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REVIEW OF THE MASSACHUSETTS VEHICLE EMISSIONS TEST EQUIPMENT

FINAL REPORT

by

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DISCLAIMER

This Final Report was furnished to the U.S. Environmental Protection Agency by Booz·Allen & Hamilton Inc., Bethesda, Maryland 20814, in fulfillment of Contract Number 68-02-3507. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those 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.

SUMMARY

This document is the final report for a "Review of the Massachusetts Equipment Specification" performed by Booz·Allen & Hamilton Inc., for the Environmental Protection Agency (EPA) under contract number 68-02-3507. The work was performed in close consultation with the Massachusetts Department of Environmental Quality Engineering (DEQE).

The study involved reviewing the Massachusetts draft computerized emission analyzer specification and then developing a final equipment specification as well as specifications for a quality assurance (QA) program, a recommended procurement schedule and a set of proposal evaluation criteria. This section of the report provides an overview of the study objectives, methodology and results. Three technical appendices contain technical documentation prepared during the course of the study (Appendix A), the final equipment specification (Appendix B) and recommended proposal evaluation procedures (Appendix C).

1. OBJECTIVES OF THE STUDY

The objectives of this study were to provide assistance to the Commonwealth of Massachusetts in (1) developing a request for proposal (RFP) for the State's computerized emission analyzer and (2) providing a methodology for evaluating the proposals received in response to the RFP. Specific objectives were to:

- Review the Massachusetts draft emissions analyzer technical and performance specifications, modify these specifications as necessary and prepare a final equipment specification (Task 1)
- Develop a manufacturing quality assurance (QA) program for the emissions analyzers (Task 2)
- Develop a schedule for the development and distribution of the computerized emission analyzers (Task 3)
- Prepare the relevant sections of the RFP (Task 4)
- Develop a methodology for use by Massachusetts in evaluating proposals received in response to the RFP (Task 5).

2. STUDY METHODOLOGY

The general methodology of the study combined (1) engineering analysis of selected analyzer specifications and QA procedures, (2) interviews with equipment manufacturers and industry representatives, (3) an analysis of the manufacturers' comments and (4) an analysis of the technical feasibility, costs and lead times for various equipment options. The specific approach applied in each task area is described below.

(1) Task 1 - Review the Existing Draft Analyzer Specification and Prepare a Final Equipment Specification

The approach to this task was organized in three steps as follows:

- The Massachusetts draft analyzer specification was compared with the recommended EPA specification for computerized emissions analyzers, the New York and California Bureau of Auto Repair (BAR) '80 specifications, and the requirements of the EPA promulgated 207 (b) emissions performance warranty regulation. The purpose of the comparison was to identify "variances" between the draft Massachusetts specification and the aforementioned analyzer specifications/207 (b) warranty regulations.

- Inquiries to the emission analyzer manufacturing industry were made to determine the technical feasibility, costs and lead times for equipment specifications found to be at variance with the previously bid specifications. Representatives of four equipment manufacturers (Sun, Hamilton Test Systems, FMC and Bear), the Equipment and Tool Institute (ETI), the State of New York and the EPA were interviewed on this subject.

- The results from the manufacturing industry interviews and comparisons of the analyzer specifications were analyzed, and recommendations for the final Massachusetts equipment specification developed.

Appendix A contains documentation of these recommendations.

(2) Task 2 - Develop a Manufacturing Quality Assurance Testing Program

The quality assurance (QA) procedures recommended by the EPA and implemented by the State of New York were analyzed and used as models for developing the Massachusetts QA testing program. Representatives of EPA, the New York Emissions Task Force and the New York Department of Environmental Conservation were interviewed regarding the merits and weaknesses of the respective QA procedures. Comments from the analyzer manufacturers on alternative QA procedures were also considered. The comments received from EPA, New York and the manufacturers were analyzed and a set of recommendations and action items prepared for Massachusetts. The final recommended QA procedures were incorporated into the equipment specification section of the RFP.

(3) Task 3 - Develop a Schedule for Analyzer Development and Distribution

A schedule was constructed for the development and distribution of the computerized emission analyzers. The schedule was based on discussions with the analyzer manufacturers and the Equipment and Tool Institute and on the following analyses:

- A review of the manufacturers' lead time requirements for analyzer development
- A review of the time required for analyzer manufacture and certification
- An evaluation of the time requirements for marketing the analyzers
- An analysis of the proper sequencing of the analyzer development and distribution efforts
- Massachusetts DEQE requirements for handling the procurement.

The final recommended schedule is contained in Appendix A.

(4) Task 4 - Prepare the Relevant Sections of the RFP

During Task 4, a chapter of the Massachusetts RFP addressing the following was finalized:

- Analyzer specifications
- Manufacturing QA procedures
- Analyzer in-use QA/QC procedures.

The chapter was written in a manner consistent in format with other sections written by the Massachusetts DEQE. It is reproduced in Appendix B.

(5) Task 5 - Develop a Methodology for Evaluating Bidders' Responses to the RFP

Proposal evaluation criteria were developed based on an evaluation of the selection criteria in the draft Massachusetts RFP and utilized in the New York emission analyzer procurement, as well as the experience of other states. Booz, Allen's experience in evaluating manufacturers' technical and cost proposals for the U.S. Departments of Transportation and Energy was useful in developing the overall proposal evaluation methodology. Standard government procurement procedures were utilized as much as possible. Close contact was maintained with the Massachusetts DEQE throughout the development of the proposal evaluation methodology. The methodology is reproduced in Appendix C.

3. STUDY RESULTS

Recommendations for the Massachusetts equipment specifications and quality assurance provisions were presented during the study and are reproduced in Appendix A. The recommendations were based on an analysis of the schedule, costs and benefits of available options, and with the intent of attracting as many bidders as possible. This section briefly summarizes the principal results of the analyses in each area.

(1) Analyzer Specifications

Based on a detailed review of the existing analyzer specifications and on an analysis of comments received from knowledgeable industry and government sources, the following recommendations were made regarding the analyzer specifications:

- Require the analyzer to have a capability for (1) automatically recording, storing and printing out test results, (2) measuring engine speed, and (3) measuring CO_2.

- Require the analyzer to have (1) a switch or selector button that enables the analyzer to be used for vehicle repair as well as inspection, (2) anti-tampering features and (3) system diagnostic features.

- Require an automatic read system (i.e. a system whereby the analyzer averages the gas samples over a specified time period).

- Require fully automatic gas span, leak and HC hang-up checks.

- Use EPA's performance specification for all parameters except the instrument accuracy profile and drift requirements. For these two specifications the BAR '80 provisions were recommended.

(2) Quality Assurance Procedures

Recommendations on manufacturing quality assurance (QA) procedures were based on evaluation of the EPA recommended procedure and comments received from manufacturers. Recommendations to Massachusetts on manufacturing QA procedures included the following:

- Adopt the revised EPA QA procedure for use in Massachusetts

- Specify in the RFP the government agency which will be responsible for evaluating the QA test results and engineering reports.

- Allow bidders to suggest alternative QA procedures that can be performed in a shorter time frame or at a lower cost than the EPA procedure, yet provide equivalent QA test data

- Do not require certification by the California BAR in addition to the EPA certification

- Require a performance bond from the successful bidder

- Require the contractor to assume responsibility for the performance and maintenance of the equipment in the field and to pay a penalty for excessive analyzer downtime.

APPENDIX A

THREE TECHNICAL MEMORANDA

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THREE TECHNICAL MEMORANDA

This appendix contains three technical memoranda which were developed to document the results of the first three tasks of the study. They include the following:

- Review and Development of Basic Analyzer Specifications (Task 1)
- Development of a Quality Assurance Testing Program (Task 2)
- Schedule for Analyzer Development and Distribution (Task 3).

Parenthetical notations have been included at various places throughout this appendix in order to more fully explain how the final equipment specifications evolved from the technical memoranda in this appendix. These technical memoranda were deliberative documents which led to further investigation of certain analyzer issues. In some cases, new information resulted in changes in some of the positions taken in the technical memoranda. While such changes were reflected in the final specifications, they were not otherwise documented.

TECHNICAL MEMORANDUM ON THE REVIEW AND DEVELOPMENT OF BASIC ANALYZER SPECIFICATIONS

This technical memorandum summarizes the results of Task 1 of a study to provide assistance to the Commonwealth of Massachusetts in developing a request for proposal (RFP) for their I/M computerized emissions analyzer. The objective of Task 1 was to review and develop the basic specification for the computerized emissions analyzer. The methodology used to accomplish this objective involved three steps as follows:

- Step 1: Compare the Massachusetts draft analyzer specification with the recommended EPA specification for computerized emissions analyzers, the New York and BAR '80 analyzer specifications, and the requirements of the 207(b) emissions performance warranty regulation. The purpose of this comparison was to identify "variances" between the draft Massachusetts specification and the aforementioned analyzer specifications/207(b) warranty regulation requirements.

- Step 2: Contact representatives of various manufacturers of infra-red exhaust emissions analyzers, the Equipment and Tool Institute (ETI) and the State of New York. The purpose of these contacts was to gather first-hand information on the position of the industry regarding what would be acceptable specifications and the experience of that one state (i.e., New York) with a decentralized I/M program employing computerized emissions analyzers. In total, representatives of four equipment manufacturers (Sun, Hamilton Test Systems, FMC and Bear), the ETI and the State of New York were interviewed.

- Step 3: Analyze the comments received from industry/state representatives and develop recommendations. Based on the comments received from industry/state representatives regarding the technical feasibility, costs and lead times associated with each of the variances, combined with our understanding of the intended purpose/scope and desired operational features of the Massachusetts I/M program, recommendations were developed. In developing the recommended analyzer specification, the EPA specification was used whenever possible unless supporting justification for not using it could be established. In those cases, an alternative specification is proposed.

The remainder of this technical memorandum describes the results of this three step methodology. Results are presented under the following headings:

- Comparison of the Massachusetts Draft Analyzer Specification, the EPA Computerized Analyzer Specification, the New York and BAR '80 Analyzer Specification, and the 207(b) Warranty Regulation

- Industry/State Comments Regarding What Would Be An Acceptable/Reasonable Analyzer Specification

- Analysis of Industry/State Comments and Recommendations.

COMPARISON OF MASSACHUSETTS DRAFT ANALYZER SPECIFICATION, THE EPA COMPUTERIZED ANALYZER SPECIFICATION, NEW YORK AND BAR '80 ANALYZER SPECIFICATIONS, AND THE 207(b) WARRANTY REGULATION

As described above, the first step of this task was to compare the Massachusetts draft analyzer specification with the EPA computerized analyzer specification, the New York and BAR '80 analyzer specifications, and the 207(b) warranty regulation. The results of this comparison are described below.

Comparison of Massachusetts (Draft), EPA, New York and BAR '80 Analyzer Specifications with 207(b) Warranty Regulation Requirements

Based on analysis of the aforementioned specifications and the 207(b) warranty regulations, it was observed that the EPA recommended analyzer specification is the only specification that fully complies with the requirements of the 207(b) warranty regulation. The BAR '80 and New York analyzer specifications comply with all requirements of 207(b) except the leak and span check frequencies. The 207(b) warranty regulation requires weekly leak and span checks while BAR '80 and New York require the following:

- <u>BAR '80</u>: Calls for the leak and span checks to be controlled by the operator, but requires the operator to maintain a log book that notes the date, time and results of all checks.

- <u>New York</u>: Requires leak and span checks to be performed monthly by the vendor of the analyzers (i.e., Hamilton Test Systems).

Comparison of Massachusetts (Draft), EPA, New York and BAR '80 Analyzer Specifications

Comparison of these four specifications in terms of technical content revealed that the most significant difference in the specifications was in the area of automation. The EPA recommends as a "fail safe" measure (i.e., to prevent improper operation of the analyzer) that a number of analyzer features be automated (i.e., controlled by an on-board computer/microprocesser). These features include zero/span check, leak check, HC hang-up, read system (i.e., sample averaging) and test sequencing. Neither the BAR '80 specification nor the New York specification require these automated features.* In addition, as a convenience measure, the EPA also suggests that the analyzer be capable of collecting and storing the emissions test results. Only the New York specification also requires this feature; the BAR '80 specification does not.

Other major differences (variances) between these specifications include the following:

- As additional fail safe measures, the EPA recommends that the analyzer be equipped with (1) a printer, (2) a switch or selector button that enables the analyzer to be used for vehicle repair as well as inspection, (3) anti-tampering features and (4) system diagnostic testing features. The BAR '80 specification doesn't require any of these features. The New York specification, however, requires all these features.

- To provide more capability, the EPA suggests that the analyzer be equipped with a CO_2 analyzer and a tachometer. Again the BAR '80 specification doesn't require either of these features while the New York specification requires both features.**

- In the area of analyzer performance, the EPA specification is slightly more stringent than the BAR '80/New York specification in the areas of calibration, drift, and HC hang-up, and slightly less stringent in the areas of interferences, leak detection, propane/hexane conversion and analyzer response time. Only very minor or no differences exist between these three specifications in other performance areas.

Based on a line-by-line comparison of the specifications, the Massachusetts draft specification requires all the fail safe/ convenience features suggested by the EPA specification but is

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* The New York specification requires test sequencing but not exactly the same as that specified in the EPA specification.

** The New York specification is essentially the BAR '80 specification with some automated features. The one exception is that the BAR '80 requirement for on-board gas was eliminated.

more closely tied in the area of analyzer performance to the New York/BAR '80 specification (although variations do exist between the Massachusetts draft specification and New York/BAR '80 specification). Major deviations between the Massachusetts draft specification, and the New York, BAR '80 and EPA specifications are in the areas of analyzer response time and the range of ambient temperatures in which the analyzer is required to operate.

INDUSTRY/STATE COMMENTS REGARDING WHAT WOULD BE AN ACCEPTABLE/ REASONABLE ANALYZER SPECIFICATION

As indicated in the previous section, the Massachuetts draft specification primarily deviated from the EPA recommended specification in the area of analyzer performance. It included most of EPA's recommendations on the automated/convenience features. However, because of the limited field experience with some of the automated/convenience features, discussions were held with industry/state representatives on both these features, as well as the differences in the performance specifications. The comments received by industry/state representatives in these areas are discussed below.*

Automation

The position of the manufacturing industry with regard to the EPA analyzer specifications for automation is that certain of the specifications are beyond current analyzer technology. The addition of the specified functions is technically feasible but will require an investment in time and money before they can be achieved.

The fundamental source of automated analyzer functions is the microprocessor. Current manufacturing capability includes companies that already build analyzers equipped with microprocessors (Sun, Hamilton Test Systems) and those that do not (Bear, FMC, other U.S. manufacturers). Companies which have not yet accomplished integration of the microprocessor into the analyzer must undertake a substantial development effort just to provide basic microprocessor controlled functions. Such basic functions specified by EPA include automatic test sequencing and automatic data collection. Sun and Hamilton Test Systems currently offer these capabilities.

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* Data from the New York program which could provide key answers to the calibration requirements of analyzers in the decentralized program will not be available for some time. At some point this data should reveal how the monthly calibration is working and whether in fact more or less frequent gas calibrations are necessary.

Four additional EPA specifications are beyond the technology currently offered by any manufacturer. These include automatic gas spanning, automatic leak detection, automatic hang-up detection and an automatic read system (calculates an integration test value from several samples rather than giving the value of a single sample). The addition of these features to Sun and Hamilton Test's equipment is technically feasible but will require a research and development effort. The other manufacturers must first integrate microprocessors into their analyzers before they can even begin the development of these more sophisticated functions. (Note: Continued research into the feasibility, costs, and time restraints of these four automated features resulted in subsequent findings that full automation was both feasible and cost-effective. Therefore, the final equipment specification contains provisions for all four of these features.)

Automatic Gas Span

All of the manufacturers interviewed questioned the cost-effectiveness of equipping the analyzer with a computer controlled gas spanning feature. While technically feasible, the manufacturers interviewed indicated that:

- The hardware necessary to facilitate automatic gas spanning is both complicated and costly and thus may add appreciably to the base cost of the analyzer
- Required software programs must be developed and tested. This task represents the longest estimated lead time -- from 6 to 18 months depending on the manufacturer.

Although not a limiting factor, several of the manufacturers also indicated that the amount of on-board calibration gas storage that would be required in an automatic spanning program would pose a potential problem. In addition, several of the manufacturers also felt that electrical spanning techniques which can be automated were adequate.

All of the manufacturers felt that a workable and more cost-effective compromise between a completely automatic gas span and a manual operation would be a semi-automatic calibration procedure. In this concept the internal plumbing, valving, electrical controls and gas storage requirements would be essentially the same as in the automatic version but the test would be initiated by the operator (i.e., by pushing a button or flipping a switch). Software could also be developed that notes when the operator performed the calibration. Opinions of the manufacturers vary on the merits of this approach. All agree, however, that the costs and lead time would be considerably less since little or no programming would be required (depending on whether it was desirable to note when the calibration was performed). The system would be very similar to the BAR '80 requirements that now exist.

Automatic Leak Check

For essentially the same reasons discussed above for automatic gas spanning all the manufacturers interviewed felt that a completely automatic leak check, while technically feasible, was not cost-effective. All felt that the semi-automatic leak check procedure recommended in EPA's revised specifications was more practical for a decentralized program. This procedure requires that span gas be available on the analyzer and that some mechanical provision be made for introducing the gas to the probe in which the operator would be involved (i.e., the operator would have to push a button or flip a switch).

In a practical sense, this procedure is tied to the gas span procedure. If the analyzer is designed and equipped for automatic or semi-automatic gas spanning, it is relatively simple for the manufacturers to provide an automatic or semi-automatic gas system leak check. What is needed is additional software. As was discussed for the semi-automatic span check, software could be developed that (1) notes every time the leak check is performed, and (2) stores this information on tape. Depending on the manufacturer, this can be either a very costly or a relatively inexpensive development effort. For Hamilton Standard and Sun whose analyzers are already equipped with microprocessors, this is a relatively inexpensive development effort. For Bear and FMC whose analyzers are not equipped with on-board microprocessors, up to 18 months of effort would be required to develop the software at a considerable expense.

HC Hang-Up

The possibility of HC hang-up in the internal and external flow system is a factor that must be considered in the analyzer design. Not only should design practices and material be incorporated to minimize the hang-up, but procedures for evaluating the amount hang-up be developed, these procedures can be manual or semi-automated. The manufacturer is free to choose the actual system hardware and approach. The main advantage of the hang-up check is found in the centralized system where the purge time between the completion of one test and the beginning of another must be minimized. In this instance the ideal system would be automatic and include a lock out feature that would prevent the next test from beginning until the HC hang-up was below the prescribed limit. In a decentralized inspection program, the manufacturers feel that the frequency of testing minimizes the need for automatic testing if not the hang-up test itself. New York State does not require the test or the equipment to do it. (Note: In a decentralized I/M program, the analyzer will not only be used for emissions inspections but also for diagnosing and repairing failed vehicles and for tune-up adjustments. In these repair modes, the analyzer may be subjected to extended exposure to potentially high concentrations of hydrocarbon emissions, thus increasing the likelihood of a hydrocarbon hang-up problem. The final Massachusetts equipment specifications include provisions for this check to be performed automatically.)

Automatic Read System

The EPA computerized analyzer equipment specification calls for a system whereby continuous samples are taken by the analyzer and averaged over a 15 second time interval. Neither the BAR '80 nor New York analyzer specifications require this feature. The advantage of the feature is that it enhances the accuracy of the test results and reduces the errors of omission and commission. It accomplishes this by minimizing the influence of "outlier" samples on the test outcome, i.e., if a single gas sample is taken as the sole determining measure of the "cleanliness" of a vehicle, and if this single sample happens to be an "outlier," it may cause a vehicle which should have failed the inspection to pass or vice versa.

The primary disadvantage of this feature is that it increases the base cost of the analyzer (although not significantly according to the manufacturers interviewed). Another consideration, however, is that while there are variations in HC and CO readings while the vehicle is idling, only in rare cases will the readings vary enough so that a car which should have failed the inspection will be passed or vice versa. Thus, the added benefit of this feature must be questioned in light of the fact that it serves to protect only a small percentage of the vehicles subjected to the mandatory inspection program.

Other Fail Safe/Convenience Features

Most of the fail safe/convenience features (i.e., printer, vehicle diagnosis capability, anti-tampering feature, self diagnostic capability, CO_2 analyzer and tachometer) recommended by the EPA are features which are either presently offered by analyzer manufacturers or could be readily offered with minor development effort. For example, Hamilton Test Systems and Sun offer all of the features identified above, while FMC and Bear only offer the printer as an option.

In discussing the necessity of these features, all agreed that the printer was needed from a public relations standpoint, while Hamilton and Sun (since they already have a microprocessor capability) saw the need for anti-tampering provisions and system self diagnostic features. All four manufacturers also saw the benefit of incorporating a vehicle diagnostic capability within the analyzer (i.e., adding a switch or selector button that enables the analyzer to be used for vehicle repair as well as inspection) since this capability enhances the marketability of the analyzer. Those features questioned by the manufacturers in terms of costs and benefits were the CO_2 analyzer and tachometer. Each is discussed below.

Tachometer

All four manufacturers were found to offer an engine speed readout capability with their analyzer, however, their approach to the display mode varied. For example, given an analyzer that is used solely for vehicle conformance evaluation (i.e., to determine that the vehicle is idling properly), three of the four manufacturers (Hamilton, FMC and Bear) preferred a digital tachometer as opposed to an analog tachometer. The primary reasons cited for this preference was the ease in which the output can be read. The other manufacturer (Sun) preferred an analog tachometer because, according to Sun, it facilitates engine diagnostic work when the analyzer is switched to the vehicle repair mode.

Vehicle Exhaust Leak Detection

All of the analyzer specifications require the analyzer to be equipped with a CO_2 monitor to detect dilution in the gas sample. The acceptable range for CO_2 dilution is from ± 2 percent to ± 3 percent. At issue is the EPA recommendation that the CO_2 monitor be available to the inspector to test for exhaust system integrity (leaks). The manufacturers assert that evidence of CO_2 in the exhaust is not a conclusive indication of a faulty exhaust system. Thus, in New York, analyzers are equipped with CO_2 monitors, but they are not used to test for faulty exhaust systems.

The position of the manufacturers is that the general condition of the vehicle exhaust should be ascertained by the inspector in a private garage system. This can be done by briefly blocking the tailpipe while the engine is running and listening for leaks. A preliminary inspection for exhaust leaks would also permit the inspector to avoid testing cars with a known failed system.

Performance

The New York performance specification is essentially the same as the BAR '80 specification with some automated features. On a line-by-line comparison, the EPA specification is slightly more stringent than New York/BAR '80 in the areas of calibration, drift and HC hang-up; and slightly less stringent in the areas of interferences, leak detection, propane/hexane conversion and analyzer response time. Other performance specifications include operating environment, operating temperature and operating time.

The manufacturers say that they can meet the specifications in the areas where the EPA requirements are more stringent. However, whether the expected minor improvements in test accuracy can justify the required equipment development effort is questioned.

Response Time

The response times recommended by the various analyzer specifications vary considerably as follows:

- EPA: 14 seconds to 95% of reading
- BAR '80: 8 seconds to 90% of reading
- N.Y.: 10 seconds to 95% of reading
- Massachusetts: 5 seconds to 95% of reading.

According to the manufacturers interviewed, the EPA requirement is the most realistic for a decentralized program.

Shorter response times are technically feasible and are in fact a requirement of most centralized inspection programs. However, these programs are concerned with high throughput whereas decentralized programs are not. All of the manufacturers can provide quicker response times but at an added cost which does not appear to be justified.

Operating Environment

The EPA, BAR '80 and New York analyzer specifications require that the unit be able to meet all system specifications within the ambient temperatures of 35^{o} F and 110^{o} F. The draft Massachusetts specification, on the other hand, calls for the unit to meet all system specifications between 20^{o} F and 110^{o} F.

According to the manufacturers interviewed, broadening the temperature range as specified in the draft Massachusetts specification will require the addition of a heater in the analyzer cabinet -- again increasing the base cost of the analyzer. While Massachusetts is known for its harsh winters, garages that perform repairs/inspections are generally equipped with space heaters. Thus, the temperature in these garages will generally not fall below 35^{o} F to 40^{o} F even on the coldest days. Hence, it is again questionable whether this added feature is actually needed.

As an alternative to requiring this feature, the garage performing the inspection can be required to maintain a minimum ambient temperature or in the case of a prolonged cold soak, it can be required to keep the analyzer turned on (see "warm-up time" below).

Warm-Up Time

The EPA does not specify a precise warm-up time for the analyzer. Rather, it specifies that the analyzer will not be operable until all circuits in the unit are functional to within specified limits. The BAR '80 and New York specifications, on the other hand, specify a warm-up time of 15 minutes.

In theory all of the manufacturers claim that they can meet the New York/BAR '80 warm-up time of 15 minutes. In practice, however, this requirement has not always been met. Situations have occurred in the New York program where, due to extreme cold soak, the equipment has not been able to perform without auxilliary heat.

In the Massachusetts specification, it may be necessary to require heating elements in the analzyer or require that the garage performing the inspection leave the analyzer turned on when an extended cold soak is anticipated (such as over a weekend). New York State has used this latter approach successfully to meet the warm up time criteria.

Calibration Curve Accuracy

The New York, California BAR and Massachusetts specifications for calibration curve accuracy vary to a small degree from the EPA specification -- the EPA specification is slightly more stringent. Thus, existing gas benches meet the New York/BAR '80 requirements, while there is currently no bench which meets the EPA specification. All the manufacturers who were contacted agree that they can meet the EPA specification with additional development effort. However, given the time remaining before the Massachusetts I/M implementation date, the wisdom of requiring a major development effort to achieve slight improvements in accuracy is questioned.

Meter Drift

There are two areas of difference between the EPA meter drift specifications and those of BAR '80, New York and Massachusetts. First, the EPA recommends a maximum meter drift of ± 2 percent full scale, while the New York and BAR '80 specifications permit a less stringent ± 3 percent full scale drift. Second, the EPA and New York permit the specified drift to a period of two hours. Massachusetts on the other hand specifies its standard in terms of ppm HC and percent CO. (Note: The full New York/BAR '80 specification for meter drift is:

zero drift - ±3% full scale low range for one hour

meter drift - ±3% full scale low range for the first hour of operation and ±2% full scale low range in any succeeding hour.

This same comment applies to the meter drift specification in Table 1 on page A-16. The correct New York/BAR '80 meter drift specification was incorporated into the final Massachusetts specifications.)

In the opinion of the manufacturers, these differences are minor. However, again, no optical bench system presently exists that meets the EPA specification. Thus, the question again is whether it is worth the added cost and time to achieve this slight improvement in accuracy.

HC Hang Up

The New York/BAR '80 specifications require the analyzer to retain less than 200 ppm of hang-up in the system within 15 seconds after a two-minute sample. The EPA specification, on the other hand, calls for less than 20 ppm hang-up prior to testing a vehicle, with no specific time limitation except that an excessively long time (five to ten minutes) to reduce the hang-up to the standard should indicate a need for maintenance. (Note: The full New York/BAR '80 specification for hydrocarbon hang-up is less than 200 ppm after 15 seconds and less than 60 ppm after 30 seconds. The EPA specification for hydrocarbon hang-up was incorporated into the final Massachusetts specifications.)

Due to the more extended time period between tests in a garage environment as compared with a centralized lane, the manufacturers believe the analyzers will easily be able to eliminate hang-up before each test. However, they feel that a machine check for hang-up prior to every test, as required by EPA, is excessively stringent and unnecessary. The New York/BAR '80 specifications have no requirement for a similar hang-up check prior to each test. (Note: Subsequent investigation led to the determination that the hydrocarbon hang-up feature could be easily incorporated into a fully automatic analyzer.)

Interferences

The BAR '80, New York and Massachusetts specifications give limitations on either five or six interference gases. In contrast, the EPA requirement specifies limitation of only three gases. Thus, the EPA specification on interference gases is attainable in the opinion of the manufacturers.

Propane/Hexane Factor

The variation in limits of the propane/hexane conversion factor is not an issue with the analyzer manufacturers at this time. All the probable respondents to the Massachusetts analyzer procurement are likely to purchase optical benches from the same manufacturer. The narrower the conversion factor range, the fewer the number of benches that will be acceptable for installation in the individual analyzers. The BAR '80 specification in this case is more stringent than the EPA specification.

ANALYSIS OF INDUSTRY/STATE COMMENTS AND RECOMMENDATIONS

Based on review of the aforementioned specifications and analysis of the industry/state comments, the following recommendations are made for the Massachusetts RFP:

- Require that the analyzer include a capability for (1) automatically recording, storing and printing out test results, (2) measuring engine speed, and (3) measuring CO_2. For at least two manufacturers (Hamilton and Sun), these features can be readily added. In fact, both already offer these features. For other manufacturers, some development will be required, but the effort will not be overwhelming. The automatic data collection feature is important from a data quality standpoint, while including a printer is important from a public relations standpoint in that the motorist receives a hard copy of the test results. The engine speed and CO_2 features are important from the standpoint that they minimize ways in which an operator can tamper with the test results (i.e., the test will not be run if the engine speed is set too high or if there are insufficient amounts of CO_2 detected).

- Require that the analyzer include (1) a switch or selector button that enables the analyzer to be used for vehicle repair as well as inspection, (2) anti-tampering features and (3) system diagnostic features. The inclusion of these features pose little problem for Sun and Hamilton (again, these two manufacturers already offer these features as options) and represent only minor additions for those manufacturers which need to develop a microprocessor capability. The requirement for these features is felt to be important for the following reasons:

  - A switch or selector button that enables the analyzer to be used for vehicle repair as well as inspection will enhance the marketability of the analyzer to the private garage.

  - The inclusion of anti-tampering and system diagnostic features serve to make the analyzer more "fool proof."

- Do not require an automatic read system (i.e., a system whereby the analyzer averages the gas samples over a specified time period). Based on our analysis of this feature, it provides little benefit and is a feature which will involve some development effort by all manufacturers. (Note: Continued investigation subsequent to this technical memorandum led to the determination that this feature was both feasible and cost-effective.)

- Do not require fully automatic gas span, leak, and HC hang-up checks. To require these checks to be fully automated will appreciably add to the base cost of the analyzer and will require a significant amount of development by manufacturers. In fact, it is questionable whether the manufacturers can complete the necessary development and produce the required number of analyzers in time to implement the program in April 1983 (see technical memorandum on the schedule). Thus, it is recommended that the gas span, leak and HC hang-up checks be semi-automated with the necessary software added to note when the check was made (as described earlier). The manufacturers can more readily comply with this requirement. Additionally, the 207(b) requirement for weekly span and leak checks can be more easily complied with if these checks were semi-automated. (Note: Continued investigation subsequent to this technical memorandum led to the determination that these features were both feasible and cost-effective.)

- Use EPA's performance specifications for all except gas calibration, and drift. No optical bench system presently exists that meets EPA's specification for calibration and drift. Thus, to require these specifications would involve some development and testing by bench manufacturers. Furthermore, comparison of the BAR '80/New York and EPA specifications for each of these items indicate very minor differences. (EPA is only slightly more stringent). Given this finding and the already tight schedule (see Technical Memorandum on the schedule), it does not appear justified to require this added accuracy.

A summary of EPA's performance specification recommendations for major items is shown in Table 1. Also shown in the table are alternative specifications for each item in which we do not recommend the EPA specification. Note that we recommend using EPAs specification in the operating temperature range (i.e., 25^{o} to 110^{o} F) instead of that required in the Massachusetts draft specification (i.e., 20^{o} to 110^{o} F). In evaluating the trade-offs, we feel that it would be more cost-effective to require the licensed inspection station to maintain minimum ambient temperatures as is done in New York then to require the manufacturers to certify their equipment to 20^{o} F.

In addition to the above, we also recommend that the New York probe design be used instead of the EPA design. The New York design is a twelve-inch flexible probe system with positive retention and a thermally insulated handle. By 1983 this probe will be compatible with almost every vehicle on the road. With its required sixteen-inch length the EPA design is too long for most cars. Furthermore, the specified anti-dilution device will be applicable only in a few isolated cases such as vehicles equipped with flame arresters at the end of the tailpipe.

The above recommendations were made (1) with the intent of attracting as many bidders as possible, and (2) based on analysis of the schedule, costs and benefits. Based on discussions with the equipment manufacturers, it is our opinion that even given the above recommendations for the specifications (which are somewhat relaxed compared to EPA's recommended specification for a computerzied analyzer) only two manufacturers -- Sun and Hamilton -- could respond (i.e., design and produce the number of analyzers required by Massachusetts) within the allotted time frame. Thus, if the specification is made much more stringent than our recommendation, Massachusetts runs the risk of either having one or no bidders, or not meeting their April 1983 start up date.

TABLE 1
RECOMMENDED PERFORMANCE SPECIFICATIONS

ITEM	EPA SPECIFICATION	OTHER		
Accuracy of Calibration Curve	Not Recommended	HC	HS	±30 PPM (400-1000 Range)
				±60 PPM (1000-2000 Range)
			LS	±12 PPM (0- 400 Range)
		CO	HS	±0.15% (2- 5% Range)
				±0.3 % (5-10% Range)
			LS	±0.06% (0- 2% Range)
Accuracy of Audit Gases	1% Traceable to NBS Standard Reference Material	--		
Accuracy of Span Gases	2% Traceable to NBS	--		
Meter Drift*	Not Recommended	± 3% f.s. ls for 1 hour		
HC Hang-Up	Less than 20 PPM Before Each Test	--		
Interferences		--		
- Gaseous	3 Items @ 1% each			
- Electrical	6 Items @ 1% each			
Leaks	3% of Comparative gas readings	--		
Operating Environment		--		
- Temperature	35 to 110°F			
- Relative Humidity	0% to 99%			
Propane/Hexane Conversion Factor	.48 - .56 @ 90% Confidence Level	--		
Response Time	14 seconds to 95% of Reading	--		

* Note: See parenthetical comment on page A-12 in the section entitled "Meter Drift".

TECHNICAL MEMORANDUM ON THE DEVELOPMENT OF A QUALITY ASSURANCE TESTING PROGRAM

This technical memorandum documents our findings and recommendations on the development of a quality assurance program for Massachusetts (Task 2). The results are based on discussions with members of the New York Emissions Task Force; employees of the New York Department of Environmental Conservation; and selected equipment manufacturers. Reports documenting the EPA and New York quality assurance procedures were also reviewed. The memorandum is organized in the following sections:

- Summary of New York and EPA Quality Assurance Procedures
- Comments from Equipment Manufacturers regarding the EPA Quality Assurance Procedures
- Recommendations for the Massachusetts RFP
- Action Items for Massachusetts.

SUMMARY OF THE NEW YORK AND EPA QUALITY ASSURANCE PROCEDURES

New York's quality assurance procedures were reviewed to identify those procedures which are applicable to the Massachusetts RFP. The EPA recommended quality assurance procedure was also reviewed and then discussed with selected analyzer manufacturers. The following sections summarize the New York quality assurance procedures and the procedure recommended by EPA.

New York State Quality Assurance Procedures

In the recent New York emission analyzer procurement the schedule was extremely tight and there was little time for formal quality assurance during the prototype and production stages. New York required the basic analyzer to be certified against the California BAR '80 specifications; the State then worked closely with the contractor to further develop the top half (interactive) part of the unit. This process started with a rough engineering mock-up which, together, the State and the contractor improved. When advanced hand-made units were available, tests were conducted on approximately 35 cars in the laboratory and a few cars in a private garage.

During procurement, New York was primarily concerned about the operation of the printer and the interface between the inspector and the unit. The correct operation of the gas analyzer was guaranteed, in the opinion of New York representatives, by the requirement for BAR '80 certification of the analyzer; a hefty performance bond submitted by the contractor; and strict contractual language requiring the contractor to assume responsibility for the equipment's performance in the field. The most pertinent contract requirements included the following:

- California Quality Assurance Accreditation. The New York equipment was required to meet the California BAR '80 quality assurance provisions.

- Performance Bond. New York required the contractor to submit a $500,000 performance bond. These funds are held by the State to be used in the event damages are suffered due to non-performance or default.

- Equipment Operation and Maintenance Agreement. The New York contractor was required to sign a maintenance agreement to ensure that the analyzers are kept properly maintained and calibrated in the field. The contractor inspects, calibrates and maintains the emission analyzers monthly at the premises of the licensed station and is responsible to the State for the correct functioning of the equipment. The contractor also provides service or equipment replacement when malfunctions are reported. To verify that the contractor is fulfilling this agreement, the State conducts unannounced periodic checks as well as concealed identity investigations of the inspection stations. The contractor also agreed to pay a penalty to the equipment purchaser, (i.e., licensed inspection station) if an analyzer remains inoperable for 8 hours during one scheduled work day.

EPA Recommended Quality Assurance Procedure

The EPA recommended quality assurance procedure is intended to be applied to a random sample of the first batch of production analyzers. The procedure is defined in two parts; the production sampling procedure and the quality assurance evaluation procedure. Each is discussed below.

- Production Sampling Procedure. The sampling procedure recommended by EPA requires the random selection of 3 of the first 20 production units; the three are then subjected to the evaluation tests. If two of the three units pass all the tests then EPA will award full accreditation valid for three years from the date the first unit was produced. If two or more units fail the evaluation tests, corrections to the design and/or production must be made, and three additional units randomly selected from a new or current production run. Two of these three must pass all evaluation tests.

- Quality Assurance Evaluation Procedure. According to a review by the New York Department of Environmental Conservation,* the EPA-recommended quality assurance evaluation procedure is essentially the same as the California BAR '80 procedure, except that acceptance criteria differ where the EPA analyzer specifications differ from the BAR '80 analyzer specifications. The EPA procedure includes a list of procedures for which California BAR '80 test results may be substituted.

  The initial EPA procedure was distributed to manufacturers for comment, and many of the manufacturer's recommendations were included in the revised version. Thus, equipment manufacturers have had an opportunity to review the procedure and become familiar with its requirements. One of the most significant requirements is that the evaluation must be conducted by a 3rd party, i.e., an authorized testing laboratory. (Note: The EPA procedure does not require, although it does recommend, a third party evaluation. The final Massachusetts specifications allow the QA testing procedures to be performed at the contractor's own facilities or at a third party testing laboratory.)

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* "A Comparative Review of EPA and NYS Exhaust Emissions Analyzer Specifications," Walter J. Pienta, New York Department of Environmental Conservation, March 25, 1981.

COMMENTS FROM THE EQUIPMENT MANUFACTURERS REGARDING THE EPA QUALITY ASSURANCE PROCEDURE

Booz, Allen contacted selected manufacturers to obtain their comments regarding the use of the EPA recommended quality assurance procedure in the Massachusetts procurement. Most of the manufacturers felt that the EPA recommended procedure was technically sound and generally could be accommodated. Specific comments and/or criticisms arose in the following six areas:

- Identification of the Reviewing Agency
- Redundancy of the EPA and BAR procedures.
- Requirement to Test Production vs. Prototype Units
- Leadtime and Cost Requirements of a 3rd party Evaluation
- Definition of Re-certification Procedures.
- Acceptance of Alternative Q.A. Procedures.

Comments received from the manufacturers in each of these areas are discussed below.

- Identification of the Reviewing Agency. EPA has not identified the agency which will take responsibility for accepting and evaluating the quality assurance test results. Either Massachusetts or the EPA will need to assume this responsibility and assign it to a qualified technician capable of fairly analyzing the results. The same is true for accepting and evaluating engineering reports on infant mortality failures and the repair of random failures in production units.

- Redundancy of the EPA and BAR '80 (California) Quality Assurance Procedures. Some manufacturers feel that the EPA and California (BAR) certification procedures are redundant, and that one or the other should be required for the basic analyzer bench, but not both. The time required for certification testing (1 to 2 months) is a critical element in the manufacturer's schedule for delivery of the equipment and delays could jeopardize timely delivery of the units. Unique aspects of the analyzer other than the basic bench, such as the interactive unit, could be tested according to a procedure developed jointly by the State and the manufacturer.

- Requirement to Test Production Versus Prototype Units. There is a feeling among some manufacturers that functional tests could be performed as effectively on prototype units identical to the planned production units as on the production units themselves. Prototype testing can verify whether the design does what it's supposed to in time to adjust costly production machinery before it is brought on line. EPA allows preliminary accreditation on pre-production units but is firm on its commitment to require that production units be tested for compliance with the analyzer specifications.

- Lead Time and Cost Requirements of a 3rd Party Evaluation. The requirement for a 3rd party evaluation raises critical questions about lead time and cost. First, adequate lead time must be built into the manufacturing schedule for delivery of the equipment to the laboratory and performance of the tests by the lab. If infant mortality or random failures occur during testing they must be documented by engineering reports justifying that the failures are not design failures. Then, in the event of random failures in production units, a plan must be developed (and documented) to prevent the specific type of failure in future production units. Furthermore, after repair of the random failures in the production units, those tests that might be affected by the repairs must be rerun. All of this activity may consume weeks out of the manufacturing and production schedules and could delay delivery of the units. Second, an unofficial estimate quoted by Bear for a 3rd party quality assurance evaluation according to the EPA procedure was $22,000. It is expected that this cost will be included as part of the manufacturer's contract and will be reflected in the price of the analyzer and the inspection fee. In the event that multiple awards are made in a single State, the expense of 3rd party evaluations could be required for two or more similar analyzers built by different manufacturers. (Note: Considering that Massachusetts intends to award a single contract for 3000 to 4000 analyzers, the cost of a third party evaluation represents only a small cost per analyzer which is negligible when compared to the expected unit cost of the analyzer. However, the final Massachusetts specifications do not require a third party evaluation.)

- <u>Definition of Re-Certification Procedures</u>. EPA has defined a procedure for mandatory re-certification of the emission analyzer design. The current (revised) procedure calls for re-certification testing on new production units every three years after the initial certification. The re-certification testing is limited to certain key parameters which, according to the manufacturers, need to be more clearly defined. The basic issue here is that the requirement for subsequent testing is too vague and that more specific language needs to be developed.

- <u>Acceptance of Alternative QA Procedures</u>. The manufacturers would like to have the opportunity to propose alternative quality assurance procedures in their bids without being considered non-compliant. Allowing the manufacturers to suggest options for QA could potentially benefit both the manufacturer and the State.

<u>RECOMMENDATIONS FOR THE MASSACHUSETTS RFP</u>

Based on evaluation of the EPA quality assurance procedure and review of comments made by manufacturers the following recommendations are made for the Massachusetts RFP:

- <u>Adopt the EPA Quality Assurance Procedure</u>. All of the manufacturers have had an opportunity to review and submit comments on the EPA QA procedure, and the revised version incorporates many of the manufacturer's recommendations. It appears that most of the manufacturers can accommodate the revised procedure in their bids.

- <u>Specify the Reviewing Agency in the RFP</u>. The government agency and/or department which will be responsible for evaluating the QA test results and engineering reports should be identified in the RFP. Any planned arrangements for supplementing an existing technical capability with assistance from, for example, EPA in Ann Arbor, should be described.

- <u>Permit the Bidders to Suggest Alternative QA Procedures</u>. The manufacturers may be able to suggest alternative QA procedures that can be performed in a shorter timeframe or at a lower cost than the EPA procedure yet provide equivalent QA test data. Massachusetts could potentially benefit by allowing the bidders to propose options in the quality assurance procedure. The proposed options should be limited by Massachusetts to modifications of the EPA procedure rather than, for example, elimination of some of the EPA requirements.

- Do Not Require Certification by California BAR in Addition to the EPA Certification. The EPA certification requirement is an independent and complete analyzer certification procedure. Requiring both California BAR and EPA certification is redundant and unnecessary.

- Request a More Detailed Specification of the Re-certification QA Procedure from EPA, and If Possible, Include it in the RFP. The EPA re-certification requirement needs more specific definition before the manufacturers can fully understand their long-term obligations under the procedure. If possible, a more detailed explanation of the re-certification requirements should be included in the Massachusetts RFP. (Note: Since Massachusetts is only concerned with a one-time production of analyzers for its I/M program, a re-certification procedure was not included in the final specifications.)

- Require a Performance Bond. The $500,000 performance bond submitted by Hamilton Test Systems in New York is a strong incentive for the contractor to meet all performance requirements of the contract. It also provides a contingency for the State in the event of non-performance or default. It is recommended that Massachusetts require a performance bond from the successful bidder. The amount should be determined by the State.

- Require the Contractor to Assume Responsibility for the Performance and Maintenance of the Equipment in the Field and to Pay a Penalty for Excessive Analyzer Downtime. The contractor should be held responsible for the correct functioning of the analyzers in the field. This responsibility includes providing service or equipment replacement when malfunctions are reported. To protect the inspection station operators from loss of income due to a malfunctioning analyzer, the contractor should be required to pay a penalty when the analyzer or associated hardware remains inoperable for an extended period. The maximum allowable downtime and the amount of the penalty should be determined by Massachusetts.

ACTION ITEMS FOR MASSACHUSETTS

Recommended action items for Massachusetts include the following:

- Identify the organization and individuals who will be responsible for evaluating test results and engineering reports on the emission analyzers.
- Request EPA to provide a more detailed explanation of the analyzer re-certification QA procedure. This material should be received in time to be included in the RFP.
- Determine the amount of the performance bond to be submitted by the successful bidder.
- Determine the maximum allowable downtime for emission analyzers in the field and the penalty to be paid by the contractor for exceeding this time period.

TECHNICAL MEMORANDUM ON SCHEDULE FOR ANALYZER DEVELOPMENT AND DISTRIBUTION

This technical memorandum documents our findings and recommendations on an appropriate schedule for the development and distribution of computerized emissions analyzers for Massachusetts I/M program (Task 3). The findings are based on discussions with representatives of four analyzer manufacturers (Sun, Hamilton, FMC and Bear) and the Equipment and Tool Institute (ETI). The memorandum is divided into the following three sections:

- Summary of Manufacturer Responses
- Analysis of Manufacturer Responses
- Recommendations.

SUMMARY OF MANUFACTURER RESPONSES

Tables 1 and 2 on the following page summarize the manufacturers' responses regarding the amount of time that would be required to develop and manufacture two types of analyzers:

- Table 1 assumes the development of an analyzer with those features recommended by Booz, Allen in the technical memorandum on basic analyzer specifications (i.e., includes automatic data collection and storage, CO_2 analyzer, tachometer, semi-automatic gas span, leak and HC hang-up checks, EPA performance specifications except for gas span and meter drift, etc.).

- Table 2 assumes the development of a computerized analyzer that fully complies with EPA's recommended specifications for computerized analyzers (i.e., includes a fully automatic gas span, semi-automatic leak check, automatic HC hang-up check, etc.).

As shown by the tables, the time required to develop and manufacture these analyzers varies considerably by manufacturer. Those manufacturers (i.e., Sun and Hamilton) that already offer analyzers with a microprocessor capability require much less lead time than those manufacturers (i.e., FMC and Bear) that don't have such analyzers. FMC and Bear indicated it would take them a minimum of 12 months to develop a microprocessor capability. As also shown in the tables, the manufacturing capability of manufacturers also varies significantly.

TABLE 1
Development and Manufacturing Time Estimates
For Analyzer Built to
Booz, Allen Recommended Specifications

SCHEDULE ITEM	MANUFACTURER			
	SUN	HAMILTON	FMC	BEAR
Development	6 mos.	6 to 9 mos.	12 mos.	12 to 18 mos.
Manufacture (4,000 units)	6 to 9 mos.	6 mos.	12 to 18 mos.	16 mos.

TABLE 2
Development and Manufacturing Time Estimates
For Analyzer Built to
EPA Specification

SCHEDULE ITEM	MANUFACTURER			
	SUN	HAMILTON	FMC	BEAR
Development	12 mos.	9 to 12 mos.	15 mos.	18 mos.
Manufacture (4,000 units)	6 to 9 mos.	6 mos.	12 to 18 mos.	16 mos.

ANALYSIS OF MANUFACTURER RESPONSES

Given the results presented in Tables 1 and 2 and assuming the milestones shown in Figure 1 are realistic, the following can be concluded:

- Even given the somewhat relaxed specifications (compared to EPA) recommended by Booz, Allen, it is doubtful that any manufacturer without a microprocessor capability at present will be able to meet Massachusetts' timetable to develop and manufacture analyzers by April 1, 1983. Assuming a 12-month development effort, the earliest any manufacturer (without a microprocessor capability) could have a prototype ready for certification testing would be January 1983.

- Both Hamilton and Sun (it appears) could comply with Massachusetts' timetable given the Booz, Allen recommended analyzer specifications and could possibly comply with EPA's timetable (i.e., develop and manufacture analyzers by January 1, 1983), assuming that (1) the analyzer certification process goes smoothly and takes no longer than one month, and (2) there are no significant schedule slippages early in the program. It also assumes that the manufacturers receive firm commitments by garages to purchase the analyzers by August 1, 1982 and that there are no major problems encountered in the analyzer development effort. Even if there are no problems, meeting the EPA schedule would still be tight since (a) the manufacturers would still have to train garagemen in the operation of the analyzer, and (b) there is a lag time between manufacture of the analyzers and delivery of the analyzers to garages. Given the EPA-recommended specification for computerized emissions analyzers, it does not appear that either Hamilton or Sun could comply with Massachusetts' timetable.

RFP's Distributed	September 11, 1981
Proposal Received by Massachusetts	November 1, 1981
Contract Award	December 1, 1981
Contract Negotiations Completed	December 15, 1981
Analyzer Development Effort Begins	January 1, 1982

FIGURE 1
Milestones for RFP Distribution,
Contract Award and Contract Negotiation

RECOMMENDATIONS

Based on the above analysis, it appears that the extra three months requested by Massachusetts is justified, given the various schedule uncertainties. Thus it is recommended that the implementation date be moved from January 1, 1983 to April 1, 1983. If after contract award, the selected manufacturer finds it can meet the EPA January 1, 1983 start up date, this extra three-month period can be used for public awareness and "debugging" purposes prior to full implementation.

APPENDIX B

EMISSION ANALYZER TECHNICAL AND PERFORMANCE SPECIFICATIONS

EMISSIONS ANALYZER TECHNICAL AND PERFORMANCE SPECIFICATIONS

This section provides the technical and performance specifications for the exhaust emissions analyzer required by the Commonwealth of Massachusetts. The specifications detailed herein are those recommended by the U.S. EPA (Document Numbers EPA-AAA-IMS-80-5-B and EPA-AAA-IMS-80-5-C) with the exception that the BAR '80 gas calibration accuracy and meter drift performance specifications have been substituted for the EPA's recommended specifications. Automatic features required by the specifications described herein include automatic gas spanning, automatic leak checking, automatic HC hang-up, automatic test averaging (i.e., automatic read system), automatic test sequencing and automatic data collection. Additionally, the specifications also require that the analyzer possesses a vehicle diagnostic capability, an anti-dilution capability and an engine speed monitoring capability.

The remainder of this section is divided into the following parts:

4.A General Requirements
4.B Construction/Materials
4.C Hardware/Design Requirements
4.D Environmental Requirements
4.E Performance Specifications
4.F Manuals
4.G Quality Assurance.

References to the U.S. EPA and BAR '80 analyzer specifications are made throughout each remaining part of this section. The reader is encouraged to use these references in responding to this specification. (Note: All references to EPA-AA-IMS-80-5-B in the text automatically include any revisions in EPA-AA-IMS-80-5-C unless specifically stated otherwise. Specifications in EPA-AA-IMS-80-5-C supersede those in EPA-AA-IMS-80-5-B).

4.A GENERAL REQUIREMENTS

4.A.1 Design Goals

The emissions analyzer shall be designed for maximum operational simplicity with a minimum number of operational decisions required in the performance of a complete exhaust emissions analysis. The analyzer shall be unaffected by ambient conditions in a typical repair facility environment and its use shall be primarily for compliance inspection purposes. It shall however be capable of vehicle diagnostic work as well.

4.A.2 Useful Life

The useful life of the analyzer shall be a minimum of five years. (Ref: EPA-AA-IMS-80-5-B, Section VII.D.1, page 23).

4.A.3 Name Plate Data

A nameplate with provisions for and including the following data shall be permanently affixed to the housing of the analyzer:

- Name and address of manufacturer
- Model description
- Serial number
- Date of assembly
- Date of analyzer system assembly
- Blank space(s) for rebuild certification.

The serial number shall also be stamped or engraved on the chassis of the analyzer housing. After installation, the manufacturer shall affix a stick-on type label to the analyzer which contains a telephone number for customer service.

4.B CONSTRUCTION/MATERIALS

4.B.1 Materials

All materials used in the fabrication of the analyzer and the appropriate housing assembly shall be new and of industrial quality and durability. Contact between non-ferrous and ferrous metals shall be avoided where possible. Suitable protective coatings shall be applied where galvanic action is likely. All mechanical fasteners shall have appropriate locking features. Use of self tapping screws shall be avoided. All parts subject to adjustment or removal and reinstallation shall not be permanently deformed by the adjustment or removal/reinstallation process and this process shall not cause deformations to adjoining parts of the equipment. Only materials that are not susceptible to deterioration when in contact with automobile exhaust gases shall be used.

4.B.2 Construction

The analyzer shall be complete and all necessary parts and equipment required for satisfactoy operation shall be furnished. A suitable means of storing the probes and sample hose shall be provided. All parts shall be manufactured and assembled to permit the replacement and/or adjustment of components and parts without requiring the modification of any parts or the basic equipment design. Where practical components and/or subassemblies shall be modularized. The analyzer cabinet finish shall be baked enamel or equivalent.

4.B.3 Mobility

The analyzer unit shall be designed for easy and safe movement over hard and/or graded surfaces. The center of gravity and wheel design shall be such that the analyzer can negotiate a vertical grade separation of 1/2 inch without overturning when being moved in a prescribed manner. Industrial grade, swivel casters shall be used to permit 360° rotation of the unit. The caster wheels shall be equipped with oil resistant tires and foot operated brakes.

4.B.4 Electrical Materials/Construction

Unless otherwise specified, all electrical components including motors, starters, switches and wiring shall conform to provisions established by the Underwriters Laboratories, National Electrical Code and applicable state and local electrical codes.

4.B.4.1 Connections

Connections to conductors and terminal parts shall be of the screw pressure (i.e., mechanically fastened) or solder type. When screw pressure type connections are used, the conductors and terminal parts shall be mechanically secured with a means to prevent loss of tightness.

Interconnecting cables terminating at the control panels shall be constructed with connectors staked to withstand shock and vibration during operation and movement.

4.B.4.2 Power Supply

The analyzer shall operate from unregulated 120 volt, 60 Hertz supply. An input voltage variation of from 100 to 130 volts and a ±1 Hz frequency variation shall not change analyzer performance more than 1% of full scale. The power cable shall be equipped with a standard three prong connector at the inlet. It shall be 30 feet in length and be extremely durable and water resistant. (Ref: EPA-AA-IMS-80-5-B, Section VII.E.8b, page 33).

4.B.4.3 Fault Protection

Each analytical system and the entire emissions analyzer shall incorporate safety devices to prevent conditions hazardous to personnel or detrimental to equipment. Circuit breakers shall be used to protect individual circuits and the analyzer. All such devices shall be readily accessible and clearly marked as to functions affected. Fuses shall not be used. The system shall be grounded to prevent electrical shock.

4.C HARDWARE/DESIGN REQUIREMENTS

4.C.1 Readout Display Control Panel

The console shall contain numerical HC (Hexane), CO, and CO_2 displays, a pass/fail display and a vehicle control group selector.

4.C.1.1 Numerical HC, CO and CO_2 Displays

The numerical displays shall be of a digital format. The resolution of the displays shall be as follows:

HC: XXXX ppm (Hexane)

CO: X.XX%

CO_2: XX.X%

The display increments shall be 0.01% CO, 1 ppm HC and 0.1% CO_2. The displays shall be capable of maximum readings of 9.99% CO, and at least 2000 ppm HC (Hexane) and 16% CO_2. See EPA-AA-IMS-80-5-B, Section VII.D.8, page 29 for negative readings.

4.C.1.2 Pass/Fail Display

Readily visible lights shall be provided to indicate pass (green) and fail (red) for HC, CO or both. An additional indicator light is to be employed for an exhaust system leak check. This light will signal excess dilution in the exhaust system based upon measurement of CO_2 emissions. The accuracy of the pass/fail set points must be ±2% of the indicated value. The failure lights must accommodate the failure points of each potential standard. An exhaust system leak will automatically yield an invalid test, and such indication will appear on the printout and data recorder.

4.C.1.4 Vehicle Control Group Selector

The analyzer shall be capable of selecting cutpoints based on vehicle model year for five vehicle control groups. Control group selection shall be accomplished by operator entry into the data acquisition analyzer storage system of the vehicle model year. Once entered, the failure points (cutpoints) for each test must then be automatically selected from the analytical console. Provisions shall be made for five (5) vehicle year control groups with additional provision for future adjustment of the control groups.

4.C.1.5 Control Panel Layout

The layout of the push button switches and lights on the panel shall be determined and justified by the contractor, subject to the requirements that: a) the operator may be wearing heavy gloves; and b) spacing of buttons and lights shall be chosen to give the panel a neat appearance.

Other important human engineering considerations include: a) visibility of numerical displays and pass/fail indicator lights from various tailpipe locations; and b) accessibility and lighting of the vehicle year control group selector.

4.C.2 Process Control System

The process control system shall perform the functions of accepting, displaying and reporting all necessary data from the various input sources. The system shall also be capable of making pass/fail decisions and of initiating automatic zero and gas spanning, leak checking and HC-hangup procedures. The latest process control technology shall be used in order to develop uniform procedures consistent with garage inspection operations.

Bidders are required to submit a process control flow diagram indicating the system logic requirements for each input. An example of a process to be controlled is as follows:

1. Enter vehicle year control group and other data
2. Automatic zeroing of meters

3. Exhaust leak analysis, pass or fail
4. HC & CO analysis, pass or fail
5. Unit in purge mode.

4.C.3 Sampling System

The sampling system consists of two subsystems: (1) external sampling system; and (2) internal sampling system. The external subsystem shall include an insulated sample probe, tailpipe extender and a 20-foot hose. The internal subsystem shall include, but not necessarily be limited to, a water trap, filtration system, sample pump, and bypass pump. Specific references to the EPA reports are identified in the following subsections.

4.C.3.1 Sample Probe

The sample probe shall incorporate a positive means of retention to prevent it from slipping out of the tailpipe when in use. A thermally insulated, securely attached hand grip shall be provided on the probe in such a manner that easy probe insertion using one hand is insured.

The probe shall be flexible enough to extend into a 1½" diameter tailpipe having a 3" radius 90° bend, 4" from the end of the pipe. The probe insertion depth shall be at least 16 inches from the end of tailpipe or tailpipe extender. All flexible materials used in the probe construction shall be of a sealed construction to prevent sample dilution. The probe assembly shall be replaceable as a unit separate from the sample line.

The probe shall also have a smooth surface near the probe tip before the flexible portion of the probe to be used for sealing of the span gas adaptor necessary for field or on-board leak checking (gas comparison) or response time checking equipment. For standardization it is recommended that the sealing surface be 1/2 inch in outside diameter and 1/2 to 1 inch long.

A probe tip cap or some other means of introducing calibration gas into the analyzer shall be provided for the sample system check described in Section 4.C.9. (Ref: EPA-AA-IMS-80-5-B, Section VII.D.5, pages 24-25).

4.C.3.2 Tailpipe Extender

In addition to the sample probe, a tailpipe extender capable of being attached to the vehicle within 60 seconds shall be provided. The tailpipe extender shall be designed to allow the attachment of standard service center building exhaust evacuation systems without affecting the vehicle or measurement process. The pressure at the end of the tailpipe or extender shall be within ±2 inches of water of the ambient barometric pressure.

The tailpipe extender shall not alter the sample and the material shall conform to all requirements described earlier. The probe and tailpipe extender shall have sufficient hardware (insulated handles, etc.) that will allow the user to insert, attach, or remove the probe or the dilution adapter safely and conveniently. The probe or tailpipe extender shall be designed in a manner that will prevent the probe or extender from being removed from the vehicle unintentionally. (Ref: EPA-AA-IMS-80-5-B, Section VII.D.5, page 25).

4.C.3.3 Sample Hose

The interconnecting hose shall be of such design and weight that it can easily be handled by the inspector. The hose shall not be longer than 25 feet nor shorter than 15 feet (excluding the probe). For standardization, a 20 foot length is preferred. The hose shall be of non-kinking construction and fabricated of materials that will not be affected by nor react with the exhaust gases. Molecular hydrocarbon hang-up shall be minimized. The hose connection to the analyzer shall be reinforced at the point of maximum bending. (Ref: EPA-AA-IMS-80-5-B, Section VII.D.6, pages 25-26).

4.C.3.4 Water Trap

The system shall be designed with a water trap in the bypass sample stream. The water trap shall be continually self-draining through a bypass pump. The trap bowl shall be constructed of a durable transparent material. The water trap and bypass pump should be located as low as possible on the analyzer so that condensed water in the sample hose will drain, by gravity, into them. However, the trap must be placed in a position readily visible to the operator. The sample for the analyzer shall be obtained from the top of the water trap. (Ref: EPA-AA-IMS-80-5-B, Section VII.D.3 d, pages 23-24 and EPA-AA-IMS-80-5-C, Section III.D.1, page 10).

4.C.3.5 Filtration

The sampling system shall be equipped with a 5 micron particulate filter upstream of the optical bench. A secondary filter upstream of the sample pump is optional. This filter must have sufficient capacity to filter the samples obtained during the routine testing of at least

500 vehicles in the inspection station. (Ref: EPA-AA-IMS-80-5-B, Section VII. D.3 e, page 24 and EPA-AA-IMS-80-5-C, Section III. D.2, page 10).

4.C.3.6 Sample & Bypass Pumps

The sample and bypass pumps shall be the positive displacement diaphragm type, with corrosion resistant internal surfaces. The pumps shall have a minimum operational life of 2,000 hours with no mechanical or electrical failure (or equivalent).

The pumps may be either a single pump, multiple pumps for the sample and bypass streams, or a dual pump for bypass flow and sample flow. The sample pump shall have integral motor overload protection and permanently lubricated, sealed ball bearings. The bypass pump shall be connected in the sample system so that any water condensed in the water trap is removed by the pump and dumped outside the system. The bypass stream does not pass through the particulate filter.

The bypass and sample pumps shall be deactivated by a test standby switch. The flow rate from the pumps shall be sufficient to obtain an overall response time of less than 14 seconds for 95 percent response to a step input of gas having either or both contaminants.

4.C.4 System Vents

No restrictions such as flowmeters may be placed downstream of any analyzer vent (a series analyzer flow path is permitted) unless the system can detect potential changes in restriction (i.e. sticking flowmeter), and

- Alert the operator of the problem which would require a new gas span and/or repair of the component causing the restriction, or
- Use automatic compensation of the analyzer readout device for the change in restriction.

A change in restriction that will cause a 3 percent of point change in the analyzer response shall activate the alert system. (Ref: EPA-AA-IMS-80-5-B, Section VII.D.10, page 30.)

4.C.5 Analytical System

The analytical system shall include carbon monoxide, carbon dioxide, and hydrocarbon analyzers. These analyzers shall be the nondispersive infrared type.

4.C.6 Fail Safe Features

4.C.6.1 Operating Temperature Lockout

Functional operation of the unit shall remain disabled through a system lockout until the instrument meets the warm-up requirements specified in section 4.E.3. (Ref: EPA-AA-IMS-80-5-C, Section III.H.1, page 19).

4.C.6.2 Low Flow Indicator

A low flow indicator shall be provided which will activate when the sample flow rate is decreased to a point which would not allow the analyzer system to meet the response time specificiations indicated in Section 4.E.4. (Ref: EPA-AA-IMS-80-5-B, Section VII.H.2, page 37).

4.C.7 Automatic Data Collection

The analyzer shall be supplied with provisions for data entry and storage. (Ref: EPA-AA-IMS-80-5-B, Section IX. A, page 50).

4.C.7.1 Data Entry System

An alphanumeric keyboard shall be used for data entry and control of the analyzer shall be via a small computer. The test mode shall be selected by using an "auto-test" key. This shall cause the preset inspection station identification number to be entered into the test record. The date may be set automatically or on a daily basis. If set daily, it need only be verified for each vehicle.

The following information will then be entered on the keyboard:

- Vehicle license plate number
- VIN
- Vehicle type (LDV, LDT, HDG, etc.)
- Vehicle make
- Vehicle model
- Vehicle model year

- Odometer reading
- Fuel type (gasoline, gasohol, methanol, ethanol, propane, hydrogen, spare channel, etc.)
- Inspector identification number
- Type of test (initial, first retest, second retest, etc.)

This action will key appropriate HC and CO limits for a pass/fail decision. After the probe is inserted into the vehicle tailpipe, the test shall be initiated by using a "start-test" key. The emission test will be conducted automatically with no further operator action, i.e. the sample will be validated (dilution check), readings will be taken, values will be compared to limits and a pass/fail determination will be made. (See Section 4.C.15.) The HC and CO readings and a pass/fail determination will then be supplied by the printer and entered on the data storage unit.

4.C.7.2 Data Storage System

The data collection device shall be compatible with the data storage system. The format of the data shall be in machine readable form. Included in this data shall be the date, inspection number, vehicle license plate number, inspection station identification number, inspector identification number, vehicle class, year, make/model of vehicle, vehicle type, odometer reading, fuel type, type of test (i.e, initial, first retest, second retest, etc), anti- dilution test criteria (i.e., air pump, no air pump), CO and HC emissions readings and overall pass/fail determination. The data storage system shall have sufficent capacity to store safety inspection-related data at a future date.

4.C.8 Printer

The analysis system shall have a printer that provides the consumer and the inspector a receipt with the following information:

a) Date (the printer may use manually input values for the date).

b) Inspection Facility Number or Instrument Serial Number.

c) Inspection Test Number (may be sequenced by initiation of Automatic Test Sequence).

d) Applicable cutpoints or standards for HC and CO for each test mode.

e) Integrated vehicle test values for HC and CO for each test mode.

f) An overall pass or fail indication for each test.

Space on the form (back or front) shall provide for safety item check off boxes and repair information based upon HC and CO emissions levels. The printer shall allow for two copies of the printed material.

4.C.9 Automatic Gas Span Check

The analyzer shall be designed for automatic gas calibration plus automatic electrical spanning. The frequency of calibration shall be every 180 hours. If the system is not calibrated or the system fails the calibration, an error message shall be displayed and the printer shall be prevented from printing. Appropriate valves, switches and electrical controls shall be installed to permit this operation. The reader is referred to EPA-AA-IMS-80-5-B, Section VIII.A, pages 41 and 42 and EPA-AA-IMS-80-5-C, Section IV.B, pages 21 for a listing of the detailed requirements associated with this feature.

4.C.10 Automatic Leak-Check

An automatic leak checking system shall be provided that will allow the vacuum side of the system to be checked for leakage using span gas. Appropriate valves, lines, and switches shall be installed to permit this operation. Minimal activity by the operator, such as setting the probe in a holder or capping the probe, is permitted, provided errors resulting from improper operator action would be identified by the computer and would require corrective action or improper operator action would tend to cause the system to fail a leak check.

The leak check shall be accomplished by comparing the span gas response when the gas is introduced through the span network (calibration port) to the response of the same gas introduced through the probe and sample line. Leakage in the vacuum portion of the sampling system shall not exceed a variation of 3 % in the reading of the gas value, when the flow through the probe and hose is compared with the flow through the calibration port.

The analyzer shall be equipped with a timer that will allow the analyzer to operate for 180 calendar hours (once per week) between leak checks. If the system is not leak checked, or the system fails a leak check, an error message shall be displayed, and the printer shall be prevented from printing. (Ref: EPA-AA-IMS-80-5-B, Section VIII.B, page 43 and EPA-AA-IMS-80-5-C, Section IV.C, page 22).

4.C.11 Automatic Hang-Up Check

The analyzer shall be designed for automatic HC hang-up checks of the sampling system using room air. The analyzer shall have a selector switch or button with indicator light labeled "Hang-up Check." Activation of the "Hang-up" switch shall cause the analyzer to automatically sample room air through the sample line and probe. The check system shall continue to sample room air until the HC response is below the value specified in Section 4.E.8. When the HC level stabilizes below this value, an indication that testing may begin shall be displayed. The analyzer shall be precluded from operating and the printer prevented from printing until the HC level is met.

A receptacle shall be provided on the analyzer with a suitable interlock that will prevent the probe from sampling air in close proximity to the floor. The analyzer shall also be locked out unless a successful hang-up check has been performed since the last activation of the test sequence or the HC analyzer has not experienced an HC level greater than that specified in section 4.E.8. (Ref: EPA-AA-IMS-80-5-B, Section VIII.C, page 44).

4.C.12 Vehicle Diagnosis

For the purpose of vehicle diagnosis and/or repairs, the analyzer shall have a selector switch or button with indicator light labeled "Vehicle Diagnosis" or "Vehicle Repair." Activation of the "Vehicle Diagnosis" switch shall allow the analyzer to continuously monitor the vehicle exhaust regardless of inspection status (e.g., system needs weekly span check, leak check, warm-up condition, etc.)

The printer, or any automatic data collection system, shall be prevented from operating anytime the analysis system is in a "Vehicle Diagnosis" status. For exceptions, see EPA-AA-IMS-80-5-B, Section VIII, Introduction, page 41 and EPA-AA-IMS-80-5-C, Section IV, Introduction, page 20. Auxilliary analog trend meters may be used provided that they are deactivated for inspections.

4.C.13 Anti-Tampering

The analyzer shall be equipped with anti-tampering features to prevent intentional tampering with the analysis system.

All switches or entry access for automatic zero/ span check adjustments, anti-dilution limits, span gas concentration values, diagnostic switches, etc. shall be contained in a box or other tamper-proof mechanism with provisions for an inspector's seal. Span gas concentration switches shall be accessible to the user and the switch values shall be stored and printed for each test. A gummed label with the inspectors initials and date which must be torn to gain access, or a braided wire and crimped lead seal (or similar device) would be sufficient for sealing.

The tamper-proof system must allow convenient access by an inspector or authorized service personnel. (Ref: EPA-AA-IMS-80-5-B, Section VIII.I, page 48 and EPA-AA-IMS-80-5-C, Section IV.F, page 25.)

4.C.14 Automatic Read System

The analyzer shall have a selector switch or button (with indicator light) labeled "start-test". Activation of the "start-test" switch shall cause the analyzer system to begin the sequence specified in Section 4.C.7.1. The sample validation can occur prior to or simultaneously with the HC and CO sampling. Integrating or averaging the analyzer response shall begin 17 seconds after the switch is activated, and continue integrating the analyzer response to a flowing sample for the next 15 seconds for HC and CO (5 seconds for CO_2). If validation occurs before HC and CO sampling, emissions sampling may occur immediately after validation. The sample and hold circuits can be either analog or digital. Digital sample rates shall be at least 10 hertz. If the manufacturer identifies that the response time to 99 percent of a step change is less than 17 seconds, the manufacturer may select anytime between the 99 percent time and 17 seconds to begin the integration. If the manufacturer elects this option, the integration start time must be boldly visable on the front of the analyzer. Failure to meet this new reponse time during field audit checks will constitute a failure of the audit.

The analyzer read-out device shall display the integrated value, and hold the display until reset. An indicator light shall signal the operator when the integrated value is displayed. The automatic test sequence (see section 4.C.15) may interact with the automatic read system to reset the display at appropriate times or within the test sequence.

The analyzer shall be prevented from printing the integrated value until the "start-test" switch is activated and the "testing" cycle is completed. See Section 4.C.7.1. (Ref: EPA-AA-IMS-80-5-B, Section VII.D, page 45.)

4.C.15 Automatic Test Sequence

The analyzer must be capable of being programmed for standard sequences and must be capable of storing the cutpoints for each mode of the test sequence used. The operator may only use State accepted criteria for selectng cutpoints. It is recommended that the following criteria by used:

- Vehicle Model Year
- Type of Vehicle
  - Light-Duty Vehicle
  - Light-Duty Truck
  - Heavy-Duty Gas Truck
- Spare Channel (fuel type)
- Spare Channel (Catalyst-non-catalyst, California-non-California)

Access to the test sequence programming, and cutpoint values and applications shall be limited to a State Auditor by means of the anti-tampering provisions discussed in Section 4.C.13. The system must identify the integrated value for each mode, make a pass or fail decision on that mode, and either immediately print the results of store the results until the completion of the test sequence. If the test sequence includes more than one mode, the system shall use the pass or fail decision from all applicable modes to determine an overall pass/fail determination. (Ref: EPA-AA-IMS-80-5-B, Section VIII.F, page 46-47).

4.C.16 Anti-Dilution

The analyzer shall be equipped with an anti-dilution feature to identify vehicle exhaust system leaks and sample dilution. The preferred technique for identifying leaks is monitoring the CO_2 levels in the exhaust. Other techniques that can demonstrate improved sensitivity to leaks may be used.

At least three lower-limit CO_2 values shall be capable of being used:

- Vehicle equipped with air pump
- Vehicle without air pump
- Spare channel.

The analyzer shall be prevented from reading the sample until a lower CO_2 limit is selected.

If the CO_2 reading is less than the lower limit, the analyzer output shall indicate an error message. The printer shall be prevented from printing and an indication of exhaust system dilution shall be displayed. (Ref: EPA-AA-IMS-80-5-B, Section IX.C, page 53 and EPA-AA-IMS-80-5-C, Section V.B, page 27).

4.C.17 Engine Tachometer

A digital tachometer shall be integrated with the console for the purposes of measuring engine speed. The hook-up to the engine shall be by means of an inductive pick-up.

A lock-out feature shall be provided in the tachometer that will cause an error message to be displayed if the test idle speed range is exceeded or if the speed fluctuates in excess of 10% of the reading. The printer shall be prevented from printing until the idle speed conditions are met. (Ref: EPA-AA-IMS-80-5-B, Section IX.E, page 55).

4.D ENVIRONMENTAL REQUIREMENTS

(Ref: EPA-AA-IMS-80-5-B, Section VII.G, page 36 and EPA-AA-IMS-80-5-C, Section III.G, page 18.)

4.D.1 Storage Temperature

While in storage, the analyzer and all components thereof shall be undamaged from ambient air temperatures ranging from -20°F to 130°F.

4.D.2 Operating Temperature

The analyzer and all components shall operate without damage and within calibration limits to ambient air temperatures ranging from +35° to 110°F.

4.D.3 Humidity Conditions

The analyzer shall be designed for use inside a building or semi-protective shelter that is vented or open to outside ambient humidity. The analyzer shall be designed for use in such locations when the outside relative humidity ranges between 0% to 100% condensing (i.e., raining or dense fog).

4.D.4 Temperature Control

Analyzer components which affect sensitivity and calibration shall have their internal temperature controlled to design temperatures when exposed to the prevailing ambient conditions of any inspection station. These include the conditions noted in the sections titled Operating Temperature and Humidity Conditions.

4.E PERFORMANCE SPECIFICATIONS

4.E.1 Overall Accuracy

Each analyzer shall have an overall accuracy which limits the maximum error to ± 3% of each range or portion thereof as follows:

HC: 0 to 400 ppm HC = ± 12 ppm
400 to 1000 ppm HC = ± 30 ppm
1000 to 2000 ppm HC = ± 60 ppm

CO: 0 to 2% CO = ± 0.06%
2 to 5% CO = ± 0.15%
5 to 10% CO = ± 0.3%

This error shall include, but not be limited to, the resolution limitations incurred when reading the equivalent instrument meters and/or other readout devices by eye at the distance of fifteen (15) feet. (Ref: BAR '80 Technical Specifications, Section 3.1.2, pages 1-2).

4.E.2 Meter Drift

For span and zero drift the instrument shall not exceed ±12 ppm HC and ±0.06% CO for the first hour of operation and shall not exceed ±8 ppm HC and ±0.04% CO for each succeeding hour of operation. Both electrical corrections shall be automatically activated at start-up each day and before every test. (Ref: BAR '80 Technical Specifications, Section 3.1.8, pages 3-4).

4.E.3 Warm-up

The analyzer shall reach stabilized operation in a garage environment within 15 minutes from power on. The lock out feature shall stay engaged until zero drift is stabilized.

4.E.4 Response

In response to a step change input concentration at the sample probe inlet, the analyzer shall reach 95 percent of final reading within 14 seconds at low flow conditions. (Ref: EPA-AA-IMS-80-5-B, Section VII.F.4, page 34.)

4.E.5 Optical Correction Factor

4.E.5.1 Range

The hexane/propane conversion factor shall be limited to values between 0.480 and 0.560. Factor confirmation shall be made on each assembled analyzer by measuring both N-hexane and propane on assembly line quality checks. (Ref: EPA-AA-IMS-80-5-B, Section VII.E.9, page 33.)

4.E.5.2 Labeling

Each instrument shall be permanently labeled with its correction factor, carried to two places (within the gas accuracy limits).

4.E.6 Interference

The effect of extraneous gas interference and electronic interference on the CO and HC analyzers shall be limited. The limit values are indicated below. (Ref: EPA-AA-IMS-80-5-B, Section VII.E.8, page 32 and EPA-AA-IMS-80-5-C, Section E.4, pages 14 and 15.)

4.E.6.1 Gas Interference

The indicated interference shall not exceed 8 ppm HC or 0.02% CO for the following components:

14% CO_2
Saturated H_2O at $100^{o}F$
100 ppm NO_2.

4.E.6.2 Electronic Interference

Interference from various sources of electrical and electronic devices and/or circuits shall be limited to 5 ppm on the HC analyzer and 0.02% on the CO analyzer. The following sources shall be considered.

- High Energy Ignition (HEI) system
- Variable and fixed speed electric tools and motors
- 110/220/440 line interference
- RFI and VHI radio bands
- Line voltage and frequency variations.

4.E.7 Sampling System Leakage

The pressure side of the sample system shall be leak free. (Ref: EPA-AA-IMS-80-5-B, Section VII.F.5 page 34 and EPA-AA-IMS-80-5-C, Section III.F.3-F.4, page 16 and 17.)

4.E.8 Hydrocarbon Hang-Up

The HC hang-up in the sampling system shall not exceed 20 ppm hexane as measured by the analyzer zeroed on room air. (Ref: EPA-AA-IMS-80-5-B, Section VII.F.6, page 35 and EPA-AA-IMS-80-5-C, Section III.F.5, page 17.)

4.E.9 Antidilution Limits

The CO_2 analyzer shall meet all the analyzer accuracy specifications between CO_2 values of 6% and 14%. Exceptions are (1) the CO_2 interference specification does not apply and (2) the uncertainty of the calibration curve shall be $\pm$0.90% CO_2 in the range of 5-10% CO_2 and $\pm$0.5% CO_2 in the range of 10 to 14% CO_2.

4.F MANUALS

Each analyzer shall be delivered with one each of the following manuals:

a) Easy Reference Operating Instructions
b) Operation Instruction Manual
c) Maintenance Instruction Manual
d) Initial Start-up Instructions.

The manuals shall be constructed of durable materials, and shall not deteriorate as a result of normal use over a five year period. Each manual shall be attached to the analyzer in a manner that will:

a) Allow convenient storage
b) Allow easy use
c) Prevent accidental loss or destruction.

The contents of the manuals are documented in EPA-AA-IMS-80-5-B, Section VII.J.1-J.7, pages 39-40.

4.G QUALITY ASSURANCE

4.G.1 Performance Bond

A performance bond in the amount of $ 500,000 will be required. These funds will be held by the State and used, in part or whole, in the event damages are suffered due to non-performance or default.

4.G.2 Prime Contractor Responsibilities

The contractor must assume total responsibility for all equipment until such time as the State has formally accepted this equipment. If any bidder's proposal includes equipment supplied by other manufacturers it will be mandatory for each bidder to assume responsibility for the maintenance of such equipment as prime contractor to the Department. These responsibilities will include procurement, delivery, installation, operator training and maintenance of all equipment and support services offered in the proposal whether or not the contractor is the manufacturer or producer of them. The Department will consider the prime contractor to be the sole point of contact with regard to contractual procurement of the entire equipment system.

4.G.3 Responsibility for Equipment Maintenance

The contractor will be responsible for inspecting and maintaining the emission equipment at least once per month at the premises of the licensed station. The contractor will include with his services a maintenance agreement to ensure that the analyzers are kept properly maintained.

4.G.3.1 Maintenance Agreement

As part of the maintenance agreement the contractor will provide service on demand for the equipment owned or leased by licensed stations. This service will include replacement if necessary. The maintenance agreement is transferable to another licensed inspection station and will continue for the length of the contract. The contractor agrees to pay penalties to the licensed stations according to the terms outlined in Paragraph 4.G.3.3 below.

4.G.3.2 Maintenance Schedule

The contractor is required to propose a preventive maintenance schedule designed to meet the needs of this program. The maintenance schedule must describe each item of maintenance, its frequency, cost and who shall perform it. Maintenance items which are more appropriately performed by the station's personnel shall be identified.

4.G.3.3 Penalty for Equipment Downtime

When the analyzer or associated hardware remains inoperable for a cumulative total of eight (8) hours or more during a month, the contractor shall grant a credit to the station for each such hour of failure. The credit shall be a percentage of the basic monthly lease charge. The specific credit amount for each hour of failure will be defined in the contract. Downtime for each incident shall commence from the time the station places the work request and shall terminate whenever the equipment is returned to operating condition.

4.G.4 Quality Assurance Testing

The contractor must test a random sample of the first batch of production units according to the quality assurance procedures outlined in the following EPA publications:

- Recommended Specifications for Emission Inspection Analyzers, EPA Report No. EPA-AA-IMS80-5-B, Chapter XI and Table VII-1.
- Change Notice No. 1 to Recommended Specifications for Emission Inspection Analyzers, EPA Report No. EPA-AA-IMS-80-5-C, Revisions to Chapter XI and Table VII-1.

The contractor may propose alternative Q.A. testing procedures so long as the intent of the EPA recommended procedure is satisfied. If an alternative procedure is proposed, the advantages of this procedure (i.e., cost, time, etc.) must be clearly delineated. The procedure may be performed at the contractor's own facilities or in a third party testing laboratory. The testing staff must have experience in performance evaluation of automotive emission testing equipment.

4.G.4.1 Pre-Production Accreditation

As stated in the EPA recommended specifications, the manufacturer may receive a preliminary accreditation, valid for 6 months, by providing a publicly released report which demonstrates that at least one pre-production unit has passed all evaluation tests.

4.G.4.2 Initial Production Quality Assurance

As specified by the EPA, the manufacturer shall select, in a random manner, three of the first 20 production units, and all three shall receive all evaluation tests. If two of the three units pass all evaluation tests, the instrument shall receive full accreditation for the production authorized under the terms of the original contract. If two or more units fail the evaluation tests, corrections to the design and/or production must be made, and three additional units selected from a new or current production run. Two of these three must pass all evaluation tests. All units covered by a preliminary accreditation and produced prior to the production run in which full accreditation is received shall be required to incorporate the necessary design and/or production fixes.

4.G.4.3 Quality Assurance Testing Criteria

As specified by EPA, two of the three production units must pass with no design failures. A design failure is defined as a failure to meet the evaluation procedure criteria.

Random failures must have sufficient documentation (i.e., published report available to the DEQE) to justify why the failure can be attributed as a random failure and not to minor design failure. Random failures may be repaired on all units. A condition to allow the repair of production analyzers is the development of a plan (where necessary) to prevent the specific type of failure in future production units. After repairs, those tests that might be affected by the repairs should be rerun.

An infant mortality is defined as the total failure of a part (usually a computer chip or related components) within a short period of time after the unit first receives any electrical power. Infant mortality failures must have sufficient documentation (i.e., published report available to regulatory bodies) to justify why the failure can be attributed as infant mortality and not minor design failure. Infant mortality failure is not classified as an analyzer failure if the failure would be obvious in the field. After repairs, those tests that might be affected by the repairs must be rerun.

4.G.4.4 Quality Assurance Testing Procedure

The test procedure for the pre-production, initial and subsequent production quality assurance testing is specified in Chapter XI of EPA Document No. EPA-AA-IMS-80-5-B and Chapter VI of EPA Document No. EPA-AA-IMS-80-5-C. Optional testing procedures suggested by bidders will be considered; however the bidder must submit a bid based an the EPA recommended procedure. If the bidder chooses to propose an optional procedure, the benefits of this optional procedure in terms of cost savings and time must be clearly delineated. The bidder must also clearly demonstrate how the optional procedure satisfies the intent of the EPA-recommended procedure.

4.G.4.5. Reviewing Agency

The Massachusetts DEQE will be responsible for evaluating the quality assurance test results and related engineering reports.

APPENDIX C

PROPOSAL EVALUATION METHODOLOGY AND INSTRUCTIONS

EVALUATION METHODOLOGY AND INSTRUCTIONS

METHODOLOGY OVERVIEW

Evaluation of the bidder's proposals will be accomplished in two parts. First, a technical and management evaluation will be performed. This evaluation will be conducted by a team of evaluators and will be performed as follows:

- Each evaluator will score each bidder's proposal based on predetermined criteria and scoring techniques described herein.
- A composite technical and management score will then be developed for each bidder's proposal by totaling the scores assigned to each bidder's proposal by each evaluator.

Following the completion of the technical and management evaluation, a cost evaluation will be performed. This evaluation will be performed by a single individual (e.g., Chairman of the evaluation team) rather than a team. The following methodology will be employed:

- Bidder's financial bids will be opened, and the bids will be rank ordered from lowest to highest. Separate rankings will be prepared for purchase price bids, lease bids and maintenance.
- Each bidder will then be assigned a score depending on its position in the ranking with the lowest bidder receiving the highest score. Separate scores will be prepared for purchase price, lease and maintenance.
- Finally, a composite financial score will be assigned to each bidder by totaling the individual scores received by the bidder for purchase price, lease and maintenance.

Award of the contract will be made to that bidder who has the highest financial score and who has completely satisfied all technical and management requirements (Note: This bidder may not have the highest technical and management score). In the event that two or more bidders have equal financial scores, the award will be made to that bidder with the highest technical and management score.

The remainder of this document presents specific instructions and techniques for conducting the technical/management and cost evaluations.

TECHNICAL AND MANAGEMENT EVALUATION INSTRUCTIONS

In evaluating each bidder's proposal, use the following scoring system:

Score	Interpretation
1	Non-responsive
2	Lacking in some way but with additional information could be responsive
3	Satisfies requirements
4	Exceeds requirements in some ways
5	Exceeds requirements in many ways

Criteria No. 1: Conformance With Equipment Specifications

Score each of the following factors from 1 to 5. The section number of the proposal associated with each factor is provided for your reference. The comments column is provided for you to note reasons for the score given.

Section Number of Specification	Factor	Score	Comments
4.A.1	Design Goals		
4.A.2	Useful Life		
4.A.3	Name Plate Data		
4.B.1	Materials		
4.B.2	Construction		
4.B.3	Mobility		
4.B.4	Electrical Materials/ Construction		
4.C.1	Readout Display Control Panel		
4.C.2	Process Control System		
4.C.3	Sampling System		
4.C.4	System Vents		
4.C.5	Analytical System		
4.C.6	Fail Safe Features		
4.C.7	Automatic Data Collection		
4.C.8	Printer		

Section Number of Specification	Factor	Score	Comments
4.C.9	Automatic Gas Span		
4.C.10	Automatic Leak Check		
4.C.11	Automatic Hang-Up Check		
4.C.12	Vehicle Diagnosis		
4.C.13	Anti-Tampering		
4.C.14	Automatic Read System		
4.C.15	Automatic Test Sequence		
4.C.16	Anti-Dilution		
4.C.17	Engine Tachometer		
4.D.1	Storage Temperature		
4.D.2	Operating Temperature		
4.D.3	Humidity Conditions		
4.D.4	Temperature Control		
4.E.1	Overall Accuracy		
4.E.2	Meter Draft		
4.E.3	Warm-Up		
4.E.4	Response		
4.E.5	Optical Correction Factor		
4.E.6	Interference		
4.E.7	Sampling System Leakage		
4.E.8	Hydrocarbon Hang-Up		
4.E.9	Anti-Dilution Limits		
4.F.	Manuals		
4.G.1	Performance Bond		
4.G.2	Prime Contractor Responsibilities		
4.G.3	Equipment Maintenance		
4.G.4	Quality Assurance Testing		

Computation Of Overall Score For Criteria No.1:

If any individual score is less than 3, the overall score is the minimum individual score assigned multiplied by 7. If all individual scores are 3 or greater, the overall score is the average of all scores multiplied by 7.

Overall score for criteria No.1 = ____________________

Criteria No.2: Conformance With Data Collection, Conversion And Transfer Requirements

Rate the bidder's proposed data collection plan from 1 to 5 based on your analysis of the following factors:

Factor	Comment
• Is the bidder proposing to collect the data recorded on the device, replace the recording medium on the equipment, and convert the data into a form acceptable to the Department on a monthly basis as required in the RFP?	
• Has the contractor proposed to provide management and work maintenance reports on the maintenance, data collection and training schedules on a quarterly basis as specified in the RFP?	
• Are there any unique aspects to the contractor's data collection and processing plan that would be advantageous to the Department? For example, does the contractor propose to provide data more frequently than on a monthly basis?	

Computation Of Overall Score For Criteria No.2:

Overall score is the score you assigned.

Overall Score For Criteria No.2 = ____________________

Criteria No.3: Evaluation Of Proposed Equipment From The Standpoint Of Operational Simplicity And As A Tool For Emissions System Repair

Rate the bidder's proposed equipment from 1 to 5 based on the following:

Factor	Comment
• How much operator training is required?	
• What skill level is required to operate the equipment?	
• Can the equipment be used for emissions system repair as well as inspection?	
• Are there any equipment features that will facilitate or hamper diagnosis and repair?	

Computation Of Overall Score For Criteria No.3

Overall score is the score you assigned.

Overall score for Criteria No.3 = ____________________

Criteria No.4: Bidders' Experience, Financial Ability And Organizational Structure

Rate the bidders' experience, financial ability and organizational structure from 1 to 5 based on the following factors:

Factor	Comment
• Does the bidder have prior experience in dealing with emissions testing equipment or systems?	
• How directly related is this experience to the proposed program in Massachusetts?	
• Does the bidder have experience in the development and manufacturing of emissions testing equipment?	
• How long has the bidder been in business?	
• Does the bidder have experience in equipment training?	
• Does the bidder have experience in servicing emissions testing equipment?	

Factor	Comment
• Does the bidder have the resources to execute the terms of the contract?	
• Is the bidder's proposed organization sound? reasonable?	
• What are the strengths and experience of proposed personnel?	
• Are there a proper mix of skills represented in the organizational structure proposed by the bidder?	
• Has the bidder committed sufficient manpower to the program for it to be successful?	
• How does the bidder propose to manage subcontractors (if subcontractors are proposed?)	
• Has the bidder presented a plan for communicating progress to the Department?	
• Has the bidder presented a schedule for equipment development and delivery?	
• Will the bidder meet the April 1, 1983 start-up date?	
• Has the bidder incorporated sufficient time in the schedule to allow Massachusetts to review/test the prototype units and make changes to the units if necessary?	
• Has the bidder identified key milestones from which Massachusetts can monitor schedule performance?	

Factor	Comment
• Overall, is the schedule realistic and justifiable?	
• Are there any unique aspects to the schedule? For example, is the bidder proposing an accelerated schedule so that the additional time before program start-up can be used for public awareness and familiarization?	

Computation Of Overall Score For Criteria No.4

Overall score is the score you assigned.

Overall score for Criteria No.4 = ______________________

Criteria No.5: Bidder's Recruiting Plans, Maintenance/Repair/ Calibration Plans And Schedule

Rate the bidders' proposed recruiting plans, maintenance/repair/ calibration plans and schedule from 1 to 5 based on your analysis of the following factors:

Factor	Comment
• Has the bidder proposed a plan for recruiting service representatives including minimum qualifications and salary levels for these individuals?	
• Is the plan reasonable?	
• Has the bidder proposed a plan for establishing a servicing/ repair network which includes:	
- Response time to a call for service.	
- Repairs to be performed at the bidder's facilities and expected downtown for repair.	
- The general location of such facilities?	

Factor	Comment

- Is the plan reasonable?

<u>Computation Of Overall Score For Criteria No.5:</u>

Overall score is the score you assigned.

Overall score for Criteria No.5 = ____________________

COST EVALUATION INSTRUCTIONS

The financial bid will be evaluated by the following means following the ranking of proposal bids as discussed in the OVERVIEW:

- <u>For Purchase Price</u> - 20 points for the lowest purchase bid; 0 points for a purchase bid equal to or greater than twice the lowest purchase bid; and purchase bids falling between these two values will receive equal single point increments assigned on a pro rata basis.

- <u>For Lease Price</u> - 20 points for the lowest lease bid; 0 points for a lease bid equal to or greater than twice the lowest purchase bid; and lease bids valuing between these two values will receive equal single point increments assigned on a pro rata basis.

- <u>For Maintenance Contract Price</u> - 5 points for the lowest maintenance contract bid; 0 points for a maintenance contract bid equal to or greater than twice the lowest maintenance contract bid; and maintenance bids falling between these two values will receive equal single point increments assigned on a pro rata basis.

The total points possible for financial bids will be 45.

EVALUATION SUMMARY

EVALUATORS NAME: ______________________

BIDDER: ______________________

TECHNICAL SCORE:

Criteria No.1 = ______________

Criteria No.2 = ______________

Criteria No.3 = ______________

Total Technical Score ______________

MANAGEMENT SCORE:

Criteria No.4 = ______________

Criteria No.5.= ______________

Total Management Score ______________

Total Technical &
Management Score ______________

FINANCIAL SCORE:

Purchase Price = ______________

Lease = ______________

Maintenance = ______________

Total Financial Score ______________

Evaluator's Signature: ______________________

Date: ______________