified should be equipped with power-fail "save" capabilities, preferably a limited battery backup system. This battery backup will supply power to the processor during power outages to ensure that at least the tests in progress can be completed and processed before switchover to manual operations becomes necessary.

The CPU is in effect the "brain" of the system and directly controls all data collection, validation, storage, and inspection report preparation through an operating system program called the System controller. At each inspection facility the processor, when programmed as described in Section 5, will perform the following functions:

- Control progress of vehicle through the test lane
- Process vehicle identification data
- Accept emission measurement data from EMS
- Correlate vehicle data and select failure standards
- Compare measured values to limits separately for each individual input
- Output test data for report printout
- Output test data for storage on bulk storage devices (diskettes)

The processor at the contractor's headquarters must be capable of performing the following functions:

- Communication with each inspection facility processor through communications interface
- Data collection and data entry for inspection data
- Data validation and compilation for periodic submission of data to the Department of Transportation

- Data analysis and summarization for network operating management
- Data management reporting
- Network software maintenance
- Preparation of magnetic tape file of inspection data for periodic submission to the Department of Transportation

The prices of minicomputer central processing units vary greatly depending upon machine cycle time, memory capacity, and the number and required speeds of the input/output and peripheral communications channels. A minicomputer processor of relatively low speed with 32 kilowords of memory, such as may be specified for the inspection facility System controller, will cost from $7,000 to $9,000. The communication interfaces necessary to drive 24 peripheral channels will add another $6,000 to $7,000 to this cost, however. A faster minicomputer processor, as might be suggested for the contractor's headquarters central computer, will start at $13,000 for a 32-kiloword memory. Again, however, the $6,000 to $7,000 for peripheral channels has to be added to this cost.

PERIPHERAL INTERFACES

The processors at both the contractor's headquarters and at all inspection facilities should be interfaced with their respective peripheral (input/output and storage) devices using an industry standard interface designated RS-232C. Both RS-232C and 20 mA current loop interfaces are available, but the RS-232C is used almost exclusively for data transfer rates of greater than 300 baud.

Use of this standard interface will allow for the future upgrading of various devices in the systems or their conversion to devices produced by not otherwise compatible manufacturers. This upgrading or conversion capability will be valuable in the event that operational problems are encountered with any of the specified hardware devices. For example, a specified terminal may be unable to withstand the temperature extremes encountered in the inspection lane and may have to be replaced by a more rugged unit.

COMMUNICATIONS INTERFACES

The processor at the headquarters will be used to collect data from the inspection facilities over normal voice-grade telephone lines using communications interfaces called modems. These modems imprint binary (machine code) data onto a carrier wave and then transmit the data over telephone lines, where another modem receives the signal and decodes the binary data. Modems should interface with their respective processors using RS232C interfaces as previously described. The modem specified for the headquarters computer should have an automatic "dial up" function to call the telephone numbers of the inspection facilities at the designated times, and the modems at the inspection facilities should have auto-answer capability. To keep long distance telephone costs to a minimum, the modems specified should be capable of asynchronous, full-duplex, or bidirectional communication at a rate of 1200 baud (approximately 120 characters per second). In lots of 25 or more for end-users the cost of a 1200-baud modem will be about $800 to $1,000.

MASS DATA STORAGE DEVICES

The online mass data storage device used by the processors should be a flexible magnetic disk (diskette or floppy disk). These are relatively small, reliable devices that store data on a sheet of flexible plastic magnetic storage media. The average capacity for available flexible disk units is about 250,000 bytes (or 250,000 characters). This is of sufficient size for even large six-lane inspection stations. Costs of flexible disk units can range from $3,500 to $4,500.

The flexible diskette units should be interfaced with the processor using an industry standard RS-232C interface and, when operating, will act as:

- A storage medium for initial system loading of the operating system software
- A storage medium for ongoing significant-event logging, inspection facility maintenance data, and emissions equipment calibration data representing ongoing inspection lane test activity
- A storage medium for daily storage of inspection and repair data that must be eventually forwarded to the Wisconsin Department of Transportation via the Contractor's Headquarters Computer
- A storage medium for online utility file data required to conduct the inspection process.

MAGNETIC TAPE UNIT

The contractor's headquarters computer facility must have incorporated a magnetic tape unit. This unit will be used to create magnetic tapes of all inspection data collected each day when the central processor receives it from the inspection facilities. These tapes will then be periodically submitted to the Department of Transportation for further data validation, statistical processing, and long-term inspection data storage. The magnetic tape device should be capable of creating 800 or 1,600 bpi nine-track tapes. If possible, the tapes should be labeled tapes coded in EBCDIC (preferably) or ASCII. Costs for magnetic tape drives can range from $8,000 to $18,000, depending upon tape speed and subsystem control needed.

CRT DISPLAY/DATA ENTRY TERMINALS

Hardware devices specified as the Vehicle Identification Terminals should be Cathode Ray Tube (CRT) display terminals with keyboards. These will be installed at the first position in each inspection lane as an input device for the entering of vehicle identification information. The CRT terminal specified should be capable of full-duplex (bidirectional) communication with the system control processor using standard ASCII code at a minimum of 1,200 baud. For compatibility or conversion purposes the CRT should be connected via a standard RS-232C interface.

For ease of display visibility by the inspector during varying light conditions, the CRT screen should possess the following minimum display characteristics:

- 12-inch (diagonal) screen minimum
- 64 displayable characters, at least 0.19 inch high by 0.125 inch wide
- 5x7 dot matrix characters
- 80 characters per line
- 12 lines on full screen minimum
- Nondestructive cursor

To minimize the inspector training necessary, the data entry keyboard should be a standard ASCII Keyboard similar to an ordinary typewriter. To protect sensitive data on the display screen during data entry operations, the system control program should be capable of making the CRT skip over protected data fields. The cursor should be capable of movement through the use of clear, tab, and home functions that can be performed without erasing the contents of the screen.

The price of CRT display terminals ranges from $1,500 to $2,000.

EMISSIONS MEASUREMENT SUBSYSTEMS (EMS)

The EMS should be specified capable of controlling, either automatically in conjunction with the System Controller, or semiautomatically, all emissions measurement and test control functions. The EMS should consist of an NDIR exhaust gas sampling device, a sample conditioner, a programmable microprocessing device, and a control pendant. During normal automated operations the EMS should be controlled by the System Controller. During equipment or power failures, the EMS will function manually but should be capable of controlling the inspection report teleprinters. Obviously, one EMS will be required for each lane.

The EMS Control Processor (EMSCP) should be a programmable 8-bit microprocessor device to control the operation of the exhaust emissions analyzers. The EMSCP will communicate with the facility's System Controller during normal automatic mode, but it should be a functionally independent modular component of the SYSTEM. The System Controller will pass to the EMSCP various data items such as the vehicle queue number and its related emissions standards. After the test is completed, the EMSCP will transmit emission values, etc. back to the System Controller for output on the inspection test report teleprinter. During System Controller downtime, however, the EMSCP should be capable of running the emissions test and outputting the results through the report teleprinter without going through the System Controller.

The EMSCP should be programmed to perform the following:

- Prompt and cue inspector during emissions measurement
- Convert raw analog measurement and status data to digital information
- Perform necessary calculations
- Correct measured instrument values including dynamometer speed and horsepower
- Compare results to the State's emissions standards
- Display emission values
- Transmit data to the System Controller, or the Inspections Report Printer during System Controller downtime.

The test control pendant will be required to serve as an interface between the inspector and the EMS. The pendant should consist of a standard computer-type keyboard enabling operator intervention during the automatic testing procedure. For example, the pendant should be capable of "interrupting" the EMS and/or the System Controller with at least the following commands:

- Start test
- Abort test
- Restart test
- Delete one or more modes of the test
- Select mode
- Control dynamometer wheel lift

The test display panel (TDP) will be used in conjunction with the control pendant to provide the man-machine (inspector-EMS) interface during the emission test procedure. The TDP will prompt the inspector with various instructions and display the test progress. In the event of any problem, the inspector can then intervene in the automatic test procedure using the control pendant as described above. Numerous informational displays can be produced by the display panal such as:

- Measured road speed
- Indicated corrected horsepower applied to the vehicles driving wheels
- Mode of operation – high cruise, low cruise, or idle

- An indication that the vehicle's road speed is not within the appropriate tolerance during the high cruise and low cruise modes

- An indication that the EMS controller has determined that all the prerequisites for a valid emission test have been satisfied and the emission inspection is progressing properly

- An indication that the test sequence is complete

- An indication that the EMS is in semiautomatic mode (not communicating with the System Controller)

- An indication that a message has been printed on the control teleprinter

- Idle RPM out-of-tolerance

- Exhaust gas sample dilution warning

TELEPRINTERS AND LINE PRINTERS

Teleprinters should be specified in the roles of inspection report printers and control teleprinters where hard copy (paper) output is desired at the inspection facility. The inspection report teleprinter will be used to print the inspection test results and other appropriate information. The report teleprinter should generate inspection reports on 8-1/2 by 11 inch report forms (one original and two copies) of the contractor's design. The control teleprinter will act as an operator console to communicate with, and print messages from, the System Control program operating in the processor.

The inspection report teleprinter and control teleprinter should be interfaced with the processor using standard RS-232C interfaces and should communicate using industry standard ASCII transmission code. The teleprinters should be capable of printing a minimum of 80 characters per line at a speed of 30 characters per second (300 baud).

For ease of reading and to avoid the necessity for confusing abbreviations in the output, the teleprinters should possess the following display characteristics:

- Minimum of 64 ASCII displayable characters
- Minimum character size 0.19 inch high by 0.11 inch wide
- Minimum 7x7 matrix characters (if applicable)

For the purpose of outputting large reports or listings from the central computer at the contractor's headquarters, a line printer may be specified. These devices print at relatively high speed (usually 300 lines/minute) and can produce listings up to 132 columns across. For compatibility they also should be connected via an RS-232C interface.

The cost of a teleprinter will be approximately $900 to $1,600, and the cost of a line printer begins at $6,000 and up, dependent upon lines per minute speed.

STATE COMPUTER FACILITIES

The 9-track, 800 or 1600 bpi magnetic tapes of inspection test results produced by the Contractor's headquarters computer will be periodically submitted to the Wisconsin DOT for further analyses. These data tapes will be used as input to various statistical analysis programs executed on the State's Amdahl 470 V/6 Model II located at the Hill Farms Regional Computing Center. The State will therefore not be required to purchase any data processing equipment for the purpose of analyzing its inspection results data base.

While no hardware will be required by the State, an interest was expressed in having a graphics CRT display terminal located at the DOT office. Program execution could then be initiated at the DOT and results displayed in the form of diagrams and plots on the CRT. This would entail the purchase, by the DOT, of a graphics CRT display terminal along with the necessary interfaces and telecommunications. CRT graphics terminals cost between $4,000 and $7,500 (average about $5,000) depending upon the memory capacity of the terminal. Communication interfaces discussed previously would cost an additional $900.

SECTION 5

DATA PROCESSING SOFTWARE REQUIREMENTS

SOFTWARE REQUIRED

The software requirements for Wisconsin's I/M program can be divided into three major categories.

- SYSTEM software
- Data transfer software
- Analysis software

SYSTEM Software

Software in this category consists of essentially all programs necessary for the System Controller to enable the SYSTEM to:

- Prompt for, accept, and verify vehicle identification data from the Vehicle Identification Terminals (VIT)
- Coordinate the emissions inspection through the Emissions Measurement Subsystems (EMS)
- Correlate vehicle emissions data, select appropriate standards and dynamometer loadings, make pass/fail determinations
- Output test data for report printout and to bulk storage
- Perform and keep records of emissions analyzer calibration checks as well as all other SYSTEM maintenance data

Related to the SYSTEM software is the EMS software. As discussed in Section 4, the EMS will be controlled by an independent (micro) processor, the EMSCP. EMSCP software consists of all programs necessary to enable the EMS to perform the following:

- Prompt and cue the inspector during the inspection
- Convert raw analog measurements into digital format
- Perform all necessary calculations
- Monitor and correct dynamometer loadings, instrument drift, etc.
- Collect and analyze emissions, make pass/fail determinations
- Display appropriate information during inspection (road speed, horsepower load, mode of test, test complete, warning messages, etc.)

Both the SYSTEM software and EMS software are classified as "real-time." By real-time we mean an information system in which inputs are immediately available enabling control of the process that generates these inputs. In I/M lane operation, as in most real-time situations, "online" processing is required. By online, we mean that the input goes directly to the System Controller at the time when it originates. This is opposed to the approach where data is gathered over some period of time and processed in "batches." In an online system, the data is processed at the time it originates. The concepts of real-time and online processing are often erroneously used interchangeably. Online is a physical concept indicating that a device (such as the dynamometer, emission analyzer, sample collector, sample conditioner, VIT, report printer, etc.) is connected directly to the computer (in this case the System Controller or the EMS control processor). Real-time, on the other hand, is a dynamic relationship involving the availability of information in time to affect future inputs.[3]

The SYSTEM and EMS software, like most real-time application software, should be written in an Assembly language. Assembly language is very close to actual machine or binary language, thereby involving a minimal amount of translation time. Assembly is the preferred language for real-time applications as it can be much more efficient than higher level languages such as FORTRAN or COBOL.

The State should require the contractor to utilize the general programming approach known as "Structured Programming." Structured Programming refers to a programming methodology or a set of procedures for creating programs. E.W. Dijkstra of the Netherlands is credited with the popularization of the term "Structured Programming." In the Dijkstra interpretation,[4-8] Structured Programming is not an algorithm nor a set of rules to be followed, rather it is an approach to be utilized in developing programs. Structured Programming involves a technique called "contructive programming" which in essence means constructing a program that is guaranteed to be correct rather than designing and coding a program first and then trying to determine why it won't work. A program created in this manner will contain two structural features and two procedural features, which are briefly outlined below. (For a more comprehensive explanation, see references 4 through 8.)

The first structural feature of this approach involves a strict adherence to the use of rigid sequencing statements in programming. This involves severly limiting the use of GO TO statements thereby eliminating difficulty in following the "flow" of a program.

The second structural feature of this approach is to reduce the complexity of a program to small manageable proportions.[4,9] This means the use of subroutines is encouraged. This is related to the first procedural corollary of Structured Programming which involves "the use of hierarchy to develop programs in a stepwise manner, pushing details into ever lower and simpler subroutines." This involves "modularization" of a program or dividing a program into many independent modules (or subroutines) and incorporating a single design decision into each module.[10] In this way any change in a design decision will usually involve changing only one subroutine within the entire system.

The final procedural feature of structured programming is more subtle and difficult to define. Essentially, Dijkstra suggests the following procedure for constructing "correct" programs: "explicitly state the conditions which must hold if we are to prove an algorithm performs correctly; then, write a program that makes the conditions come true."[9]

A Structured Program will achieve the following basic goals (listed in order of importance):

- Reliability - Does the program consistently give dependable results that are accurate?
- Modifiability - Can the program be modified easily to respond to changing standards, requirements, or desires?
- Understandability - Since the State will likely reserve the option to purchase the SYSTEM, including all software, will the State programmers be able to understand the program logic well enough to use, update, and modify it?
- Efficiency - Does the program operate as efficiently and inexpensively as possible?

In responding to the RFP, bidders will not, for obvious reasons, be able to provide the software for the SYSTEM and EMS. They should be required, however, to propose an overall plan for the design and implementation of all software. In evaluating software plans, consideration should be given to proposals that point out that the software will be developed using "Structured Programming," "constructive programming," or "modular programming." The State should be cautious in considering proposals suggesting dissimilar programming approaches or proposals that call for real-time programs in other than Assembly or macro-level languages.

Data Transfer

Transfer of data from individual facility system controllers to the headquarters computer does not require a processing system as rigorous as real-time. Rather, this function can be achieved using queued processing. In queued processing, transactions are processed according to a particular scheduling algorithm (e.g., "first come, first served," or a priority ranking). The important criteria of the data transfer software is successful relaying of bulk storage data from each facility to the headquarters computer. This software controls the modems and telecommunications links and is, like real-time software, generally programmed in an Assembly-level language. Like all software developed in connection with the I/M program, the structured or modular programming approach should be employed.

Data Analyses

Two subcategories of software exist under the analysis heading: those developed by the contractor (recordkeeping, reporting, etc.) and those developed by or for the State (program evaluation, cutpoint selection, etc.). Since immediate response is not necessary for these analyses, they fit into the batch processing category. A system in which processing is performed in a batch mode differs from real-time, online, or queued processing in the following areas:

- First, a request for information is made through the data processing center with the time delay inherent in this procedure.
- Second, processing of the request will have to await completion of job(s) already being processed.
- Third, the information report must be physically delivered from the data processing center to the person who made the request, unless the requestor has an on-line printer.

The major differences between real-time, queued, and batch processing involves response time. This is shown in Table 5.

TABLE 5. RESPONSE TIME FOR VARIOUS PROCESSING MODES[11]

Processing mode	Magnitude of response time	Example
Batch	Minutes-hours	Simple billing systems
Queued	Minutes	Document retrieval system
Online	Seconds	Reservation or banking system
Real time	Microseconds	Process control

As is the case for other software categories, batch software should also be written using structured or modular programming. Unlike real-time or queued programming, batch programs can be written in higher level languages (e.g., FORTRAN, PL/I, etc.). Again, the particular language or strategy used is of considerably less importance than the program's ability to fulfill the four goals generally met by Structured Programming: reliability, modifiability, understandability, and efficiency.

CONTRACTOR-DEVELOPED SOFTWARE

As previously mentioned, bidders should be required to submit an overall plan for the design and implementation of all software. The plans should contain an implementation schedule pointing out when the major events (designing, coding, testing, etc.) will begin and end. The proposals should also include a plan describing how the bidder proposes to assure close cooperation with WDOT during the development process. The State should require regular progress meetings between the contractor, WDOT, and staff programmers, engineers, and analysts (from Hill Farms Computing Center).

Software Documentation

Following development of the software, the contractor should be required to provide complete documentation of all software. Documentation involves more than a simple listing of all program steps. Although there is some obvious overlap between them, the following general types of documentation can be identified:[9]

- Design documentation
- Construction documentation
- User documentation
- Maintenance documentation

Design documentation consists of a description of the concepts a system is built on and its overall structure. This type of documentation is a "blueprint" for developing the system. This would constitute the overall plan for designing and implementating the software and, thus, can be a requirement of the proposals.

As the software is developed, construction documentation can be provided. This would include precise formats, data layouts, algorithms, etc. Another important function of this type of documentation is to provide information about the current development status, program names, etc. This type of documentation should be a contractor requirement for the regular progress meetings.

User documentation restates and expands upon the functional specifications the system is supposed to fulfill. This category would include user's manuals and operator's guides which present precise information on the functions of the system and how to use them.

Maintenance documentation should consist of complete descriptions of the system itself in its final format. This type of documentation should include information on limitations of the system, procedures to be followed in updating or modifying the system, and listings of all program statements for all developed software.

STATE-DEVELOPED SOFTWARE

The State will be required to develop software enabling performance of the program evaluations described in Section 3. There are three options open to the State in fulfilling this requirement.

1. Develop specific software "in house"
2. Use preexisting software packages
3. Obtain the services of a software firm to develop software and/or conduct the analyses

The first option is the preferred solution provided that sufficient resources are available to undertake this type of task. By completing the development "in house," the State is assured of the highest degree of interface between WDOT, WDNR, and the computer programming staff that undertakes the project. No RFP would have to be developed, proposals evaluated, or contracts drawn as would be the case if an independent firm were hired. The second alternative, use of preexisting data analysis packages, may be feasible on a one- or two-time basis, however, for analyses that will be performed periodically, it is generally much more efficient to develop a program for that specific application. Preexisting packages run the following risks:

1. The algorithm may solve the wrong problem.
2. The algorithm may solve only a portion of the problem.
3. The algorithm may solve a more complex problem than necessary.

An example of the above three risks can be demonstrated as follows: Say, for instance, an algorithm is needed to find the roots of a quadratic equation. The consequences of the first risk (solution of the wrong problem) would be similar to trying to use the best algorithm for solving a linear equation. While it may be a good algorithm, it is of no use for the intended application. The second example (solving only a portion of the problem) would be like using an algorithm to find only the real roots of a quadratic equation, when in fact, the actual problem may have been to find all of the roots. The last example could be using an algorithm to find the roots of a quadratic equation when only the roots of a linear equation are needed. Certainly an algorithm to find the roots of a quadratic equation could be used to find the roots of a linear equation; however, this is a much more elaborate algorithm than necessary, and will likely be less efficient and more costly than an algorithm designed specifically for the intended application. In using predeveloped program packages, the third situation would most often exist. Packages are usually designed for general applications, thus containing excess capability at the cost of efficiency. When the cost of developing a specific program is weighed against the cost of running a perhaps less efficient (due to excess capabilities) preexisting program, the determining factor will generally be how frequently the program is to be run. It will almost always be more cost effective to develop specific software when the algorithm called for is to be used many times. However, for analyses that will be performed only a limited number of times, a preexisting package can be extremely worthwhile. There are a number of sources for preexisting algorithms.[3]

- A professional organization publication. (For example, each month algorithms for solving various problems are published in the Communications of the ACM. Once each year an index of algorithms that appeared during the preceding year is published in the same source.)
- A computer manufacturer's library of internally developed programs. (Computer manufacturers often develop libraries of programs for solving various problems. For example, IBM has a set of programs for solving mathematical and statistical problems that it calls the Scientific Subroutine Package. The cost of these programs varies widely.)

- A computer manufacturer's library of user-contributed programs. (As a service to its customers, many computer manufacturers maintain a library of programs submitted by users. These are usually available to their customers at little or no cost.)

- Another state which has an I/M program.

- A standard package from a software house. (A software house is a business which exists to develop programs for the solution of a particular class of problems. The programs they develop are their products to sell.)

The last source, a software house, can also be contracted to develop application-specific programs, which would be a similar solution to in-house development except involving the extra costs of contracting, and the software house's overhead and profit. If the State's in-house staff lacks the time and/or expertise to develop the analysis software, contracting out the work is the most logical alternative. Additionally, software houses may be more efficient in developing programs due to experience, expertise, etc. and could actually be cheaper than in-house development despite profit and contracting costs. This is dependent on the experience, efficiency, and expertise of the State's data processing staff.

SOFTWARE DEVELOPMENT COSTS

The costs for development of software are dependent on the following:

- The skill, experience, and efficiency of the programming team.

- The length of time required to develop the program.

- The hourly rate associated with the programming team.

More specifically related to the software requirements for a centralized I/M program are the following factors:

- Will the contractor develop the software in-house or subcontract the work out?

- Does the contractor (or subcontractor) have directly applicable experience in I/M software development?

- What hardware configuration will the contractor propose?

The number and degree of cost variables prohibit the presentation of a precise cost for this element. Alternatively, an estimate was developed based on experiences of other states involved in I/M, discussions with representatives of software houses, and an analysis by members of the GCA data processing staff. Based on these sources, the following estimates were developed.

Contractor's Software--

For development and installation of real-time programs, data transfer programs, report making, and data handling programs an estimate of 3,500 man-hours was developed. In addition, it is estimated that approximately 1,000 man-hours will be required for developing documentation and progress reporting:

Contractor's software	3,500 man-hours
Contractor's documentation	1,000 man-hours
Total	4,500 man-hours

To translate hours into a dollar cost, a standard hourly charge of $30 was assumed. The total estimated cost for development of the contractor's software, then, equates to approximately $135,000.

State's Software--

For developing and/or modifying statistical and recordkeeping programs an estimate of 1,000 man-hours was developed. For developing documentation an additional 200 man-hours is estimated:

State's software	1,000 man-hours
State's documentation	200 man-hours
	1,200 man-hours

Using the same $30 per hour rate, this translates to a total cost of $36,000 for the State's software.

SECTION 6

RFP CONSIDERATIONS

In establishing a contractor-operated I/M program, it is important to obtain as many good quality proposals as possible. The quality of the proposals submitted is somewhat directly proportional to the quality of the RFP issued by the State. If the RFP is vague or ambiguous, bidders will be forced to try to "read the minds" of the State officials. This could eliminate highly qualified contenders from consideration simply because they could not interpret the State's desires. It is important, then, that the RFP be very specific about the functional requirements of the data collection, handling, and processing system. The bidders should be well aware of the State's expectations concerning what data should be collected, generated, stored, and supplied to the State. They should know the minimum acceptable specifications for data gathering and processing equipment as well as what software they will be required to produce.

There is a risk, on the other hand, of developing an RFP that is too specific. While the bidders must be made well aware of what they must do, the RFP should be left somewhat open concerning how it is accomplished. By being too specific concerning how data is collected, stored, and processed, the bidders could be prohibited from proposing what could be a higher quality or more cost-effective data handling system than that specified in the RFP. Additionally, if the RFP is overly specific, the technical portions of the proposals received will be too similar to enable evaluation of the technical problem solving capabilities of the prospective contractors.

The State should solicit proposals from as many potential contractors as possible. Some concern has been raised that the number of interested and qualified firms is very limited. Much of this concern stems from the fact that to date, only one firm, Hamilton Test Systems, is operating motor vehicle emissions inspection programs. The U.S. EPA Emission Control Technology Division held an information seminar in May 1979 for prospective contractors and subcontractors. At this seminar a total of 23 firms expressed interest in becoming prime contractors and 15 others indicated a desire to become subcontractors in one or more of the following areas.

- Instrument procurement and maintenance
- Data analysis
- Systems design, engineering or evaluation
- Emission testing operations
- Public relations and information

- Data processing
- Building and construction of facilities

Based on this information, Wisconsin should not encounter a lack of responses to the RFP.

The remainder of this section consists of a model data processing section of an RFP for Wisconsin's I/M program. The rationale for the various functional requirements and specifications are presented in Sections 4 and 5. This portion of the RFP is divided into three sections, Functional Requirements, Equipment Specifications, and General Requirements. These three sections are prefaced by a general introduction which could appear within the overall introduction to the RFP or at the beginning of the data processing portion. Definitions of key terms are provided following the RFP.

MODEL DATA PROCESSING PORTION OF A REQUEST FOR PROPOSALS
FOR A MOTOR VEHICLE EMISSIONS INSPECTION PROGRAM

Preface

The contractor shall design, acquire sites for, construct, equip, and operate a network of motor vehicle emissions inspection facilities within the specified areas of the State of Wisconsin. Within each of the inspections facilities the contractor shall provide and install an inspection SYSTEM, a description of which shall be included in the proposal. The SYSTEM shall be capable of performing loaded-mode (key mode) testing in accordance with the inspection procedures specified in Section of this RFP.

The specifications provided within this RFP represent the State's desired configuration for the inspection SYSTEM. The contractor is free to deviate from the specific assemblies, methods, procedures, and logic, and to arrange the equipment physically in any manner, provided the functional requirements defined below are satisfied. Wherever the contractor deviates from the configurations provided within the RFP, however, he shall provide a comprehensive description of the deviation, justification for the deviation, and rationale as to why the proposed SYSTEM will be of higher quality or be more cost effective than that specified in the RFP. The Contractor shall also be prepared to demonstrate (if required) that the functional requirements of the SYSTEM are fulfilled despite deviation from the RFP.

Functional Requirements

The SYSTEM shall be capable of measuring hydrocarbons (HC) carbon dioxide (CO_2)* and carbon monoxide (CO) emissions from light-duty and medium-duty vehicles (GVW <8,001 lb), excepting those vehicles exempted by draft legislation or WDNR administrative rules, that will be subject to steady-state, loaded-mode

---

*Although no standards for CO_2 will exist, this concentration is necessary to verify valid emissions measurements as specified in Trans .09(1), Emission Testing Criteria.

testing on chassis dynamometers at high cruise, low cruise, and at idle as will be defined by the motor vehicle emissions inspection rules.

Vehicle testing measurements, data entry, data processing, and data output shall be capable of simultaneous and independent occurrence in all lanes of any given facility and shall have no effect on the testing of any other vehicle within that or any other lane.

The SYSTEM shall be capable of receiving inputs from outside the SYSTEM via data entry devices and measurement devices incorporated within the SYSTEM. The proposal shall present a description of the information types, data entry devices, measuring devices, and the ranges and characteristics of data input.

The proposal shall describe a method of vehicle registration data entry, which will allow the SYSTEM to match test results with the vehicle in question. It is the State's desire that the inspectors enter and verify registration data using a standard typewriter formatted keyboard and alpha-numeric Cathode Ray Tube (CRT) for a Vehicle Identification Terminal (VIT); and that the inspectors be trained CRT operators. Verification of the data shall occur as follows:

- Keyboard entered data shall be retransmitted by the SYSTEM to the VIT.
- Data shall be limit checked on a field by field basis immediately following entry of each field. Data found to be in error will cause the VIT to backspace its cursor and command the inspector to reenter that field.
- When the inspector signals that he has completed entry of all items (ESCAPE logoff), the SYSTEM shall verify that all entry fields have been filled. If not, the logoff shall be overriden, the cursor returned to the unfilled field, and the inspector prompted to enter the required data.

At all times during the inspection process, the inspector will be able to terminate any or all portions of the test (e.g., eliminate one or more cruise portions for reasons specified in the draft rules). The SYSTEM must be able to accept commands indicating whether the vehicle is to be retested, excluded from one or more portions of the test, or excluded from all further testing. If the vehicle is to be retested, any data gathered during the retest shall replace data from the original file.* If the test is terminated, a test report shall be generated furnishing the following information:

---

*This is for the case of immediate retesting due to an error or malfunction. This should not be confused with retesting of failed vehicles following repair.

- Test serial number
- Date and time of test
- VIN
- Vehicle make
- License plate number
- Reason(s) for termination

Vehicles refused inspection for safety reasons as specified in the draft Transportation Administrative Rules will also receive the above information with reason(s) for safety rejection replacing reason(s) for termination. In the case of a safety rejection, this data will be placed in the test data bulk storage file. In the case of termination for other reasons, no record of the test need be stored.

For each steady-state, loaded-mode condition specified in the draft Transportation Administrative Rules, the SYSTEM shall receive data from the Emissions Measurement Subsystem (EMS). This data shall be measured and averaged in such a way as to assure that each derived measurement is a valid representation of the true desired measurement. The proposal shall include a scheme to ensure the validity of the emissions measurements including: the number of samples to be collected for each mode of the test, the sampling rate, the averaging technique, and a general description of all software to be used.

The bidder shall propose a testing algorithm for the SYSTEM, including verification checks of the data (CO plus CO_2, idle speed, etc.) as specified in the draft Transportation Administrative Rules, and pass/fail determination based on standards developed by the Wisconsin Department of Natural Resources.

All vehicle test data shall be stored in a test data bulk storage file for later transcription and delivery to the State. The test data bulk storage file shall include all information included on the test report issued to the public and shall consist of, but not be limited to, the following:

- Test or retest(s)
- Inspection mode (manual, automatic, semiautomatic)
- License number
- Vehicle Identification Number (VIN)
- Model year
- Vehicle make
- Vehicle style
- Vehicle class
- Mileage (thousands)
- Emission standards:
  - High cruise CO
  - High cruise HC

- Low cruise CO
- Low cruise HC
- Idle CO
- Idle HC

- Emission measurements:
  - High cruise CO
  - High cruise HC
  - Low cruise CO
  - Low cruise HC
  - Idle CO
  - Idle HC
- Pass/Fail:
  - High cruise CO
  - High cruise HC
  - Low cruise CO
  - Low cruise HC
  - Idle CO
  - Idle HC
- Analyzer ID
- Date: day/month/year
- Time: hour/minute
- Serial number of report
- Serial number of previous report (retests only)
- Station number
- Lane number
- Inspector number
- Test modes performed
- Inspection abort/reason
- CO and CO_2 sum (measured)
- CO and CO_2 sum (standard)
- CO and CO_2 sum result (valid/not valid)
- Special case ID and code
- Waiver indication

The SYSTEM should be capable of printing legible inspection reports automatically upon completion of the inspection. The inspection report must consist of, but is not limited to, the following:

- License plate number
- Vehicle identification number
- Model year of vehicle
- Make of vehicle
- Style of vehicle
- Vehicle classification
- Mileage
- Emissions standards
- Emissions measurements
- Statement of pass/fail, comply/noncomply, or waiver, if applicable
- Serial number or identification number of emissions analyzer used in making test
- Date and time of inspection
- Serial number of report
- Inspection number by station and lane
- Inspector number
- Identification of test or retest
- Prior test report number (in the case of a retest)

The Report Form shall also provide space for the following:

- Itemization of the repairs performed
- Cost of repairs or cost of estimated repairs required if such repairs exceed the maximum specified repair cost

- Name and address of the business firm or person making the repairs

- Signature of person certifying repairs

The Inspection Report format, which shall comply with all requirements within the draft Transportation Administrative Rules, shall be included in the proposal.

The SYSTEM shall be capable of either manual and/or automatic gas analyzer span and zero drift checks. If either span and/or zero drift exceeds tolerances prescribed by the Department of Transporation, the analyzer must be calibrated prior to performance of additional tests. If both span and zero drift are within tolerances, the measured amount of drift shall be used to correct all other gas measurements until the next span and zero drift check.

System maintenance data shall be maintained on a data bulk storage device and the contractor shall make such records available for inspection by the State representative. The maintenance records to be stored shall include:

- Number of tests on each lane since last dynamometer calibration, maintenance, etc.

- Number of tests on each lane since last EMS maintenance or calibration

- EMS analyzer and dynamometer cross check and calibration data

- Daily log of significant operator transactions with the System Controller

- Daily log of aborted tests including time of day and reason

The contractor shall propose a format for maintenance data storage and log printout.

The SYSTEM shall accept and act upon various operator commands and inquires entered via the Control Teleprinter. The system functions and capabilities, which shall be specified in the proposal, as a minimum, shall:

- Allow the operator to set the date and time.

- Allow selection of the number of vehicle tests between automatic span and zero drift checks.

- Print daily logs stored in the maintenance data bulk storage file.

- Print vehicle inspection data from the vehicle data bulk storage file.

Equipment Specifications

The following equipment configuration represents the State's desired system. The contractor is free to propose alternative configurations provided that the functional requirements are met. Wherever the proposal deviates from the State's desired configuration, the contractor must demonstrate that the function requirements are met.

The SYSTEM equipment* shall be configured as follows:

- The System Controller shall be responsible for data entry and validation, data processing, data management, and report printing. The System Controller shall control all of the Emissions Measurement Subsystems (EMS), Vehicle Identification Terminals (VIT), Bulk Data Storage Devices, the Control Teleprinter, and Report Printers within a facility.

  The System Controller shall have real-time control of the SYSTEM. The System Controller shall be a stored program device consisting of a program processor and adequate memory for program and data storage.

  The System Controller shall perform the following functions:

  - Accept vehicle identification data from Vehicle Identification Terminals.
  - Accept emission measurement data from Emission Measurement Subsystem.
  - Correlate vehicle data and select failure standards.
  - Compare measured values to limits separately for each individual input.
  - Output test data for report printout.
  - Record maintenance records on data bulk storage devices.
  - Output test data for storage on bulk storage devices.

---

*Only data handling and processing equipment are discussed here. Wisconsin's RFP should contain specifications for other SYSTEM equipment as well (e.g., sample conditioners, gas analyzers, dynamometers, exhaust venting systems, etc.).

The System Controller shall have as a minimum 24 kilowords of 16-bit word length memory, and a real-time clock interface to support a real-time operating system. The System Controller may utilize Core or semiconductor memory. (Proposals specifying semiconductor memory must include battery backup provisions to maintain memory for a minimum of 5 minutes in the event of external power loss.) The CPU memory must be of sufficient size to support the real-time operating system, all program modules, and sufficient space required to process the maximum possible number of vehicles being tested at the same time.

The System Controller shall be equipped with a modem to interface with the contractor's headquarters computer. The modem shall meet the following minimum specifications:

- 1200 baud digital telecommunications interface
- Auto-answer capability

- The System Bulk Data Storage Device shall consist of flexible magnetic disk (diskette or floppy disk) and shall be controlled by the System Controller. The System Bulk Storage Device shall fulfill the following functions:

  - A storage medium for logging of events, facility maintenance data, and equipment calibration data.
  - A storage medium for initial loading of the operating system software.
  - A storage medium for daily storage of inspection data which must be eventually forwarded to the Wisconsin Department of Transportation via the contractor's headquarters computer.
  - A storage medium for online storage of data required to conduct the inspection process.

- The Emission Measurement Subsystem shall perform all emissions measurement and test control functions. The EMS consist of NDIR exhaust gas analysis equipment as specified in draft rules, an exhaust gas sampling device, and a control pendant. The EMS shall control and monitor dynamometer loadings. The EMS shall be controlled by the System Controller; in the event of System Controller failures, the EMS shall control the report printer(s). One EMS shall be required per lane.

- The EMS Control Processor (EMSCP) shall be a functionally independent modular component of the SYSTEM. The EMSCP shall perform the following functions:

  - Prompt and cue inspector during measurement.
  - Convert raw analog measurement and status data to digital information.
  - Perform necessary calculations.
  - Correct measured instrument values including dynamometer speed and horsepower.
  - Compare results to the State's emissions standards.
  - Display emission values.
  - Transmit data to the System Controller, or the Inspections Report Printer during System Controller downtime.

Peripheral Equipment--

The Vehicle Identification Terminal (VIT) shall be a Cathode Ray Tube (CRT) Terminal and keyboard. The VIT shall meet the following minimum specifications:

- General characteristics
  - Standard ASCII transmission keyboard
  - Cursor control
  - Clear, return, and tab functions
- Display functions
  - Selected fields protection (System Controller or EMS may "protect" certain data fields)
  - Tab to unprotected fields
  - Overstrike editing
  - Cursor wraparound

- Two-way communication with System Controller
  - Standard ASCII transmission code
  - Full duplex, RS-232C interface
  - 1000 baud minimum speed
- Display characteristics
  - 12-inch (diagonal) screen minimum
  - 64 displayable characters, at least 0.19 inch high by 0.125 inch wide
  - 5x7 dot matrix characters per line
  - 80 characters per line
  - 12 lines on full screen minimum
  - Nondestructive cursor

The Test Control Pendant shall serve as the interface between the inspector and the EMS. The Pendant shall consist of a computer type keyboard capable of entering the following commands into the EMS and/or the System Controller.

- Start test
- Abort test
- Restart test
- Delete one or more modes of the test
- Select mode
- Control dynamometer wheel lift

The Test Display Panel (TDP) shall assist the inspector in performing the test. The TDP shall prompt the inspector with, but not limited to, the following instructions and display information.

- The measured road speed.
- The horsepower applied to the vehicles driving wheels.
- The mode of operation — high cruise, low cruise, or idle.
- An indication that the vehicle's road speed is not within the appropriate tolerance during the high cruise and/or low cruise modes.

- An indication that the EMS controller has determined that all the prerequisites for a valid emission test have been satisfied and the emission inspection is progressing properly.

- An indication that the test sequence is complete.

- An indication that the EMS is in semiautomatic mode (not communicating with the System Controller).

- An indication that a message has been printed on the control teleprinter.

- Exhaust gas sample dilutions.

The Inspection Report Printer (IRP) shall print the inspection test results and appropriate information. The printer shall generate inspection reports on 8-1/2 by 11 inch report forms of the contractor's design but approved by the State. The Inspection Report Printer shall provide the following functions:

- Display characteristics
  - Minimum of 64 ASCII displayable characters
  - Minimum character size 0.19 inch high by 0.11 inch wide
  - Minimum 7x7 dot matrix characters (if applicable)
  - Minimum 80 characters per line
  - Minimum 30 characters per second print speed
  - Capability of one original and two additional copies
  - ASCII transmission code
  - RS-232C interface

The vehicle inspection report shall provide the information specified in the draft rules.

The Control Teleprinter shall provide operator communication with and print messages from the System Controller. The control Teleprinter shall meet the following minimum specifications:

- Standard 64 ASCII transmission character set
- Teletype format keyboard
- Thermal or impact single copy printout
- Full Duplex mode
- 30 characters per second minimum print speed
- 80 characters minimum line length

Peripheral Equipment Interface--

All SYSTEM peripheral equipment, the EMS, and the IRP shall interface with the SYSTEM through industry standard RS-232C interfacing.

Headquarters Computer System--

The Contractor's Headquarters Computer System (HCS) must be capable of supporting the following functions:

- Data collection and data entry for inspection and repair data.
- Data validation and compilation for monthly submission of data to the Department of Transportation.
- Data analysis and summarization for network operating management.
- Data management reporting.
- Network software maintenance.

The Headquarters Computer System (HCS) must be compatible with the facility System Controllers and shall be capable of supporting the network information processing and network communications capabilities required. The HCS must be capable of producing magnetic 1/2 inch wide, industry standard 9-track tapes at 800 or 1600 bpi in EBCDIC code (must be translated from ASCII).

The contractor may propose any configuration for the Headquarter's computer, but the computer should have as a minimum a System Teleprinter, online interactive terminal(s), and a high-speed line printer, or any other configuration enabling the contractor to generate the operating reports and data tapes required for submission to the Department of Transportation.

The HCS shall provide for communication interface with the facility System Controllers. This shall be accomplished with the following:

- 1200 baud, asynchronous communication modem
- Automatic call-up function
- Bidirectional communication capability with all test facilities

General Design Requirements

The SYSTEM shall be designed and constructed so as to comply with all applicable OSHA requirements.

All electrical systems and their installation shall comply with the National Electric Code and any and all applicable State and/or local electrical codes.

Mechanical and electrical interchangeability shall exist between like assemblies, components, and their replacement parts.

Batteries shall not be incorporated in the design of any equipment (except that batteries may be used to maintain semiconductor memory during power outages).

Electronic enclosures shall provide dust-protective housing of sheltered equipment. Ventilating air flow shall be filtered. The enclosures shall provide complete dust-protective housing of equipment. Electronics Industries Association (EIA) standards for enclosures shall be applied.

Performance of equipment shall be protected from degradation by the presence of interference signals which may be present at any facility. It shall be the contractor's responsibility to determine the degree of interference control required at each site. Equipment shall be prevented from generating interference signals which will affect proper operation of any equipment in the facility.

Except as otherwise specified, equipment to be housed within the building core equipment room shall be capable of operation as specified within an ambient temperature range of 5^{o} to $30^{o}C$. Equipment to be operated in the inspection lanes shall be capable of operating as specified within an ambient temperature range of 0^{o} to 45^{o} C.

All equipment shall be capable of operating as specified when exposed to a relative humidity of 10 to 90 percent (noncondensing) for both continuous and intermittent periods.

SYSTEM Software--

The SYSTEM software shall consist of all necessary programs for the System Controller which shall cause the SYSTEM to correctly perform all of the functions specified herein.

All applications software written for use on the SYSTEM shall be prepared using the general programming approach known as "Structured Programming," to achieve the basic goals listed below in order of importance:

1. Reliability
2. Modifiability
3. Understandability
4. Efficiency

The proposal must address and include a proposed schedule for the software development process, including monthly meetings with the Department of Transportation during the design and development stages. Bidders should be aware that the selected contractor will eventually be required to provide full documentation of all software utilized in the vehicle inspection and data management processes, including master block diagrams of the complete SYSTEM and pneumatic and electrical schematics of the SYSTEM.

DEFINITIONS

The RFP should contain a section of definitions of the key and technical terms used in the text. The following terms were used in the model data processing portion of the RFP. In the final RFP, only one definitions section, covering the entire RFP, should be included.

Control Teleprinter

Teletype device used to enter commands into or receive information from the System Controller.

CRT

Cathode Ray Tube, T.V. screen device associated with a computer terminal.

EMS

Emissions Measurement Subsystem of the SYSTEM including all equipment necessary to draw a gas sample, condition and analyze it, and transmit data to the SYSTEM.

EMSCP

Emissions Measurement Subsystem Control Processor. (Micro) processor controlling all functions of the EMS.

Headquarters Computer

Central computer system which receives, processes, and stores data from each individual facility computer.

IRP

Inspection report printer.

Modem

Device enabling telecommunication between computer systems.

NDIR

Nondispersive infrared gas analysis device.

SYSTEM

All equipment hardware, peripheral hardware, and software used in the inspection process.

System Bulk Data Storage Device

Magnetic disk, diskette, floppy disk, or other device used for bulk storage of vehicle inspection and SYSTEM maintenance data.

System Controller

(Mini) computer used to control all SYSTEM functions and equipment.

Test Display Panel

Device used to prompt inspector during the emissions test and display pertinent information to assist in test performance.

Test Control Pendant

A data entry keyboard used to control the performance of the emissions test.

VIN

Vehicle Identification Number; a unique 13-character set of alpha-numeric characters used to identify a vehicle.

VIT

Vehicle Identification Terminal. CRT terminal used to enter vehicle registration information into the System Controller.

REFERENCES

1. Midurski, T.P., L.A. Coda, P.O. Phillips, N.K. Roy, F.M. Sellars, and T.P. Synder. Evaluation of Motor Vehicle Emissions Inspection and Maintenance Programs in Wisconsin – Phase II. Prepared for U.S. Environmental Protection Agency under Contract No. 68-02-2607, Work Assignment No. 16. GCA Corporation, GCA/Technology Division, Bedford, Massachusetts. EPA-905/2-78-003. September 1978.

2. Midurski, T.P., L.A. Coda, R.O. Phillips, N.K. Roy, F.M. Sellars, T.P. Synder, and D.L. Vlasak. Evaluation of Motor Vehicle Emissions Inspection and Maintenance Programs in Wisconsin – Phase III. Prepared for U.S. Environmental Protection Agency under Contract No. 68-02-2607, Work Assignment No. 20. GCA Corporation, GCA/Technology Division, Bedford, Massachusetts. EPA-905/2-78-004. November 1978.

3. Walker, Terry M. Introduction to Computer Science: An Interdisciplinary Approach. Allyn and Bacon, Inc. Boston, Massachusetts. 1972. 530 pp.

4. Dijkstra, E.W. Complexity Controlled by Hierarchical Ordering of Function and Variability. In Naur and Randell. 1968.

5. Dijkstra, E.W. Solution of a Problem in Concurrent Programming Control. CACM 8,9:569. 1969.

6. Dijkstra, E.W. Structured Programming. In Buxton and Randell. 1969.

7. Dijkstra, E.W. Notes on Structured Programming. In Structured Programming. O.J. Dahl, E.W. Dijkstra, and C.A.R. Hoare. Academic Press. London. 1972.

8. Dijkstra, E.W. The Humble Programmer. CACM 15,10:859-866. 1972.

9. Freeman, P. Software Systems Principles. Science Research Associates. Chicago, Illinois. 1975. 663 pp.

10. Parnas, D.L. 1972. On the Criteria to be Used in Decomposing Systems into Modules. CACM 15,12:1053-1058.

11. Gotlieb, C.C., and A. Borodin. Social Issues in Computing. Academic Press. New York. 1973. 284 pp.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-905/2-79-006	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Data Processing Procedures and Equipment for the Wisconsin Inspection and Maintenance Program		5. REPORT DATE
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Frederick M. Sellars, Dominic Caracciolo Jr., Michael W. Kozenko		8. PERFORMING ORGANIZATION REPORT NO. GCA-TR-79-75-G
9. PERFORMING ORGANIZATION NAME AND ADDRESS GCA Corporation, GCA/Technology Division, Burlington Road, Bedford, MA 01730		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-2887, Task Order No. 8
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency, Region V Office, Chicago, Illinois		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The Wisconsin Department of Transportation (WDOT) and Department of Natural Resources (WDNR) are currently involved in planning for the implementation of a motor vehicle emissions inspection and maintenance program. Once operational, the program will be generating a considerable amount of data. In addition to the obvious problem of handling and analyzing this data, any system developed must be easily integrated with existing computer systems in WDOT and WDNR.

This document defines the computer hardware specifications for emission testing installations so that needed data can be readily collected, stored, and transferred to WDOT systems. In addition, the required software systems and specifications that will enable manipulation and analysis of data either on the selected I/M contractor's central computer or the State's system are identified. Finally, a model data processing portion of an I/M Request for Proposals (RFP) is provided.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Automobile engines Exhaust detection Exhaust emissions	Inspection and Maintenance Data Management Computer Requirements	

18. DISTRIBUTION STATEMENT Unlimited distribution	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 80
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)