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GUIDANCE ON QUALITY CONTROL FOR INSPECTION/MAINTENANCE PROGRAMS

FINAL REPORT

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NOTICE

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1.0 INTRODUCTION

Inspection/Maintenance (I/M) programs reduce emissions from vehicles by requiring the repair of those vehicles that fail an emissions test. In order for a program to operate effectively and equitably, it is extremely important that accurate tests be performed at all inspection stations. Therefore, the quality control of the emissions analyzers and inspection procedures play a major role in the overall success of an I/M program. Auditing of inspection stations by state personnel is one means for assuring the quality of emissions measurements. However, to maintain the effectiveness and equity needed in the auditing system, the quality control of the auditing process is equally important.

The first step in designing an adequate quality control program for an I/M program is to develop a quality control plan. The quality control plan describes which items need to be maintained or evaluated and at what frequency the maintenance (including adjustments) or evaluations need to be performed. To implement the quality control plan, a quality control manual containing specific quality control procedures must be developed to assure that all analyzers are routinely checked and maintained in proper working order, all records are completed and reported accurately, and all prescribed regulations and procedures are being followed by inspection station personnel. Without these assurances, I/M program officials cannot ensure that motorists are receiving fair and accurate inspections.

Quality control in I/M measurements is also important because of the emissions performance warranty. The emissions performance warranty allows owners of 1981 and later model year vehicles to obtain warranty repairs if their vehicles fail an I/M test. In order for owners to get these repairs, however, the I/M test must meet certain requirements and a minimum level of quality control must be provided in the I/M program. Thus, it is important that the quality control program meet the requirements established in the emissions performance warranty regulations, if warranty coverage is to be made available.

This report provides guidance on the areas that need to be addressed in a quality control plan and on recommended quality control procedures that can be used in the quality control program. This guidance is consistent with the provisions of the emissions performance warranty regulations. In addition, the following general assumptions were made in developing this report.

1. The I/M program will use a manually operated emissions analyzer which meets the general analyzer specifications of the emissions performance warranty regulations.

2. The emissions test will consist of a simple idle inspection test along with a brief 2500 rpm preconditioning mode for pre-1981 model year vehicles.

3. A two-speed idle test (where vehicles will be subjected to emissions standards for each speed) will be used for 1981 and later model year vehicles.

The following section discusses the quality control plan and procedures that the individual inspection facilities should be required to use to insure that analyzers maintain accuracy. Section 3.0 of this report provides quality control procedures to assure that the test procedures are performed correctly. Section 4.0 describes quality control procedures that can be used during auditing by administrating agency personnel to further assure that accurate inspections are being performed. Section 5.0 discusses the importance and role of the quality control elements in providing overall quality assurance in the I/M program.

2.0 QUALITY CONTROL FOR EMISSIONS ANALYZERS

The nondispersive infrared (NDIR) analyzer is the primary inspection instrument used in I/M programs. The NDIR analyzer consists of a gas analyzer which produces an electrical signal in response to exhaust gas concentrations, and a meter display (analog or digital) that translates the electrical signal for the user. The emissions analyzer is used to determine the concentrations of carbon monoxide (CO) and hydrocarbons (HC) in vehicle exhaust. In an I/M program, emissions analyzer accuracy must be maintained to assure that vehicles are properly passed or failed during inspections. Therefore, periodic checks of a NDIR analyzer are needed to verify its accuracy.

Several different checks can be performed to verify the accuracy of a NDIR analyzer as noted below. The first two checks verify that the meter displays correctly portray the electrical output from the gas analyzer. The third and fifth checks verify that the gas analyzer is generating appropriate electrical output in response to exhaust gas concentrations. The purposes of the other checks are described below.

1. Mechanical zero check of analog meter -- If the analyzer is equipped with analog meters, a check can be made to assure that the meter needles are aligned with the zero readings before the instrument is turned on. If necessary, adjustments are usually made with a setscrew on the face of each meter. See the diagram in Figure 2 on page 13.

2. Electrical span -- On analyzers with analog meters, it is possible to perform an electrical span to make sure that the meter needles align with the span lines on the meters when the analyzer is in the "span" mode. For analyzers with digital meters, when the analyzer is placed in "span" mode, the analyzer should respond with predetermined meter readings. If necessary, adjustments are made by turning the HC and CO span adjustment potentiometers. On some analyzers electrical span adjustments are automatically performed as needed.

3. Zero check through the port -- This check is performed by putting the analyzer in "zero" mode to assure that the analyzer does not indicate concentrations of HC or CO when room air or zero gas is being sampled. If necessary, adjustments are made by turning the zero adjustment potentiometer on each meter. On some analyzers zero adjustments are automatically performed as needed.

4. Hydrocarbon hang-up check -- This check is very similar to the zero check and it is performed to assure that the sampling system (i.e., the probe, filters, and sampling lines) is not a source of hydrocarbon readings. Hydrocarbon hang-up problems can usually be alleviated by purging the sampling system with clean dry air, changing filters, or cleaning the sample hose.

5. Gas spanning -- Gas span checks consist of introducing a known concentration of span gas into the analyzer and determining whether the analyzer response to the span gas is correct. If the analyzer's response is outside the specified limit, adjustments need to be made to the analyzer so that the readings obtained are accurate.

6. Low scale/high scale correlation check -- This check assures that the analyzer's response to a span gas is the same on both the low and high scales (if applicable). Most analyzers have setscrews that can be used to adjust the low scale/high scale correlation, if necessary.

7. Leak check -- This check is performed to assure that there are no excessive leaks in the sampling system of the analyzer. Leaks cause sample dilution resulting in potentially large measurement errors and are one of the most common sources of error in I/M measurements.

In addition to the above checks, some simple, common sense quality control checks need to be included in the quality control manual. These checks should include such things as a reminder to periodically check the water trap and sample filters and the importance of properly warming up the analyzer before testing.

The emissions performance warranty regulations contain certain minimum quality control requirements for emissions analyzers. In order for a vehicle owner to receive warranty repair, the following quality control provisions must be incorporated into the I/M program.

1. Within one hour prior to a test, the analyzer must have been zeroed and electrically spanned.

2. Within one week of a test the analyzer shall have been checked with a span gas that is traceable to NBS standards (±2%). The span gas used shall have concentrations either between the standards specified by the warranty regulations (see Table 1) and the local jurisdiction's inspection standards for 1981 or later model year vehicles, or be within -50% to +100% of the standards shown in Table 1.

3. Within one week of a test, a leak check must have been made. If the analyzer has a separate calibration/span port, the CO readings using span gas through the probe and through the port shall be made. Differences of over 3% between the port and probe readings shall require the repair of leaks. (The warranty regulations do not expressly identify how to leak-check analyzers that do not have separate span ports.)

Table 1. Emissions Performance Warranty Emissions Standards

Test and Mode	HC[1] (ppm)	CO (percent)
1. Idle:Idle	220	1.2
2. 2-speed idle:		
2500 rpm	200	1.0
Idle[2]	200	1.0
3. Two mode loaded:		
30 mph loaded	220	1.2
Idle	220	1.2

[1] ppm as hexane.

[2] Lowest individual HC and CO readings observed at the two idle modes.

By incorporating the quality control requirements of the emissions performance warranty regulations along with other provisions that are necessary for good quality control, it is possible to develop a standard quality control program for emissions analyzers. This program should address daily quality control items, weekly quality control items, preventive maintenance, and audits.

2.1 Daily Quality Control Checks

Certain analyzer functions need to be checked daily to assure accuracy of the emission measurements. These checks are usually an integral part of the inspection procedure; therefore, the recommended procedures to be followed are contained in Section 3.0 of this report. However, these daily checks will be described briefly in this section. They mainly cover the following areas: zero checks, electrical spans, filter and water trap checks, hydrocarbon hang-up checks, and adequate warm-up of the analyzer.

Zero checks and electrical span checks are conducted in order to identify and eliminate electronic errors of zero and span drift, respectively, in the analyzer. Most analyzers are designed to drift less than 2 to 3 percent per hour for both zero and span. Therefore, zero and span drift usually represent only small errors in the emissions measurement. Even though these errors are small, they are additive to other errors in the measurement system. Moreover, they can be easily eliminated by simple adjustments which take only seconds.

Filter and water trap checks are conducted as additional safeguards against damage to the analyzer. These devices are designed to collect particulates and water that are in the exhaust sample to keep them out of the sample cell where they cause soiling, possible damage and improper readings. To make sure that these devices stay in proper operating condition, the operators should visually inspect them regularly.

Hydrocarbon hang-up checks are performed to make sure that the analyzer's hydrocarbon readings are not being biased by hydrocarbon adsorption and de-adsorption within the sampling system. In a decentralized I/M program the analyzer is not only 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. If hydrocarbon hang-up is allowed to go unchecked and uncorrected, related errors of 10 to 30 percent are typical. On the other hand, if a hydrocarbon hang-up check is used routinely, and any detected problems are corrected, measurement errors due to hydrocarbon hang-up can be virtually eliminated.

Adequately warming up the analyzer before use is critical to obtaining accurate emissions measurements. If an analyzer is not fully warmed up, the analyzer electronic components are unstable, causing potentially severe zero and span drift and erratic readings. In addition, an analyzer that is not fully warmed up may not be very sensitive to changes in pollutant concentrations. Because of these influences, measurements made with an analyzer that is not adequately warmed up could have very large errors. Available data indicate that these influences can cause errors from 0 to 200 percent in individual cases. Since analyzer warm-up can have such a major influence on the accuracy of emissions measurements, the importance of adequate analyzer warm-up should be stressed in the quality control manual.

2.2 Weekly Quality Control Checks

The weekly quality control checks consist mainly of spanning the analyzer with a span gas of known concentration (preferably the span gas should meet the requirements in the emissions performance warranty regulations). In addition, a leak check should be performed once a week. The procedures for recommended weekly quality control checks are presented later in this section.

Gas spanning needs to be conducted periodically to identify and correct errors caused by shifts in the sensitivity of the instrument. These shifts occur mainly because of changes in environmental conditions, such as barometric pressure and ambient temperature. However, internal changes in the analyzer can also affect the analyzer's accuracy. These influences do not usually cause abrupt changes in analyzer accuracy; they cause gradual change from day to day. From week to week, however, the total change can be significant (greater than ±5 percent error). Therefore, weekly gas spanning is recommended as a precaution (and required for compliance with the emission performance warranty regulations).

Leaks in the sampling system are probably the source of the largest and most frequent errors that occur in emissions measurements. This is because a leak is transformed directly into a measurement error (i.e., a 15 percent leak results in a 15 percent error). Because analyzers are moved around in the inspection stations and the sampling hose and probe have a high potential for damage, the potential for system leaks is high. Therefore, leak checks are recommended as a weekly quality control check. Leak checks should also be performed whenever analyzer maintenance (such as, filter replacement or hose replacement) is performed that could cause a leak.

A combination gas span/leak check can be performed in a few minutes. Properly done, these checks ensure that the accuracy of the analyzer is maintained within an acceptable range of ±5 percent.

2.2.1 Procedures for Weekly Quality Control Checks

As mentioned, the weekly quality control checks consist primarily of low scale gas spanning and leak checking.

2.2.1.1 Equipment Required

1. Span gas and related equipment -- In order to perform gas spanning, it is necessary for the station to have a supply of span gas. For efficiency it is recommended that the station purchase a full-size (I-A) cylinder that contains a triblend of carbon monoxide (CO) and hydrocarbons (HC) (as propane) in nitrogen. The concentrations in the cylinder should be approximately 1.5% CO and 600 ppm propane. This gas should be traceable to $\pm2\%$ of NBS standards. These concentrations are used to assure that the analyzer is accurate near the emissions standards specified in the emissions performance warranty regulations. It should be noted that most analyzer manufacturers recommend gas spanning on the high scale (usually 80 to 90 percent of full scale on the high range). Gas spanning on the low range, as recommended here, does not decrease the overall accuracy of the analyzer; it just assures that the accuracy is obtained on the low range where most vehicles are passed and failed in an I/M program. An important issue regarding span gas is the accuracy (or traceability) of the span gas. It is beyond the scope of this report to cover the details of this issue. However, EPA and the gas industry are jointly investigating the current practices of gas manufacturers in naming span gases in order to determine the proper naming procedures. This will be the subject of a future EPA report.

2. Pressure regulators -- The span gas cylinder must have a pressure regulator attached to it. This regulator should be set to the pressure that is specified in the analyzer operating manual. In the absence of a specification, the pressure should be set at 5 to 6 psi (gauge pressure). Downstream of the pressure regulator there should also be another valve to regulate the flow of span gas. In addition, some manufacturers recommend that a restricting orifice be placed in the line to limit the maximum flow rate.

3. Manifold and equipment to introduce span gas into analyzer probe -- Several different designs for a manifold can be used to introduce the span gas into the analyzer probe. The main point behind each method is to assure that the analyzer is not being overpressurized or starved of span gas while introducing the span gas through the probe. Following are descriptions of different methods that can be used.

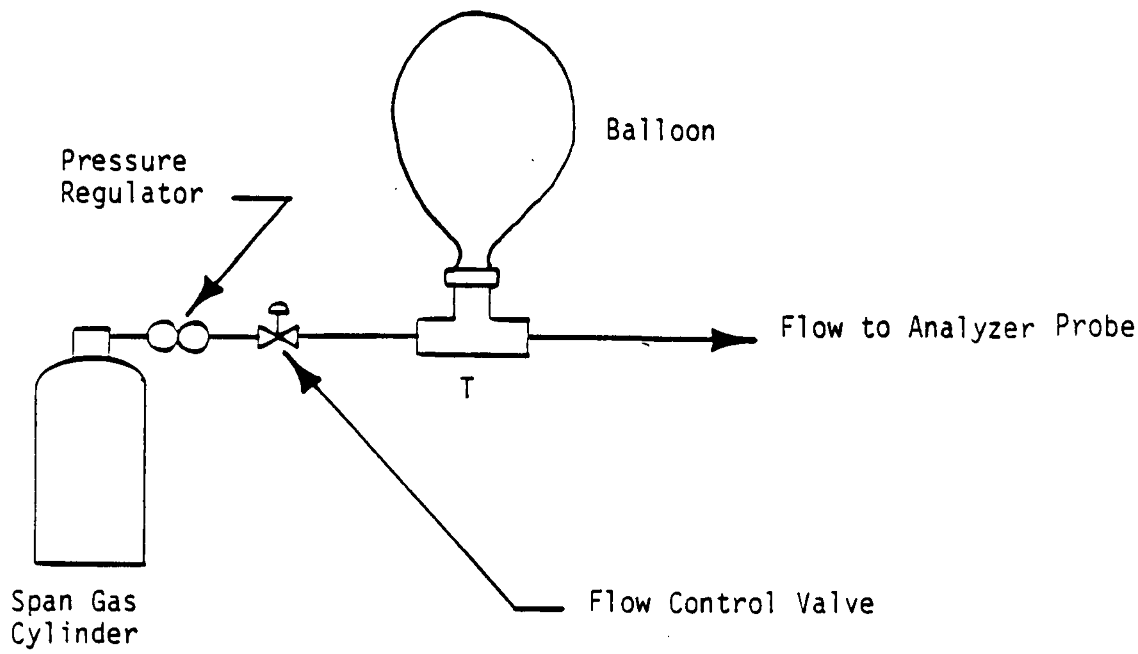
<u>Method A</u> -- With this method, a tee connection is placed into the line that connects the span gas cylinder to the analyzer. A balloon is placed over the open end of the tee (see Figure 1). When the gas is introduced to the analyzer, the flow valve is adjusted such that the balloon is inflated and then closed just enough to allow the balloon to maintain a constant inflation during spanning. This assures that the analyzer is obtaining adequate quantities of span gas while, at the same time, not being overpressurized. A screen in the tee can be used to prevent the balloon from being sucked into it in the event that the span gas flow is too low.

<u>Method B</u> -- With this method, a rotometer is used instead of the balloon in Method A. In this case, the flow valve is adjusted until the rotometer indicates a slight amount of flow through the rotometer. This method should be used only in well ventilated areas in order to guard against CO poisoning.

<u>Method C</u> -- In this method, which was developed by EPA, an "audit box" is placed in the span gas line. This box contains a vacuum gauge that indicates when the sample line is under vacuum. When span gas is introduced into the

analyzer, there should be close to zero vacuum in the lines. Thus the flow valve is adjusted until the audit box indicates that there is zero vacuum in the line. More details on the audit box are available from EPA.

Figure 1. Methods of Introducing Span Gas to Analyzer Probe



Method A

Method B - Rotometer instead of balloon.

Method C - "Audit box" (or vacuum gauge) instead of balloon.

4. Connectors to span port and probes -- Inspection stations which have analyzers with separate span ports will need connectors that will allow them to introduce the span gas into the port and probe. If the analyzer does not have a separate span port, then the station will need only a connector for the probe. Generally most analyzers have serrated male nipples for the span ports; thus the only equipment that is needed is a piece of properly sized, flexible tubing attached to the manifold to get a leak-tight fit. Alternatively, "quick-connect" couplings may be used, but they must be kept in good repair. In order to introduce span gas into the probe, it is necessary that the connector be leak-tight. Again, some form of flexible tubing with a hose clamp should provide a leak-tight connection.

2.2.1.2 Procedures to Conduct a Combination Gas Span/Leak Check

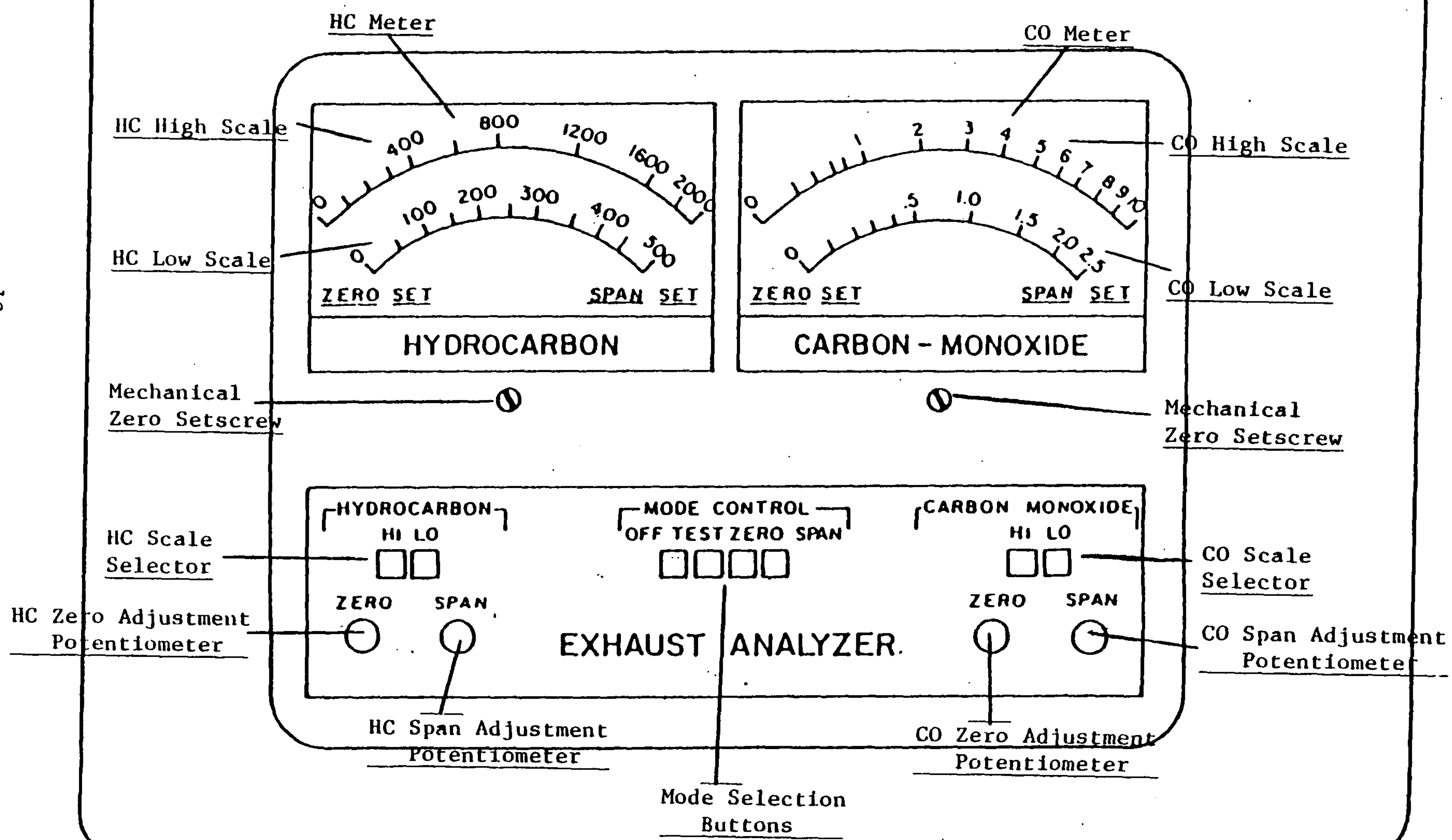
A combination gas span/leak check provides an easy and efficient way of evaluating an analyzer's ability to properly respond to a known span gas concentration and, at the same time, to assure that there are no excessive leaks in the sampling system. The procedures listed below should be utilized to perform a combination gas span/leak check.

A typical control panel and analog meter display is shown in Figure 2. The actual location of various adjustment mechanisms varies considerably among different makes and models of analyzers. Therefore, the analyzer manual should be consulted to determine the exact location of the applicable adjustment mechanisms.

Gas spanning is affected, to an extent, by the room temperature of the station. Therefore, it is recommended that gas spanning be conducted at a time during the day when the room temperature is at a normal level.

Note: For analyzers with analog meters, care must be taken in setting the meter or taking readings in order to avoid errors due to parallax. Analog

Figure 2: TYPICAL ANALYZER FRONT PANEL WITH ANALOG METERS



meters are properly read from directly in front of the meter. Standing off to one side or above the meter when settings are made or readings are taken can introduce errors because of an improper line of sight.

Combination Gas Span/Leak Check Procedures

(from analyzer "off" mode)

1. If the analyzer has analog meters, then prior to turning on the analyzer the mechanical zero should be checked. If necessary, the mechanical zero should be adjusted by means of the setscrew on the face of each meter. (Note that this setscrew is not the zero adjustment potentiometer.)

2. If the analyzer has analog meters, static electricity can build up on the meters and affect their operation. The meters can be checked for static electricity build-up by the operator simply touching each meter with his/her hand while the analyzer is warming up. If excessive static electricity is present, the meter needle will waver. If static electricity is present, it can be removed by spraying the meter face with a static removal spray and wiping off the meter face with a clean cloth. Alternatively, the meter face can usually be freed of static electricity by wiping it with a clean, damp cloth.

3. The analyzer must be warmed up as required by the manufacturer (or 30 minutes in absence of manufacturer's recommendation). The analyzer should be warmed up in the standby mode (unless the manufacturer recommends otherwise) to avoid unnecessary operation of the analyzer pump.

4. A visual check should be made of the water trap and filters to make sure that drain lines are not clogged and/or the filters are not dirty. Repairs should be made if necessary.

5. After the analyzer is warmed up, turn on the analyzer pump and check the zero setting by activating the zero switch (if analyzer is so equipped) on the face of the analyzer. If necessary, the HC and CO meters can be adjusted to zero using the zero adjustment potentiometer on each meter (see note below). Zero checks and adjustments should be made on the low scale unless the manufacturer recommends otherwise.

6. Check electrical span by activating the electrical span switch. Electrical spanning and adjustments must be made on the scale specified by the manufacturer in the analyzer manual. The needle should align with the span line on the meter. If necessary, adjustments can be made by turning the HC and/or CO span adjustment potentiometers.

7. The zero and electrical span should be alternately checked until both adjustments are correct. Some analyzers have automatic zeroing and/or electrical spanning systems that automatically adjust these parameters.

Note: If the meters will not zero by adjusting the zero adjustment potentiometer, do not use the mechanical zero setscrew to zero the meters. Call a qualified service technician or the instrument manufacturer to have the necessary repairs made.

Note: Altitude adjustment -- Some analyzers have an expanded span setting with different span lines corresponding to different altitudes. If the analyzer is so equipped, the altitude of the locale in question should be a consideration in setting or checking the electrical span. The manufacturer's recommended procedure should be followed.

8. Perform HC hang-up check. With the analyzer on the low range (analog meters), allow the probe to sample zero or room air for 30 seconds. If the hydrocarbon reading is greater than 20 ppm after 30 seconds, then the system should be allowed to purge itself by sampling room air. If after 2 minutes of purging, the HC reading is still greater than 20 ppm

HC, the probe and line should be disconnected from the analyzer and cleaned (usually by blowing clean, dry compressed air through it). In some cases, it may be necessary to change the filter to alleviate the HC hang-up problem.

9. After making sure the analyzer pump is turned on, connect the span gas cylinder to the probe using one of the recommended configurations. (See Section 2.2.1.1) Slowly open the span gas cylinder valve. Make sure there is proper flow by observing the rotometer ball position, balloon, or vacuum gauge. Allow the analyzer to sample the span gas for 30 seconds. Record the meter reading for carbon monoxide (CO). Then, immediately close the cylinder valve.

10. Introduce span gas through the calibration/span port (if the analyzer is so equipped--see note below) as follows.

    a. Connect the hose from the span gas cylinder to the span port in a leak-tight manner.

    b. Turn off the analyzer pump (unless the manufacturer recommends otherwise).

    c. Set the control switch on the analyzer to calibrate (if so equipped).

    d. Open the span gas valve to introduce the span gas into the analyzer. The meter response should be almost instantaneous. As soon as the meter responses peak (approximately 5-10 seconds), record the meter responses for both HC and CO. Then, immediately turn off the span gas valve. The CO meter response should be within $\pm$5% of the span gas labeled CO value. The HC meter response should be within $\pm$5% of the value obtained by multiplying the span gas labeled propane value times the analyzer's hexane/propane equivalency factor. If the CO and/or HC responses are not within $\pm$5%, adjustments are necessary.

Note: If the analyzer does not have a span port, the span adjustment must be checked while span gas is being introduced through the probe in step 9 of these procedures. In this case, however, both CO and HC readings would be recorded during step 9. Analyzers which do not have span ports cannot be leak checked using the method in these procedures (the flowing span gas leak check). Instead the leak checking method recommended in the analyzer service manual should be used to make sure that no gross leaks are present in the sampling system. Some small leaks, which would ordinarily be detected using the flowing span gas leak check, may not be detected by the alternative methods recommended in the service manual (these alternatives include mostly vacuum based checks, such as vacuum decay checks, maximum vacuum checks, or low flow indicator checks). However, checking and adjusting the gas span through the probe will compensate for any errors caused by such small leaks.

11. Determine the percent difference between the CO response obtained through the span port and the CO response obtained through the sampling probe as follows:

$$\% \text{ Difference} = \frac{\text{Response PO} - \text{Response PR}}{\text{Response PO}} \times 100$$

Where:

Response PR = CO response with span gas sampled through probe.

Response PO = CO response with span gas sampled through port.

The percent difference must not exceed 3% to comply with the emissions performance warranty regulations. If it does, the leak should be located and fixed before further vehicle testing is conducted with the analyzer.

12. Adjust span, if necessary, as described below.

Note: Span adjustments should be made with the span gas being introduced through the span port. If the analyzer has no span port, then the span gas must be introduced through the probe while span adjustments are made. Steps a and b should be performed while span gas is flowing through the sample cell (pump off, if introducing span gas through the port; pump on, if introducing span gas through the probe). When the adjustments are completed, the span gas cylinder valve should be immediately closed in order to limit the amount of CO being released into the room as well as to conserve span gas.

a. While span gas is flowing through the sample cell, using the HC span adjustment potentiometer, adjust the HC meter response to read the correct value (cylinder propane concentration times the hexane/propane equivalency factor). (The HC span adjustment potentiometer is sometimes located on the back of the analyzer rather than as shown in Figure 2.)

b. While span gas is flowing through the sample cell, using the CO span adjustment potentiometer, adjust the CO meter to read the correct value (cylinder CO concentration). (The CO span adjustment potentiometer is sometimes located on the back of the analyzer rather than as shown in Figure 2.)

c. Turn off the span gas cylinder.

d. Purge the sample cell by turning on the pump and allowing the analyzer to sample room air for a few seconds.

e. Put the analyzer in "zero" mode (pump on) and recheck zero on each meter. If necessary, adjust meters to zero with zero adjustment potentiometers. With the pump off (unless spanning through the probe), reintroduce the span gas. The meter responses should be within ±2% of the readings in steps a and b. If not, repeat steps a, b, c, d and e until the meter readings are repeatable within ±2%.

f. Repeat steps c and d; then activate the electrical span and adjust the electrical span setscrew (usually internal) on each meter so that the meter needles align with the span line (analog meters) or the meters obtain the appropriate value (digital meters).

Note: The electrical span setscrew is not the span adjustment potentiometer.

Note: Step f is a most critical step in gas spanning the analyzer. The electrical span setscrew sets the electrical reference point vis-a-vis the span gas for the analyzer bench. Failure to make this final adjustment correctly would defeat the purpose of gas spanning. The electrical span setscrew should never be adjusted except in conjunction with the gas spanning procedure.

13. While gas spanning, perform a low scale/high scale correlation check (analog meters only). The low scale/high scale correlation check is performed by reading the analyzer response during gas spanning on both the low and high scales and comparing the two readings. The readings should be equal. If they are not, an adjustment should be made if possible. There is usually an internal setscrew to adjust the scale correlation.

Note: In order to comply with the emissions performance warranty regulations, it is necessary that the analyzer be checked for leaks (and gas spanned) at least once a week. In addition, leak checks should be performed after all maintenance that could create a leak in the sampling system (for example, after filter replacement).

2.2.1.3 <u>Quality Control Checks for Analyzers with Automatic Quality Control Systems</u>

Some analyzers, particularly those which meet the EPA computerized analyzer specifications, have automatic quality control systems. These analyzers have automatic gas spanning, leak checking, and hydrocarbon hang-up checking capabilities as well as other automatic functions, such as automatic testing and automatic data collection. When analyzers with these capabilities are used, the inspection station and the auditor are, to an extent, relieved of their responsibilities to perform the routine analyzer quality control checks. However, these automatic systems are not totally foolproof. The analyzer manufacturer should be required to provide information to the administrating agency on how the auditors can assure that the automatic systems are operating properly. In addition, the inspection station should be required to have certified service technicians periodically service the analyzer to assure that it is maintained in proper operating condition.

2.3 Preventive Maintenance

Another very important part of the quality control for emission analyzers is preventive maintenance. As defined in the EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume 1, preventive maintenance is an orderly program of equipment cleaning, lubrication, reconditioning, adjusting and/or testing in order to prevent a failure of a system or parts thereof during use. Most analyzer operating and/or service manuals include specific preventive maintenance schedules for particular makes and models of analyzers which should be followed if available. A schedule for preventive maintenance which can be used when the manufacturer's recommended schedule is not available is described in Table 2. Table 2 is broken down by weekly and monthly tasks. It should be noted that some of the items listed in the table should be replaced as needed. This is determined by the inspection that is performed at periodic intervals. The inspector must review the operating manual for the analyzer to determine if other preventive maintenance is needed.

Emissions analyzers are generally very durable and usually need minimal maintenance, if properly used and given proper care. The most frequent maintenance items are the sample filter and water trap. Failure to properly service the analyzer will lead not only to inaccurate emissions measurements but also to premature failure of the analyzer. The frequency of replacement or cleaning of parts is directly affected by the outside environment.

TABLE 2. PREVENTIVE MAINTENANCE SCHEDULE

Equipment	Part	Maintenance
	Weekly Items	
CO, HC Analyzer	Sample Filter	Inspect (Replace as needed)
CO, HC Analyzer	Whole System	Leak check (also leak check after any analyzer maintenance)
	Monthly Items	
CO, HC Analyzer	Sample Lines	Remove and Blow-out, Replace as needed
CO, HC Analyzer	Probe	Inspect and Clean
Pressure Regulator	Line	Leak-check with soap solution

Note: The water trap should be inspected at least daily for water build-up. This is especially true for those analyzers which do not have a continuous drain line. But even if drain lines are used, the associated check valve can become plugged with exhaust deposits.

By observing certain operating practices, inspection station personnel can extend some of the variable maintenance intervals. For instance, filter life can be extended if the inspector will remember the following.

1. Do not start or warm up a vehicle with the probe inserted into the tailpipe. (Each time a vehicle is started loose deposits are blown out the tailpipe.)

2. Purge the analyzer sampling system after use by allowing the analyzer to sample fresh air away from the tailpipe.

3. Remove the analyzer probe as soon as possible after the emissions readings are taken.

These same three operating practices will also keep the sampling hose cleaner and reduce the likelihood of hydrocarbon hang-up. Some other common sense operating practices are listed below.

1. Do not drive over the sampling hose.

2. Do not unnecessarily expose the sampling hose to exhaust heat.

3. Always coil and properly store the sampling hose and probe after use.

4. Keep the analyzer in a location that is relatively free of temperature changes and drafts.

5. Do not store materials (such as manuals or tools) on top of the analyzer.

6. Keep the analyzer as free as possible of dirt and grease.

2.4 Documentation

Another very important function is to document all of the weekly quality control checks, maintenance,and audits that are performed on the analyzer.

An instrument log should be kept that documents the occurrence and results of these activities. This logbook should provide a continuous chronological record of the condition of the analyzer. Ideally, the logbook should be physically attached to the analyzer in order to prevent its loss as well as to serve as a reminder to the inspectors and auditors to make the appropriate entries.

The responsibility for making analyzer quality control checks and for ensuring proper analyzer maintenance rests with the inspection station personnel. To insure compliance in frequency and procedure, as well as to identify trends in analyzer operation, it is important that major analyzer quality control checks (such as gas spans and leak checks), analyzer maintenance, and analyzer audits be recorded in the analyzer logbook. Such information is not only useful to ensure that required quality control checks and maintenance are performed, but also provides the administrating agency with a way to evaluate the relative in-field performance by different makes and models of analyzers.

To minimize the time required to maintain analyzer logbooks, the log sheets should be designed to be as simple as possible. If this is done, only a few minutes a week would be required to keep these analyzer records.

Figure 3 is an example of a log sheet that can be used to record the quality control checks and maintenance that are performed. All weekly quality control checks and any maintenance that is performed should be recorded on this log sheet. The following gneeral instructions should be followed when making an entry on the log sheet:

1. The specific procedure should be clearly identified. At a minimum, the following procedures should be recorded.

    a. Leak check
    b. Gas span check
    c. Filter replacement

Figure 3. Sample Analyzer Log Sheet

Site: Swanson's Gulf Service

Analyzer Manufacturer, Model and Serial No.: Allen model # 23390, serial # AE14369

Hexane/propane Equivalency Factor: 0.52

Span Gas Cylinder No.: X403

Concentration: 1.69 % CO 632 ppm Propane

Type of zero air: Room Air

DATE	PROCEDURE	RESULTS/COMMENTS	OPERATOR
2-5-80	gas span/leak check	CO probe - 1.64% CO port - 1.67% HC port - 335 ppm leaks-ok CO span-ok HC span - ok	T. Swanson
2-12-80	gas span/leak check	CO probe - 1.68% CO port - 1.72% HC port - 350 ppm leaks-ok CO span-ok HC span - adjust	T. Swanson
2-12-80	span adjust	CO port - 1.69% HC port - 328 ppm	T. Swanson
2-16-80	filter replacement gas span/leak check	CO probe - 1.67% CO port - 1.69% HC port - 330 ppm leaks-ok CO span - ok HC span - ok	C. Wallace
2-22-80	audit gas span/leak check span gas cylinder pressure	leaks - ok span - ok 1450 psi	J. Thompson

d. Sample line maintenance
e. Sample line replacement
f. Probe maintenance
g. Maintenance to pressure regulator

2. The date should be indicated for each procedure.

3. The results should be specific. If the system is okay, state so. If a defect or discrepancy is found, state the nature and degree of the defect, and the corrective action taken.

4. Operator or other person performing the procedure should be indicated on the form (signature or initials).

2.5 Audits

If performed correctly, the weekly quality control checks that are performed by the inspection station personnel should be adequate, in most cases, to maintain the accuracy of the analyzer. Nevertheless, it is still important for personnel from the administrating agency to periodically visit (audit) the stations and independently verify the accuracy of the analyzer. Recommended procedures to use in conducting the audits are presented in Section 4.0 of this report.

Checking the analyzer and analyzer logbook are very important aspects of the audit. Checking the analyzer and the logbook allows the auditor to assure that the analyzer is being properly maintained in good operating condition. Audits by the administrating agency can also satisfy several other purposes, such as, reviewing inspection records and verifying that the station complies with applicable licensing requirements.

Internal audits conducted periodically by the shop foreman, service manager, or another appropriate supervisor within the larger inspection stations are useful to ensure analyzer accuracy, inspector proficiency, and data quality. Internal audits enhance the quality in the I/M program by improving inspector accountability. In addition, stations which routinely conduct internal audits will undoubtedly have fewer problems passing audits by the administrating agency.

3.0 QUALITY CONTROL FOR INSPECTION TEST PROCEDURES

The previous section described methods to assure that the analyzer is accurately measuring the emissions from a vehicle. However, a key aspect in the overall accuracy of the emissions measurement is the inspection test procedures and how well they are performed. Quality control is important in every aspect of the emissions inspection.

There are three basic parts of the inspection process. Prior to the actual inspection, the inspector must go through pre-test procedures to prepare the analyzer and the vehicle for the inspection. The next step is the inspection itself. Following the inspection, certain post-test activities, including the documentation of the inspection results, must be conducted. It is very important that the documentation be performed carefully, since the data collected in an I/M program play an important part in the evaluation of program effectiveness.

This section provides specific quality control procedures to integrate into the three parts of the emissions inspection process. These procedures should be emphasized in training programs that are conducted by the administrating agency prior to the start and during the operation of an I/M program. In addition, the administrating agency should stress these procedures when it is supervising the emissions inspectors, especially in those stations which have apparent problems with quality control.

3.1 Quality Control Procedures Prior to the Test

The pretest procedures consist primarily of the preparation of the analyzer for the inspection along with the preparation of the vehicle.

3.1.1 Procedures for Analyzer Preparation

Prior to performing an emissions inspection, the analyzer must be prepared for testing. The following procedures are recommended for analyzer preparation.

Note: See the reference to errors caused by parallax on page 12.

1. Before the analyzer is turned on, perform a mechanical zero check (analog meters). See Section 2.2.1.2, Step 1. If the meter needle is not aligned with the zero reading, it is necessary to adjust the setscrew on the face of the meter.

2. Before inspections may be performed, the analyzer must be adequately warmed up. While the analyzer is warming up, the meters (analog) should be checked for excessive static build-up. See Section 2.2.1.2, Step 2. Several methods can be used to insure that the analyzer is warmed up.

   a. It is recommended to turn the analyzer on when the first person arrives at the inspection station. Having the analyzer ready for testing as early as possible in the work day may reduce customer inconvenience by reducing waiting time.

   b. The analyzer should be on for a minimum of 30 minutes prior to testing, unless the manufacturer recommends a shorter period. The analyzer should be in the standby mode (pump off) during warm-up in order to conserve the pump, conserve electricity, and reduce noise. If there are doubts whether the analyzer is warmed up, the operator could check it with span gas. If the meter reading increases slowly, the analyzer is not warmed up. Or, if an unstable reading is obtained, the analyzer may not be warmed up.

   c. Some analyzers, in particular those meeting the EPA computerized analyzer specifications, will not sample unless they are warmed up. Thus, if the station has one of these analyzers, other provisions to assure that the analyzer is warmed up may not be necessary.

3. The operator should check the analyzer log sheets to determine when the last gas span and leak check were performed. If a week or more has elapsed, then the analyzer needs to be gas spanned and leak checked (see Section 2.2).

4. Several times during the day, the operator should visually check the water trap and empty it as required. Even if equipped with a continuous drain line, the water trap should be checked anyway, because the check valve can become easily clogged. Filters should also be visually checked at least daily and changed as necessary.

5. Immediately after warm-up and before each test the operator should check and adjust the zero and electrical span.

6. Before each test, a hydrocarbon hang-up check should be performed. See Section 2.2.1.2, Step 6.

7. The inspectors should check any warning signals on the analyzer to make sure that they are not illuminated. These signals include the low flow indicator and maintenance warning lights.

It should be noted that the first two steps in the analyzer preparation do not need to be repeated for each test, unless the analyzer is turned off between emissions tests. The third check (checking the analyzer log sheets) need only be performed once a day. However, the last three checks should be performed before each test.

3.1.2 Procedures for Vehicle Preparation

Prior to performing an emissions test, the vehicles should be prepared for testing as follows.

1. All accessories, such as, air conditioning, heater, lights, etc., should be turned off.

2. The vehicle should be checked to make sure it is adequately warmed up. The recommended method to assure that the vehicle is at normal operating temperature is to check the vehicle's temperature gauge (if so equipped) to make sure it is in the warmed-up position, or to feel the radiator or top radiator hose to determine if it is warm. (Caution: Be careful to avoid contact with the engine fan.) One or more of the following additional simple checks can also be used for this purpose, but they are not considered to be as reliable as the above method.

   a. If the vehicle has been idling for greater than five minutes, then most likely it is adequately warmed up. The vehicle may not be warmed up if it is still on fast idle.

   b. If the vehicle was just driven into the inspection station, ask the vehicle operator how far it was driven. If driven over three miles in warm weather or over five to six miles in cold weather, then the vehicle should be adequately warmed up. This check is not always conclusive and is especially variable in cold weather.

   c. During cold weather if water vapor is coming out of the exhaust, this may indicate that the vehicle is not adequately warmed up. However, this type of check is not always conclusive.

   d. If the inspection also includes a safety inspection, perform the emissions test after all the safety checks have been made. During the safety inspection, allow the vehicle to idle whenever possible. (Make sure that the exhaust is adequately vented.) If the safety program requires a road test, the emissions test could be performed after this road test.

Note: If the vehicle has to be warmed up, the inspector can make efficient use of his or her time by filling in the vehicle information portion of the inspection record and checking the analyzer while the vehicle is warming up.

3. The inspector should determine if the vehicle has exhaust leaks since they may cause dilution of the test sample. Most leaks should be audible to the inspector; however, a visual check should always be made to ensure that the exhaust system is intact. If doubt exists, the inspector could momentarily restrict the tailpipe and listen for leaks. Most safety programs require a leak-free exhaust. In this case, the emissions could be checked after the exhaust system has been checked for leaks and passed. If leaks cannot be repaired or the test sample taken upstream of the leak, the test must be voided. (Caution: Exhaust leaks are safety hazards to both the driver and to the inspector.)

3.2 Quality Control Procedures During the Test

The following general quality control procedures should be followed during the emissions test.

1. Switch the analyzer to sample mode (it should be on standby between emission tests).

2. When the idle test is being used, precondition the vehicle by operating the engine at 2,500 (± 300) rpm for up to 30 seconds (15 seconds is usually sufficient). Preconditioning is not necessary when the two-speed idle test is being used. (Note: Preconditioning removes any pollutants which may build up in the exhaust system while the vehicle is idling and/or warming up. Although preconditioning is included as a recommendation of this report, the idle test without preconditioning is an acceptable and effective short test for I/M programs.

3. With the vehicle running, insert the probe into the exhaust pipe--If the probe cannot be inserted 16 inches into the tailpipe, an extender (leak tight fit) should be placed on the end of the tailpipe to meet this criterion. The 16 inch insertion depth is recommended to avoid dilution. A clip or other devices on the probe can be used to prevent the probe from falling out during the inspection.

4. Read the analyzer according to the following instructions:

   a. Wait a minimum of 30 seconds or until a stable reading is obtained on the analyzer. (Most analyzers have response times of 15 seconds or less.) On some Ford vehicles, erroneous readings may result if the vehicle has been idling for very long (as a result of the air injection system diverting to the atmosphere). The air system can be reactivated by turning off and restarting the engine. (Remember to remove the probe while restarting.) The emissions test should be conducted immediately after restarting.

   b. If the analyzer has analog meters, make sure that errors due to parallax are avoided. See reference on page 12. Analog meters typically have both the high and the low scales on the same meter; therefore, the operator must take care to make sure that the proper scale is read.

   c. If the emission levels fluctuate during the test, it is recommended to use the average of the low and high readings. However, individual states may have different procedures to handle this situation.

   d. The emissions results should be recorded immediately on the form. However, if machine readable forms are used, the blanks can be filled in later.

e. If a two-speed idle test is performed, a tachometer must be connected to the engine. The analyzer can be positioned beside the front fender so the inspector can control the throttle and take readings simultaneously. Alternatively, an idle speed adjustment tool can be affixed to the throttle to maintain the proper high idle speed.

5. Additional items to be aware of during the inspection.

a. Of foremost importance is that the inspector uses the correct emission standards in testing a vehicle. All I/M programs have specific standards for different types of vehicles, generally, for vehicles of similar model years. Thus it is very important that the inspector correctly identifies the model year of the vehicle. If there is any doubt about the model year, the inspector should check the vehicle registration card. Some I/M programs may classify emission standards in other ways, e.g., by engine size or number of cylinders. Whatever the case, inspection station personnel must be very careful to use the proper emission standards in testing a vehicle.

b. The inspector must make sure that vehicles exempt from the inspection requirements are properly identified. For example, in some I/M programs vehicles older than 15 years are not required to be inspected. In addition, vehicles above certain gross vehicle weights are exempt from I/M tests in many programs.

c. The inspector must make sure that there are no kinks in the sampling hose and that the vehicle is not parked on the hose.

3.3 Quality Control Procedures After the Test

The following general quality control procedures should be followed after the emissions inspection is completed.

1. Put the analyzer back on standby--After the test is completed the inspector should place the analyzer back in the standby mode. This is done to reduce the contamination of the sampling line with water, pollutants and dirt, and it also adds to the life of the pump and other related equipment. In addition to putting the analyzer back on standby, the hose and probe should be properly stored after each test.

2. Complete data recordings--After the test is finished, the inspector should complete the data forms. As mentioned earlier, most of the vehicle data should be recorded prior to the inspection, while the vehicle is being warmed up. Afterwards the inspector needs to make sure that all appropriate items have been filled in, and, if the form is machine readable, the appropriate slots need to be shaded. Care must be taken to keep the form neat and clean. This is especially important when machine readable forms are used. The inspector must carefully determine the pass/fail status of the vehicle. In addition, if the vehicle is receiving a waiver, the inspector must also make sure that all appropriate data items have been completed on the waiver form.

3. Optional: Provide evaluation forms to the motorist--The administrating agency should consider the merits of requiring the inspection station to provide a brief inspection station evaluation form to each motorist after the emissions inspection has been completed. After completing the form, the motorist would mail it directly to the agency. The evaluation forms would be designed to document the motorist's perceptions of the performance of the inspection station (both positive and negative). It is recognized that motorists would be more

likely to report inferior performance through these evaluations; thus, they would provide an additional means to identify and correct quality control problems.

3.4 Inspection Checklist

In order to assure that the inspection is performed properly, an inspection checklist, which outlines all inspection procedures, should be provided to the station. This list could be posted on the analyzer to prompt or remind the inspector. Figure 4 is an example of an inspection checklist.

Figure 4. Inspection Checklist

PRETEST

Analyzer Preparation

Daily Items

- Check mechanical zero.
- Warm up analyzer in standby mode.
- Check analyzer log. Does analyzer need to be spanned or leak checked?
- Check water trap and filter. (Check several times a day.)

Before Each Test

- Warm up analyzer (if turned off after previous test).
- Check zero and electrical span.
- Check warning indicators.

Vehicle Preparation

- Turn off all accessories.
- Warm up vehicle.
- Check for exhaust leaks.

TEST

- Switch to test mode.
- Precondition vehicle (if necessary).
- Insert probe.
- Connect tachometer lead for 2-speed test.
- Read analyzer after 30 seconds or until levels stabilize.
- Do not let Ford vehicles idle for more than 1 minute before taking readings.
- Record emission readings.

POST TEST

- Switch analyzer to standby.
- Complete data recordings.

4.0 QUALITY CONTROL FOR INSPECTION STATION AUDITING

Periodic audits play an important part in the quality control of inspection/maintenance programs, especially decentralized ones. By randomly visiting inspection stations, auditors for the administrating agency can help assure that each inspection station is performing in accordance with the state's licensing requirements.

There are two basic purposes for audits. One purpose is to check for the presence of the required equipment and supplies (i.e., analyzer, span gases, tachometer, spare parts, inspection forms, stickers, manuals, etc.) and to check the performance of the emissions analyzers and related equipment. The other purpose is to check the performance of the inspectors (or other personnel) in conducting inspections, calibrating and maintaining the analyzer, and keeping records.

Generally, for decentralized programs only one person would be needed to audit a station, although a two-person team would be able to conduct the audits in less time by dividing the individual audit tasks. For example, while one auditor is checking the analyzer, the other auditor could be reviewing records. For centralized programs, a two-person audit team may be needed to inspect the station in a reasonable time period.

Auditors play a key role in the I/M program. The auditors are the communication link between the inspection stations and the program managers. The auditors provide supervision and guidance to the inspection stations. In addition, the auditors directly control much of the feedback which the program managers receive about the I/M program. The two primary mechanisms for feedback are the inspection records and the audit reports. The auditors are responsible for assuring the quality of the former during audits, and they directly generate the latter. Because of the significant role that auditors play, especially in a decentralized I/M program, it is critical to the success of the program that the administrating agency develop an effective and comprehensive auditing program.

This section presents procedures to use in performing audits of the inspection stations. The sequencing of checks during the audit depends upon several factors and should be left to the discretion of the auditor. Normally, the inspection station should be ready to conduct an inspection when the auditor arrives. In this case, it is usually easier for the auditor to perform the analyzer checks first, and then check the proficiency of the inspection station personnel (as needed) and check the records. However, if the analyzer is not turned on when the auditor arrives, the auditor should check the records and other items first, while the analyzer is warming up. In addition, if a vehicle is being inspected when the auditor arrives, or at any other time during the audit, the auditor should take the opportunity to observe the inspection and evaluate the inspector. A checklist (Figure 5) is provided at the end of this section that can be used to assure that the auditor adequately assesses all areas of importance during the audit.

4.1 Checking the Performance of the Equipment

The following procedures can be used to check the performance of the test equipment. If the analyzer is already turned on, these checks can usually be performed in 30 minutes or less (per analyzer).

4.1.1 Checking Equipment Readiness

When the auditors arrive at the station, they should inquire as to whether or not the station is ready to perform an inspection. If so, the audit team needs to check the condition and state of the analyzer. They need to determine if it is turned on and properly warmed up. Generally, the analyzer should be left on in the standby mode throughout the day. However, if the audit team arrives early in the day, it is reasonable to expect that the analyzer has just been turned on or it may not be on at all. If the audit team does arrive before the analyzer is turned on, the auditors should take the opportunity to observe a normal power-on routine. This routine is described in Section 3.1.1.

4.1.2 Checking the Performance of the Analyzer

4.1.2.1 Equipment Required

The equipment required to check the performance of the analyzer is similar to the equipment described in Section 2.2.1.1 (Equipment Required for the Inspection Station). However, the following additional or different equipment will be needed in order to conduct an audit.

1. Zero gas -- A bottle of zero gas that is hydrocarbon free (99.9% nitrogen) or an air supply with an activated charcoal filter and a water trap. (Using zero gas for zero checks should ensure that background pollutants in the station's room air do not bias the zero settings.)

2. Audit span gas -- As mentioned earlier, the station should have a bottle of span gas that is close to the emissions standards of the emissions performance warranty regulations, (i.e., 1.5% CO, 600 ppm propane). The auditors should also have a bottle of span gas with similar concentrations. Since the inspection station's span gases are accurate to ±2% NBS, it is recommended that audit span gases be accurate to ±1% NBS.

4.1.2.2 Procedures

1. Check the zero and electrical span, adjusting as necessary.

2. Perform a HC hang-up check, preferably using a zero gas. If the HC reading through the probe is greater than 20 ppm after 30 seconds while the reading through the port is 0 ppm, the appropriate maintenance needs to be recommended to the inspection station. See Section 2.2.1.2, Step 6. If the analyzer has no span port, this step must be omitted.

3. Using the audit span gas, perform a combination gas span/leak check per the procedures in Section 2.2.1.2. The analyzer should be within ±5% of

the audit gas concentrations for both HC and CO and should not have any leak greater than 3%. If analyzer accuracy is not within the ±5% limit, the auditors should attempt to determine if there are any overt reasons for the discrepancy (other than the need for span adjustments). The check should include a comparison of the operator's span gas with the auditor's span gas to determine if the span gas concentration is different from the value on the bottle. If the analyzer does not have a separate calibration port (i.e., the span gas has to be entered through the probe), it is possible that a leak could be responsible for a low reading. See Section 2.2.1.2 for description of methods to leak check analyzers that do not have span ports. Any span adjustment or leak problems identified in an audit should be immediately corrected by the inspection station, or the analyzer in question should be immediately removed from service until it is repaired. See Section 2.2.1.2, Step 10 for recommended span adjustment procedures.

4. Since gas spanning is being done on the low range, the auditor should check the low scale/high scale correlation to make sure that the analyzer is accurate on the high range.

5. Check other equipment on the analyzer -- In addition to the span checks, the auditors should check other items related to the analyzer. These include filters and water drains. In addition, the auditor should check the function of any of the automated checks if applicable.

4.2 Checking Procedures for Routine Tasks

In addition to checking the accuracy of the equipment that is used for the emissions test, the auditors should also check to see that the inspector is proficient in performing different tasks. These checks do not need to be performed during all audits; however, if there is evidence from previous audits and/or from data analysis that the inspection station may not be performing properly, then the proficiency of inspectors should be checked. In some cases, the inspectors may be performing inspections while the auditor is on the premises. In this case the auditor should always take the opportunity to observe the inspections.

4.2.1 Observing Weekly Quality Control Checks

If the analyzer is found to be out of calibration, the auditor should have the inspector attempt to adjust it. The auditor should note if the inspector does not perform the span adjustment properly (as described in Section 2.0 of this report) and initiate appropriate actions to correct the problem (i.e., demonstrate the proper method to the inspector, or, if necessary, as in recurring cases, require the inspector to go through total retraining and recertification.

4.2.2 Observing Inspections

As already mentioned, if possible the auditors should observe an inspection while they are on the premises. If there are no vehicles on the premises that need inspection, the station could perform an inspection on the auditor's vehicle. When the inspection is being performed, the auditor should first note whether the vehicle was adequately prepared. That is, the vehicle should be correctly warmed up and have no exhaust leaks. In addition, the auditor should note whether or not the analyzer was properly prepared for the inspection.

The auditors need to answer the following questions to determine if the inspection is correctly performed.

1. Is probe inserted correctly?

2. Has the analyzer stabilized?

3. Is the proper scale used (if dual scale)?

4. Are the data recorded correctly? During the inspection the auditors

should record the values and compare these values with the values the inspector reports. The auditor should also check to see that other data on the form are correctly completed.

5. Were the correct emissions standards used?

4.2.3 Checking Documentation

Another important aspect of the performance of the inspection station is maintaining adequate documentation for both analyzer records and inspection records. At least 10 percent (or 10-15 records, whichever is greater) of the inspection records should be checked during each audit. However, if problems are found, or if there are recurring problems with particular stations, the auditors may need to check a larger percentage of the inspection records. Approximately 30 minutes should be allocated to checking documentation unless automated data collection is used for inspection records. In this case, documentation checks should take approximately 10 minutes, since only the analyzer records will need to be reviewed during the audit.

4.2.3.1 Checking Analyzer Records

The auditors should inspect the records that are kept in the log book to make sure that the weekly quality control checks are being performed. In addition, the auditors should note whether preventive maintenance is performed per the manufacturer's schedule or the schedule discussed in Section 2.3. Finally, the auditors should note the pressure in the span cylinder, record it in the analyzer logbook,and compare this pressure with the pressure recorded during the last audit. If weekly span and leak checks are performed as required by the emissions performance warranty regulations, then cylinder pressure (assuming full size I-A cylinders) should drop approximately 50 to 100 psi per month. If a lower drop is noted, then the station may not be performing weekly gas span/leak checks. If other than size I-A span gas cylinders are used, the amount of pressure drop may differ from the 50 to 100 psi noted above.

The auditor should also qualitatively review the analyzer records. They should note whether all pertinent data are included in entries and if reasonable values are entered. In addition, they should also note if the records are being completed as the analyzer is maintained. (That is, are the records current?) At the same time, the auditors could note any indications of fraudulent record keeping.

It should be noted that the use of standard forms such as the log sheet discussed in Section 2.4 will greatly aid in the proper maintenance and review of analyzer records.

4.2.3.2 Reviewing Inspection Records

The auditors can make several random checks on the inspection records.

1. Are the records properly completed? Are values entered for all fields? Are they legible? The use of standard inspection forms that are easy to read and easy to understand will greatly aid record keeping; however, care must still be taken by the inspector in order to insure that data are recorded properly.

2. Verify the garage's emissions test summaries, monthly reports, etc. (when applicable). It is recommended that the garages prepare summaries or reports of their inspection activities on a monthly basis. Doing so not only assists the state in reviewing the station's records, but also helps to ensure that the inspection station operator periodically reviews his/her station's performance. One method to verify the accuracy of these summaries would be for the auditor to tabulate the overall failure rate for the preceding month. The failure rate that the auditors arrive at could then be compared with the garage's tabulation.

3. Randomly review 15 or 20 forms to answer the following questions.

a. Are proper standards being used?

b. Are vehicles being properly passed or failed?

c. Are recorded emissions readings reasonable?

d. Is there any evidence of improper record keeping? For instance, is there a recognizable pattern to emissions readings (e.g., all CO readings are "__.0", etc.)?

e. Are the waivers legitimate as indicated by cost, type of repair, and the emissions reductions?

f. Is the repair data reasonable (if available)? The auditors could look at the cost versus type of repair to determine if the garage is charging excessive costs for simple repairs. The auditors could also question extremely high repair cost, especially if there is a very low emissions reduction. At the same time, the auditors can note the general distribution of the repair costs. That is, are most less than $10, between $10 and $20 and so forth? These general distributions could then be compared with program trends to date. If the station appears to have questionable repair data, then those stations could be audited more frequently.

4. It is still necessary to manually review the data even if they are recorded on machine readable forms. These forms must be checked to make sure that the data are entered in the proper fields and that they are coded properly. In addition, it must be stressed that the forms must be clean and undamaged, and all the appropriate fields are completed.

4.2.3.3 Checking Sticker Records

While the auditors are at the garages, they should also review the records kept on the inspection stickers. Since most programs that use stickers stagger inspections over the calendar year, the auditors could collect the unused stickers from the previous month. The auditors could note the serial numbers of these stickers (or the number of stickers, if not serially numbered), and with the aid of past data on the serial numbers of stickers (or the number of stickers) issued to the station, the auditors could determine the number of inspections that should have been performed. This number could then be compared with the number of inspections as noted by inspection records for the same time period. The auditors could also be responsible for the delivery of stickers which would aid in the accounting of them.

4.3 Other Items to Inspect During the Audit

Aside from checking the accuracy of the analyzer and the procedures used by the inspectors, the auditors could perform other checks while they are at the station. First, they could determine whether all licensing requirements are being met. In many cases, for example, inspection stations must have current repair manuals or certain equipment in addition to the emissions analyzer on the premises in order to comply with state licensing requirements. Furthermore, some state specifications require that certain documents such as the station's license, the inspection procedure, emission standards, etc. be posted in the station. Depending on the particular state's rules and regulations, there may be other licensing requirements which apply to the stations.

It is also important for the auditors to review complaints with the inspector and/or the station manager. Complaints regarding repair practices and emission challenge checks should be carefully reviewed.

4.4 Taking Corrective Action

All of the audit functions discussed thus far have dealt with the things that auditors evaluate during an audit--the analyzer, the records, the proficiency of the station personnel, etc. In making these evaluations, the auditor in each case should have predetermined limits (or ranges) of acceptability in order to be able to rate the performance of the station. Suggested limits of acceptability for emissions analyzers were discussed in Section 2.0; i.e., an analyzer should be accurate within ±5% during gas spanning and should have no leaks which cause errors of more than 3%. The quantification of performance and the limits of acceptability are less precise for record checks and personnel proficiency checks. In these cases, more variability in performance must be expected because of the differences in the abilities and attitudes of the people involved directly in these areas. In contrast, the analyzer is a machine built to specific tolerances and, therefore, can be expected to perform to tight and well-defined limits. Table 3 lists some examples of the criteria that can be used in developing limits of acceptability for record checks and personnel proficiency checks; however, the reader should not construe Table 3 as an exhaustive listing of these criteria.

In some cases (hopefully a small minority), during the conduct of audits of inspection stations, the auditor will inevitably identify problems which need to be corrected. The problem may be as simple as untidy record keeping or as serious as a flagrant disregard of proper testing procedures by the inspector. Depending on the severity of the identified problem(s) and on the system of penalties for malperformance in the particular state involved, the auditor may have various courses of corrective action open to him/her. Many problems can be corrected cooperatively simply by identifying and discussing them with the appropriate station personnel. If this is not successful, the auditor may be able to correct the less severe problems, such as the case of untidy record keeping, by giving the station personnel an oral or written warning and then following up during the next audit to make sure the problem was corrected. In more serious cases or in cases where there are recurring problems, the auditor may need to take harsher action, such as, suspending an inspector's license and/or the station's license or requiring that an inspector go through retraining and recertification. Whatever the case, the auditor must be prepared to take appropriate corrective actions as problems are identified. At the same time, auditors must be careful to document all the facts before making a judgment about the performance of an inspector or inspection station. In some cases, a definite problem may not be identified conclusively in a single audit and must be followed up in a series of

TABLE 3: AUDIT CRITERIA FOR RECORD CHECKS AND PERSONNEL PROFICIENCY CHECKS

Record Checks

1. Is an inspection record being completed for each inspection (i.e., are there an appropriate number of inspection records as compared to the number of stickers issued)?

2. Is each record completed properly? All fields completed? Reasonable entries? Any indications of incorrect or fraudulent entries?

3. Are the inspection records legible?

4. Are vehicles being properly passed or failed?

5. Are the correct emission standards being used?

6. Is the failure rate realistic? Too high? Too low? Are suspected inconsistencies explainable?

7. Are repairs consistent with the failure mode? In other words, are the problems with failed vehicles being properly diagnosed and repaired? (This information may not always be available.)

8. Is the repair cost consistent with the repair? (This information may not always be available.)

9. Are there variations in performance (failure rates, repair costs, etc.) between inspectors within the same inspection station?

10. Are any required monthly summaries or reports being done properly and on time?

(Continued)

TABLE 3: (Continued)

Personnel Proficiency Checks

1. Does the inspector know and use the proper testing procedures?

   a. Does he/she know how (and why) to properly prepare the analyzer for testing?

   b. Does he/she know how (and why) to properly prepare the vehicle for testing?

   c. Can he/she perform the emissions test properly?

   d. Does he/she know and follow prescribed quality control procedures after the test is completed?

   e. Does he/she know how to properly complete an inspection form?

2. Does the inspector or other appropriate person know how, why, and when to conduct periodic quality control checks and/or preventive maintenance on the emissions analyzer?

3. Does the analyzer logbook document that prescribed quality control checks and/or maintenance are being conducted at the appropriate times by qualified personnel?

4. Is the inspection station supervisor or owner knowledgeable about the conditions within the station and performance of his/her inspectors?

5. Are all inspection stickers accounted for?

audits, or through other investigations, in order to fully document the problem.

To ensure that auditors deal with inspection stations in a fair and equitable manner, the administrating agency should identify the kinds of corrective actions which should be applied to particular offenses. This information should most likely be included in operating guidelines or procedures for auditors to follow. In addition, auditor supervisors should routinely review corrective actions that have been taken against offenders to ensure that the actions were consistent with agency policy.

4.5 Documentation

To aid in the performance of an audit, a checklist or audit form should be completed during the audit. As mentioned earlier, some of the items on the checklist, i.e., reviewing inspector proficiency, may not need to be performed during each audit. However, the checks of the emissions analyzer and records should be performed every time the auditors are at the station. It is important to evaluate the emissions analyzer(s) during every audit because of the analyzer's relative sensitivity to its external environment. This results in a high potential for measurement errors which can be minimized through frequent routine analyzer checks. Routinely checking records during every audit will better enable the auditor to assure that records are being kept properly and that the station is performing satisfactorily. Frequent routine record checks also provide assurance that any problems that may exist are identified and corrected promptly. Figure 5 is a sample of an audit checklist that could be used in a decentralized program.

The audit checklist (or audit report) should be designed to allow complete documentation of the audit. Space should be provided for the auditor to enter explanations and descriptions of his/her findings and/or recommendations. In particular, there should be space provided at the end of the form for the auditor to report the results of the audit, any needed follow-up activities,

Figure 5: Sample Audit Checklist

Inspection Station Number 3205 Date 3-18-81

Name Excel Service Garage Time 9:30 a.m.

Location 802 Parker St., Springfield, MA Auditor B. Higgins.

Station Official's Signature/Title Rod Scofield, Service Manager

Yes/No	Operation	Comments
	EQUIPMENT READINESS	Analyzer turned on by auditor at 9:35 a.m. No inspection had been made on 3-18-81 as of that time. It was suggested to R. Scofield that the analyzer be routinely turned on early in the workday to avoid testing delays.
No	1. Analyzer on?	
No	2. Analyzer warmed up?	
No	3. Zero and span set?	
	ANALYZER CONDITION	
Yes	1. Zero ok?	Gas span - OK Leak check - OK
No	2. HC hang-up?	
Yes	3. Gas span within ±5%?	(see gas span/leak check worksheet)
NA	If no, was span adjusted successfully?	
No	4. Leaks?	
NA	If yes, were they corrected?	
Yes	5. Scale correlation ok?	
No	6. Other defects?	
	INSPECTOR PROFICIENCY (ID # 1487)	Auditor observed inspector prepare analyzer after warm-up. No vehicle inspection or weekly QC checks were observed.
Yes	1. Sets span and zero correctly?	
NA	2. Performs proper leak check?	
NA	3. Makes sure vehicle is warmed up?	
NA	4. Checks for exhaust leaks?	
NA	5. Inserts probe properly?	
NA	6. Reads analyzer correctly?	
NA	7. Uses proper emission standards?	
NA	8. Completes form correctly?	
NA	9. Other factors?	
	ANALYZER RECORDS	
Yes	1. Weekly QC checks being performed?	2-21-81 cylinder pressure - 1425 psi
Yes	2. Span cylinder pressure drop consistent?	3-18-81 - 1300 psi
Yes	3. Regular maintenance performed?	
Yes	4. Records current?	
No	5. Indications of fraudulent or improper record keeping?	Analyzer records - OK
No	6. Other factors?	

Figure 5: Sample Audit Checklist (continued)

Yes/No	Operation	Comments
	INSPECTION RECORDS	INSPECTION RECORDS NOT ALWAYS NEAT AND LEGIBLE. THIS SITUATION WAS DISCUSSED WITH R. SCOFIELD AND WILL BE CORRECTED.
Yes	1. Records properly completed?	
_No_	2. Records neat and clean?	
_No_	3. Records legible?	
Yes	4. Failure rates reasonable?	
Yes	5. Repair costs reasonable?	
_No_	6. Missing or unaccounted for stickers?	
_No_	7. Indications of fraudulent or improper record keeping?	INSPECTION RECORDS - OK EXCEPT AS NOTED ABOVE.
_No_	8. Other factors?	
	GENERAL	ALL REQUIRED MATERIALS POSTED. REQUIRED TOOLS, MANUALS AND SPAN GAS WERE ON PREMISES.
Yes	1. All licensing requirements being met?	
_No_	2. Any serious problems or complaints?	
_No_	3. Other factors?	

NOTES: (Indicate in this space all findings, recommendations, areas needing follow-up, explanations, etc. resulting from this audit.)

No problems IDENTIFIED except for the messy RECORD Keeping. Follow-up IS NEEDED TO MAKE SURE THIS problem IS CORRECTED.

Auditor's Signature B Higgins

Reviewed By O. Jenkins Date 3-22-81

Figure 5: Sample Audit Checklist (continued)

Audit Gas Span/Leak Check Worksheet

Analyzer Make/Model ____Sun 1115____
Propane/Hexane Equivalency Factor (PEF) ____0.51____

Audit Gas Concentrations: CO ____1.58____ %
HC ____620____ ppm propane

1. Acceptable Analyzer Response Ranges (±5%):

CO: (0.95 X CO Audit Gas Concentration) to
(1.05 X CO Audit Gas Concentration)

(0.95 X ____1.58____) to (1.05 X ____1.58____)

____1.50____ to ____1.66____

HC: (0.95 X Propane Audit Gas Concentration X PEF)
to (1.05 X Propane Audit Gas Concentration X PEF)

(0.95 X ____620____ X ____0.51____) to (1.05 X ____620____ X ____0.51____)

____300____ to ____332____

2. Analyzer Responses to the Audit Gas:

CO probe ____1.60____
CO port ____1.62____
HC port ____325____

3. Gas Span Result: ____Pass____

4. Acceptable Leak Limit:

CO port response should be less than (1.03 X CO probe response)

(1.03 X CO probe response) = (1.03 X ____1.60____

= ____1.65____

5. Leak Check Result: ____Pass____

and any corrective actions required. A well designed audit form will help ensure thorough audits, complete documentation of them, and equitable treatment to all inspection stations.

Written documentation of the audit findings is also important to the inspection station. The station supervisor/owner (or other person in charge at the time of the audit) should be given a copy of those parts of the audit form which indicate the results of the audit and any corrective actions that were taken or that are needed. If a multiple copy audit form is used, the station's copy of the audit report can be generated automatically as the report is completed by the auditor. Since some of the auditor's comments or findings may need to be confidential, there should be certain parts of the audit form which do not duplicate on the station's copy. To assure that the inspection station receives this feedback on the audit, it is recommended that an appropriate space be provided on the audit form for the station official in charge to sign it. His/her signature would then signify that the audit was conducted at the time indicated and that the auditor discussed the results of the audit with him/her. The station official's signature would also provide assurance to the administrating agency's audit supervisor that the audit was conducted.

5.0 QUALITY ASSURANCE IN AN I/M PROGRAM

The previous sections of this report have dealt with various aspects of quality control for an I/M program, i.e., the system of activities needed to provide a quality I/M program. Sections 2.0 and 3.0 dealt specifically with internal (within the inspection stations) quality control aspects while Section 4.0 shifted to external quality control aspects, or quality assurance. Quality assurance is the system of activities needed to provide assurance that the quality control system is performing adequately. In other words, quality assurance is quality control for the quality control system.

Audits (Section 4.0) are one aspect of quality assurance. Each audit provides the mechanism for quality assurance for the particular inspection station involved. Taken together, the audits for all inspection stations provide data which allow program managers one way to assess whether the I/M program is operating as intended. Further data for this purpose are provided through inspection records, public opinion surveys, special studies, air quality data and other sources. With these sources of information, program managers can track trends in the program, identify problem areas, and institute needed program modifications to correct them. These kinds of continuous feedback are needed for the I/M program managers to keep the program on track toward meeting the desired objectives. (Note: Further information on I/M data analyses is available in another EPA report prepared by Radian Corporation entitled "Guidance on Data Handling and Analyses in an Inspection/ Maintenance Program".)

To assure that the quality assurance function is given adequate consideration by top management, a specific organizational unit(s) should be given the quality assurance and quality control responsibilities for the I/M program. In addition, clear and specific objectives for quality assurance should be defined as well as ways to measure whether the quality assurance objectives are being achieved. Table 4 lists examples of the kinds of questions that the quality assurance program should be designed to answer; however, the reader should not construe Table 4 as an exhaustive list. (Note: Further information on quality assurance planning is available in an EPA report entitled "Quality Assurance Handbook for Air Pollution Measurement Systems".)

TABLE 4: QUALITY ASSURANCE QUESTIONS FOR AN I/M PROGRAM

1. Is the I/M program operating as intended? Are I/M program objectives being achieved?

   a. Are the inspection stations being operated properly?

   b. Is the failure rate as expected?

   c. Are vehicles being properly repaired? At a reasonable cost?

   d. Is the waiver rate reasonable?

   e. Is there reasonable public acceptance of the program?

2. Are there any special problems or trends which need to be addressed?

   a. Do the emission standards for any particular class(es) of vehicles need to be changed?

   b. Are any changes needed in the forms or data collection system?

   c. Are there any enforcement problems? Is the appropriate number of vehicles being inspected?

   d. Are there any problems with certain makes or models of analyzers?

   e. Are there any special repair or diagnosis problems which should be addressed through future training?

   f. Is the audit system functioning properly?

   g. Are there any special problems involved with testing or repairing certain vehicles which EPA should be made aware of in order to

TABLE 4: Continued

notify other states or to investigate methods of resolution?

3. What is the proper mechanism to address any problems?

   a. Through changes in the training program?

   b. Through changes in the quality control system?

   c. Through changes in program procedures (i.e., testing procedures, emission standards, enforcement, record keeping, reporting, auditing, etc.)?

   d. Through changes in the public awareness program?