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Quality Assurance Handbook for Air Pollution Measurement Systems

Volume II: Part 1

Ambient Air Quality Monitoring Program Quality System Development

Foreword

This document represents Volume II of a 5-volume quality assurance (QA) handbook series dedicated to air pollution measurement systems. Volume I provides general QA guidance that is pertinent to the remaining volumes. Volume II is dedicated to the Ambient Air Quality Surveillance Program and the data collection activities of that program.

The intent of the document is twofold. The first is to provide additional information and guidance on the material covered in the Code of Federal Regulations pertaining to the Ambient Air Quality Surveillance Program. The second is to establish a set of consistent QA practices that will improve the quality of the nation's ambient air data and ensure data comparability among sites across the nation. Therefore, the document is written for technical personnel at State and local monitoring agencies and is intended to provide enough information to develop a quality system for ambient air quality monitoring.

The information in this document was revised/developed by many of the organizations implementing the Ambient Air Quality Surveillance Program. Therefore, the guidance has been peer reviewed and accepted by these organizations and should serve to provide consistency among the organizations collecting and reporting ambient air data.

This document has been written in a style similar to a QA project plan, as specified in the document "EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations" (EPA QA/R5). Earlier versions of the Handbook contained many of the sections required in EPA QA/R5 and since many State and local agencies, as well as the EPA, are familiar with these elements, it was felt that the document would be more readable in this format.

This document is available on hardcopy as well as accessible as a PDF file on the Internet under the Ambient Monitoring Technical Information Center (AMTIC) Homepage (http://www.epa.gov/ttn/amtic). The document can be read and printed using Adobe Acrobat Reader software, which is freeware that is available from many Internet sites (including the EPA web site). The Internet version is write-protected and will be updated every three years. It is recommended that the Handbook be accessed through the Internet. AMTIC will provide information on updates to the Handbook. Hardcopy versions are available by writing or calling:

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Recommendations for modifications or revisions are always welcome. Comments should be sent to the appropriate Regional Office points of contact identified on AMTIC bulletin board. The Handbook Steering Committee plans on meeting quarterly to discuss any pertinent issues or proposed changes.

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Acronyms and Abbreviations

AIRS	Aerometric Information Retrieval System
ADBA	AIRS data base administrator
AMTIC	Ambient Monitoring Technical Information Center
APTI	Air Pollution Training Institute
AQSSD	Air Quality Strategies and Standards Division
AWMA	Air and Waste Management Association
CAA	Clean Air Act
CBI	confidential business information
CFR	Code of Federal Regulations
CMD	Contracts Management Division
CO	Contracting Officer
CSA	consolidated statistical area
DCO	Document Control Officer
DD	Division Director
DQA	data quality assessment
DQAO	Deputy QA Officers
DQOs	data quality objectives
EDO	environmental data operation
EMAD	Emissions, Monitoring, and Analysis Division
EPA	Environmental Protection Agency
EPAAR	EPA Acquisition Regulations
ESD	Emission Standards Division
ETSD	Enterprise Technology Services Division
FAR	Federal Acquisition Regulations
FEM	Federal Equivalent Method
FIPS	Federal Information Processing Standards
FRM	Federal Reference Method
GIS	geographical information systems
GLP	good laboratory practice
HAP	hazardous air pollutants
IAG	interagency agreement
IDP	Individual Development Plans
IT	information technology
ITPID	Information Transfer and Program Integration Division
LAN	local area network
MACT	Maximum Achievable Control Technology
MQAG	Monitoring and Quality Assurance Group
MQOs	measurement quality objectives
MPA	monitoring planning area
MSA	metropolitan statistical area
MSR	management system review
NAAQS	National Ambient Air Quality Standards
NAMS	national air monitoring station
NECMSA	New England county metropolitan statistical area
NESHAP	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NPAP	National Performance Audit Program
NSPS	New Source Performance Standard
OAQPS	Office of Air Quality Planning and Standards
OARM	Office of Administration and Resources Management
OIRM	Office of Information Resources Management

OMB	Office of Management and Budget
ORD	Office of Research and Development
PAMS	Photochemical Assessment Monitoring Stations
P&A	precision and accuracy
PC	personal computer
PE	performance evaluation
PR	procurement request
PMSA	primary metropolitan statistical area
PSD	Prevention of Significant Deterioration
PDW	primary wind direction
QA	quality assurance
QA/QC	quality assurance/quality control
QAARWP	quality assurance annual report and work plan
QAD	EPA Quality Assurance Division
QAM	quality assurance manager
QAO	quality assurance officer
QAPP	quality assurance project plan
QMP	quality management plan
RCRA	Resource Conservation and Recovery Act
SAMWG	Standing Air Monitoring Workgroup
SCG	Source Characterization Group
SIPS	State Implementation Plans
SIRMO	servicing information resources management officer
SLAMS	state and local monitoring stations
SOP	standard operating procedure
SOW	statement or scope of work
SPMS	special purpose monitoring stations
SYSOP	system operator
TSA	technical system audit
TSP	total suspended solids
VOC	volatile organic compound
WAM	Work Assignment Manager

0. Introduction

0.1 Intent of the Handbook

This document is Volume II of a 5-volume quality assurance (QA) handbook series dedicated to air pollution measurement systems. Volume I provides general QA guidance that is pertinent to the four remaining volumes. Volume II is dedicated to the Ambient Air Quality Surveillance Program and the data collection activities of that program. This guidance is one element of a quality management system whose goal is to ensure that the Ambient Air Quality Surveillance Program provides data of a quality that meets the program objectives and is implemented consistently across the Nation.

The intent of the Handbook is twofold. First, the document is written for technical personnel at State and local monitoring agencies to assist them in developing and implementing a *quality system* for the Ambient Air Quality Surveillance Program. A quality system, as defined by *The American National Standard-Specifications and Guidelines for Environmental Data Collection and Environmental Technology Programs*[9], is "a structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan for ensuring the quality in its work processes, products, and services. The quality system provides the framework for planning, implementing, and assessing work performed by the organization and for carrying out required quality assurance (QA) and quality control (QC)". An organizations quality system for the Ambient Air Quality Surveillance Program is described in their QA project plan. Second, the Handbook provides additional information and guidance on the material covered in the Code of Federal Regulations (CFR) pertaining to the Ambient Air Quality Surveillance Program.

Based on the intent, the first part of the Handbook has been written in a style similar to a QA project plan as specified in the draft *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations (EPA QA/R5)*[34]. Earlier versions of the Handbook contained many of the sections required in *QA/R5* and because many State and local agencies, as well as EPA, are familiar with these elements, it was felt that the Handbook would be more readable in this format. The information can be used as guidance in the development of detailed quality assurance project plans for State and local monitoring operations.

Earlier versions of the Handbook focused on the six criteria pollutants monitored at the State and Local Ambient Monitoring Stations (SLAMS) and National Ambient Monitoring Stations (NAMS). This edition includes quality assurance guidance for the Photochemical Assessment Monitoring Stations (PAMS), open path monitoring and the fine particulate standard ($PM_{2.5}$). The majority of the PAMS and open path information are derived from the *Photochemical Assessment Monitoring Stations Implementation Manual* and the *Network Design, Siting, and Quality Assurance Guidelines for the Ultraviolet Absorption Spectrometer (UV-DOS) Open Path Analyzer* respectively.

0.2 Handbook Structure

The document has been segregated into two parts. Part 1 includes general guidance pertaining to the development and implementation of a quality system (based upon *QA/R5*), and Part 2 includes the methods, grouped by pollutant, and written as guidance for the preparation of standard operating procedures.

0.3 Shall, Must, Should and May

This Handbook uses the accepted definitions of *shall, must, should* and *may*, as defined in *ANSI/ASQC E4-1994*[9]:

- *shall, must* When the element and deviation from specification will constitute non-conformance with 40 CFR and the Clean Air Act
- *should* when the element is recommended
- *may* when the element is optional or discretionary

0.4 Handbook Review and Distribution

The information in this Handbook was revised and/or developed by many of the organizations implementing the Ambient Air Quality Surveillance Program (see Acknowledgments). It has been peer-reviewed and accepted by these organizations and serves to provide consistency among the organizations collecting and reporting ambient air data.

This Handbook is accessible as a PDF file on the Internet under the AMTIC Homepage:

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Recommendations for modifications or revisions are always welcome. Comments should be sent to the appropriate Regional Office Ambient Air Monitoring contact or posted on AMTIC. The Handbook Steering Committee will meet quarterly to discuss any pertinent issues and proposed changes.

1. Program Organization

Figure 1.1 Ambient Air Program Organization

Federal, State, Tribal and local agencies all have important roles in developing and implementing satisfactory air monitoring programs. EPA's responsibility, under the Clean Air Act (CAA) as amended in 1990, includes: setting National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to the public health and environment; ensuring that these air quality standards are met or attained (in cooperation with States) through national standards and strategies to control air emissions from sources; and ensuring that sources of toxic air pollutants are well controlled. Within the area of quality assurance, the EPA is responsible for developing the necessary tools and guidance so that State and local agencies can effectively implement their monitoring and QA programs. Figure 1.1 represents the primary organizations responsible for the Ambient Air Quality Monitoring Program. The responsibilities of each organization follow.

1.1 Organization Responsibilities

1.1.1 Office of Air Quality Planning and Standards (OAQPS)

OAQPS is the organization charged under the authority of the CAA to protect and enhance the quality of the nation's air resources. OAQPS sets standards for pollutants considered harmful to public health or welfare and, in cooperation with EPA's Regional Offices and the States, enforces compliance with the standards through state implementation plans (SIPs) and regulations controlling emissions from stationary sources. OAQPS evaluates the need to regulate potential air pollutants and develops national standards; works with State and local agencies to develop plans for meeting these standards; monitors national air quality trends and maintains a database of information on air pollution and controls; provides technical guidance and training on air pollution control strategies; and monitors compliance with air pollution standards.

Within the OAQPS Emissions Monitoring and Analysis Division, the Monitoring and Quality Assurance Group (MQAG) is responsible for the oversight of the Ambient Air Quality Monitoring Network. MQAG has the responsibility to:

- ensure that the methods and procedures used in making air pollution measurements are adequate to meet the programs objectives and that the resulting data are of satisfactory quality
- operate the National Performance Audit Program (NPAP)
- evaluate the performance of organizations making air pollution measurements of importance to the regulatory process
- implement satisfactory quality assurance programs over EPA's Ambient Air Quality Monitoring Network

- ensure that guidance pertaining to the quality assurance aspects of the Ambient Air Program are written and revised as necessary
- render technical assistance to the EPA Regional Offices and air pollution monitoring community

In particular to this Handbook, OAQPS will be responsible for:

- coordinating the Steering Committee responsible for continued improvement of the Handbook
- seeking resolution on Handbook issues
- incorporating agreed upon revisions into the Handbook
- reviewing and revising (if necessary) the Handbook (Vol II) every three years

Specific MQAG leads for the various QA activities (e.g, precision and accuracy, training, etc.) can be found within the OAQPS Homepage on the Internet (http://www.epa.gov/oar/oaqps/qa/) and on the AMTIC Bulletin Board under "Points of Contact (QA/QC contacts)"

1.1.2 EPA Regional Offices

EPA Regional Offices have been developed to address environmental issues related to the ~~states~~ within their jurisdiction and to administer and oversee regulatory and congressionally mandated programs.

The major quality assurance responsibilities of EPA's Regional Offices in regards to the Ambient Air Quality Program are the coordination of quality assurance matters between the various EPA offices and the State and local agencies. This role requires that the Regional Offices make available to the State and local agencies the technical and quality assurance information developed by EPA Headquarters and make known to EPA Headquarters the unmet quality assurance needs of the State and local agencies. Another very important function of the Regional Office is the evaluation of the capabilities of State and local agency laboratories to measure the criteria air pollutants. These reviews are accomplished through network reviews and technical systems audits whose frequency is addressed in the Code of Federal Regulations. To be effective in these roles, the Regional Offices must maintain their technical capabilities with respect to air pollution monitoring.

Specific responsibilities as it relates to the Handbook include:

- serving as a liaison to the State and local reporting agencies for their particular Region
- serving on the Handbook Steering Committee
- fielding questions related to the Handbook
- reporting issues that would require Steering Committee attention
- serving as a reviewer of the Handbook and participating in its revision

1.1.3 State and Local Agencies

40 CFR Part 58 defines a State Agency as "the air pollution control agency primarily responsible for the development and implementation of a plan (SIP) under the Act (CAA)". Section 302 of the CAA provides a more detailed description of the air pollution control agency.

40 CFR Part 58 defines the Local Agency as "any local government agency, other than the state agency, which is charged with the responsibility for carrying out a portion of the plan (SIP).

The major responsibility of State and local agencies is the implementation of a satisfactory monitoring program, which would naturally include the implementation of an appropriate quality assurance program. It is the responsibility of State and local agencies to implement quality assurance programs in all phases of the data collection process, including the field, their own laboratories, and in any consulting and contractor laboratories which they may use to obtain data.

Specific responsibilities as it relates to the Handbook include:

- serving as a representative for the State and local agencies on the Handbook Steering Committee
- assisting in the development of QA guidance for various sections
- reporting issues and comments to Regional Contacts or on the AMTIC Bulletin Board

1.1.4 Reporting Organizations

40 CFR Part 58 Appendix A defines a reporting organization as "a State, subordinate organization within a State, or other organization that is responsible for a set of stations that monitor the same pollutant and for which precision or accuracy assessments can be pooled. States must define one or more reporting organization for each pollutant such that each monitoring station in the State SLAMS network is included in one, and only one, reporting organization." Common factors that should be considered by States in defining a reporting organization include:

1. operation by a common team of field operators,
2. common calibration facilities,
3. oversight by a common quality assurance organization, and
4. support by a common laboratory or headquarters.

Reporting organizations are used as one level of aggregation in the evaluation of quarterly and yearly data quality assessments of precision, bias and accuracy.

1.1.5 National Exposure Research Laboratory (NERL)

The mission of NERL is to develop scientific information and assessment tools to improve the Agency's exposure/risk assessments, identify sources of environmental stressors, understand the transfer and transformation of environmental stressors, and develop multi-media exposure models. The NERL provides the following activities:

- develops, improves, and validates methods and instruments for measuring gaseous, semi-volatile, and non-volatile pollutants in source emissions and in ambient air
- supports multi-media approaches to assessing human exposure to toxic contaminated media through development and evaluation of analytical methods and reference materials, and provides analytical and method support for special monitoring projects for trace elements and other inorganic and organic constituents and pollutants
- develops standards and systems needed for assuring and controlling data quality
- assesses whether emerging methods for monitoring criteria pollutants are "equivalent" to accepted Federal Reference Methods and are capable of addressing the Agency's research and regulatory objectives
- provides an independent audit and review function on data collected by NERL or other appropriate clients

Historically, NERL was responsible for the development and maintenance of all five volumes of the Handbook and will continue to assist in the following activities for Handbook Volume II:

- serving on the Steering Committee
- providing overall guidance
- participating in the Handbook review process
- developing and submitting new methods including the appropriate QA/QC

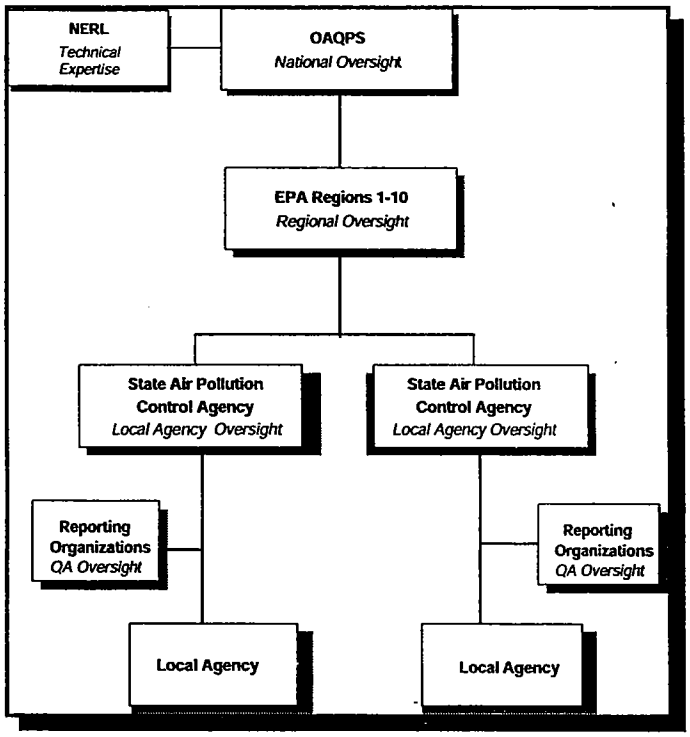


Figure 1.2 Lines of communication

1.2 Lines of Communication

In order to maintain a successful Ambient Air Quality Monitoring Program, effective communication is essential. Figure 1.2 illustrates the lines of communication between the different organizations responsible for this program. The figure represents a general model. Specific lines of communication within an EPA Region may be different as long as it is understood and maintained among all air monitoring organizations. Lines of communication will ensure that decisions can be made at the most appropriate levels in a more time-efficient manner. It also means that each organization in this structure must be aware of the regulations governing the Ambient Air Quality Monitoring Program. Any issues that require a decision, especially in relation to the quality of data, or the quality system, should follow this line. At times, it is appropriate to obtain information from a level higher than the normal lines of communication, as shown by the dashed line from a local agency to the EPA Regional Office. This is appropriate as long as decisions are not made during these information seeking communications. If important decisions are made at various locations along the line, it is important that the information is disseminated in all directions in order that improvements to the quality system can reach all organizations in the Program. Nationwide communication will be accomplished through AMTIC and the subsequent revisions to this Handbook.

1.3 The Handbook Steering Committee

The Handbook Steering Committee is made up of representatives from following four entities in order to provide representation at the Federal, State and local level:

- **OAQPS-** OAQPS is represented by the coordinator for the Handbook and other representatives of the Ambient Air Quality Monitoring QA Team.
- **Regions-** A minimum of 1 representative from each EPA Regional Office.
- **NERL -** A minimum of one representative. NERL represents historical knowledge of the Handbook series as well as the expertise in the reference and equivalent methods program and QA activities.
- **SAMWG -** A minimum of three members from SAMWG who represent State and local air monitoring organizations.

The mission of the committee is to provide a mechanism to meet the goals of the Handbook; which are to provide guidance on quality assurance techniques that can help to ensure that data meet the Ambient Air Quality Monitoring Program objectives and to ensure data comparability across the Nation.

The Steering Committee will meet quarterly to discuss emerging ambient air monitoring issues that have the potential to effect the Handbook. Issues may surface from comments made by State and local agencies to Regional liaisons, AMTIC bulletin board comments, or the development/revision of regulations. The committee will also attempt to meet on an annual basis at a relevant national air meeting. This will provide another forum to elicit comments and suggestions from agencies implementing ambient air monitoring networks.

2. Program Background

2.1 Ambient Air Quality Monitoring Network

The purpose of this section is to describe the general concepts for establishing the Ambient Air Quality Monitoring Network. The majority of this material as well as additional details can be found in the CAA, 40 CFR Part 58[24] and their references.

Between the years 1900 and 1970, the emission of six principal pollutants increased significantly. The principal pollutants, also called criteria pollutants are: particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead. In 1970 the CAA was signed into law. The CAA and its amendments provides the framework for all pertinent organizations to protect air quality.

As illustrated in Figure 2.1, air quality samples are generally collected for one or more of the following objectives:

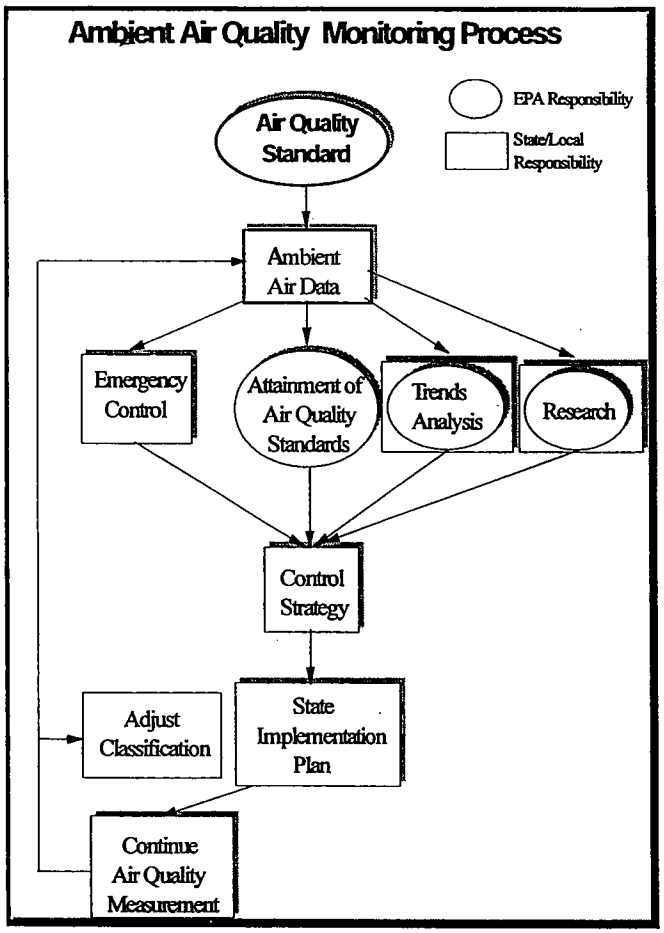


Figure 2.1 Ambient air quality monitoring process

- to judge compliance with and/or progress made towards meeting ambient air quality standards
- to activate emergency control procedures that prevent or alleviate air pollution episodes as well as develop long term control strategies
- to observe pollution trends throughout the region, including non-urban areas
- to provide a data base for research and evaluation of effects: urban, land-use, and transportation planning; development and evaluation of abatement/control strategies; and development and validation of diffusion models

With the end use of the air quality samples as a prime consideration, the network should be designed to:

1. determine the highest concentrations expected to occur in the area covered by the network;
2. determine representative concentrations in areas of high population density;
3. determine the impact on ambient pollution levels of significant sources or source categories;
4. determine the general background concentration levels;

5. determine the extent of regional pollutant transport among populated areas, and in support of secondary standards; and
6. determine the welfare-related impacts in more rural and remote areas (such as visibility impairment and effects on vegetation)

These six objectives indicate the nature of the samples that the monitoring network will collect and will be used during the development of data quality objectives (Section 3). As one reviews the objectives, it becomes apparent that it will be rare that sites can be located to meet more than two or three objectives. Therefore, each organization needs to prioritize their objectives in order to choose the sites that are most representative of that objective and will provide data of adequate quality.

Through the process of implementing the CAA, a number of ambient air quality monitoring networks have been developed. The EPA's Ambient Air Quality Monitoring Program is carried out by State and local agencies and consists of four major categories of monitoring stations or networks that measure the criteria pollutants. These stations are described below.

State and Local Air Monitoring Stations (SLAMS)

The SLAMS consist of a network of ~ 4,000 monitoring stations whose size and distribution is largely determined by the needs of State and local air pollution control agencies to meet their respective state implementation plan (SIP) requirements. The SIPs provide for the implementation, maintenance, and enforcement of the national ambient air quality standards (NAAQS) in each air quality control region within a state.

National Air Monitoring Stations (NAMS)

The NAMS (~1,000 stations) are a subset of the SLAMS network with emphasis being given to urban and multi-source areas. In effect, they are key sites under SLAMS, with emphasis on areas of expected maximum concentrations (category A) and stations which combine poor air quality with high population density (category B). Generally, category B monitors would represent larger spatial scales than category A monitors.

Special Purpose Monitoring Stations (SPMS)

Special Purpose Monitoring Stations provide for special studies needed by the State and local agencies to support SIPs and other air program activities. The SPMS are not permanently established and can be adjusted to accommodate changing needs and priorities. The SPMS are used to supplement the fixed monitoring network as circumstances require and resources permit. If the data from SPMS are used for SIP purposes, they must meet all QA and methodology requirements for SLAMS monitoring.

Photochemical Assessment Monitoring Stations (PAMS)

A PAMS network is required in each ozone non-attainment area that is designated serious, severe, or extreme. The required networks will have from two to five sites, depending on the population of the area. There is a phase-in period of one site per year which started in 1994. The ultimate PAMS network could exceed 90 sites at the end of the 5-year phase-in period.

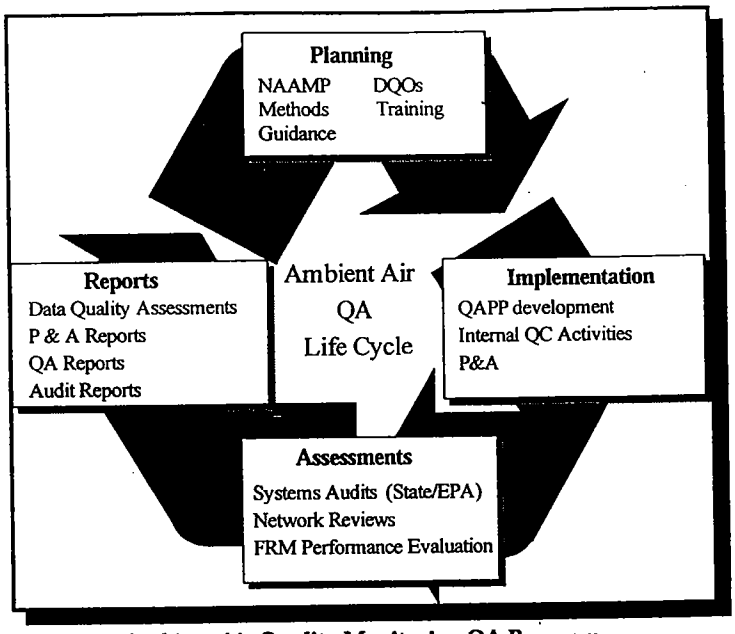


Figure 2.2 Ambient Air Quality Monitoring QA Program

2.2 Ambient Air Monitoring QA Program

Figure 2.2 represents the stages of the Ambient Air Quality Monitoring QA Program. The planning, implementation, assessment and reporting tools will be briefly discussed below.

2.2.1 Planning

Planning activities include:

The National Ambient Air Management Plan (NAAMP) - This is a document that describes how the QA activities that are the responsibility of the EPA Regions and Headquarters will be implemented.

Data Quality Objectives (DQOs) - DQOs are qualitative and quantitative statements derived from the outputs of the DQO Process that: 1) clarify the study objective; 2) define the most appropriate type of data to collect; 3) determine the most appropriate conditions from which to collect the data; and 4) specify tolerable limits on decision errors which will be used as the basis for establishing the quantity and quality of data needed to support the decision. This process is discussed in Section 3.

Methods- Reference methods and measurement principles have been written for each criteria pollutant. Since these methods can not be applied to the actual instruments acquired by each State and local organization, they should be considered as guidance for detailed standard operating procedures that would be developed as part of an acceptable QA project plan.

Training - Training is a part of any good monitoring program. Training activities are discussed in Section 4.

Guidance - This QA Handbook as well as many other guidance documents have been developed for the Ambient Air Quality Monitoring Program. A list of these documents is included in Appendix 2.

2.2.2 Implementation

Implementation activities include:

QA Project Plan (QAPP) Development - Each State and local organization must develop a QAPP. The primary purpose of the QAPP is to provide an overview of the project, describe the need for the measurements, and define QA/QC activities to be applied to the project, all within a single document. The QAPP should be detailed enough to provide a clear description of every aspect of the project and include information for every member of the project staff, including samplers, lab staff, and data reviewers. The QAPP facilitates communication among clients, data users, project staff, management, and external

reviewers. Effective implementation of the QAPP assists project managers in keeping projects on schedule and within the resource budget.

Internal QC Activities - Quality Control (QC) is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; that are used to fulfill requirements for quality[9]. In the case of the Ambient Air Quality Monitoring Network, QC activities are used to ensure that measurement uncertainty is maintained within established acceptance criteria for the attainment of the DQOs.

Federal regulation provides for the implementation of a number of qualitative and quantitative checks to ensure that the data will meet the DQOs. Each of the checks attempts to evaluate phases of measurement uncertainty. Some of these checks are discussed below and in Section 10.

Precision and Accuracy (P & A) Checks - These checks are described in the Code of Federal Regulations[14], as well as a number of sections in this document, in particular, Section 10. These checks can be used to provide an overall assessment of measurement uncertainty.

Zero/Span Checks - These checks provide an internal quality control check of proper operation of the measurement system. These checks are discussed in Section 10 and 12.

Annual Certifications - A certification is the process which ensures the traceability and viability of various QC standards. Standard traceability is the process of transferring the accuracy or authority of a primary standard to a field-usable standard. Traceability protocols are available for certifying a working standard by direct comparison to an NIST-SRM[66 91]. Certification requirements are included in Section 10 as well as the individual methods in Part 2.

Calibrations - Calibrations should be carried out at the field monitoring site by allowing the analyzer to sample test atmospheres containing known pollutant concentrations. Calibrations are discussed in Section 12.

2.2.3 Assessments

Assessment, as defined in *E4*[9], are evaluation processes used to measure the performance or effectiveness of a system and its elements. It is an all inclusive term used to denote any of the following: audit, performance evaluation, management systems review, peer review, inspection, or surveillance. Assessments for the Ambient Air Quality Monitoring Program, as discussed in Section 15, include:

Technical Systems Audits (TSA) -A TSA is an on-site review and inspection of a State or local agency's ambient air monitoring program to assess its compliance with established regulations governing the collection, analysis, validation, and reporting of ambient air quality data. Both EPA and State organizations perform TSAs. Procedures for this audit are included in Appendix 15 and discussed in general terms in Section 16

Network Reviews - The network review is used to determine how well a particular air monitoring network is achieving its required air monitoring objective(s), and how it should be modified to continue to meet its objective(s). Network reviews are discussed in Section 16.

Performance Evaluations- Performance evaluations are a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst , laboratory, or measurement system. The following performance evaluations are included in the Ambient Air Quality Monitoring Program:

State Performance Evaluations (Audits) - These performance evaluation audits are used to provide an independent assessment on the measurement operations of each instrument by comparing performance samples or devices of "known" concentrations or values to the values measured by the instrument. This audit is discussed in Section 16.

NPAP - The goal of the NPAP is to provide audit material and devices that will enable EPA to assess the proficiency of agencies who are operating monitors in the SLAMS, NAMS, PAMS and PSD networks. NPAP samples or devices of "known" concentration or values, but unknown to the audited organization, are compared to the values measured by the audited instrument. This audit is discussed in Section 16.

$PM_{2.5}$ Federal Reference Method (FRM) Performance Evaluation -The FRM Performance Evaluation is a quality assurance activity which will be used to evaluate measurement system bias of the $PM_{2.5}$ monitoring network. The pertinent regulations for this performance evaluation are found in 40 CFR Part 58, Appendix A[14]. The strategy is to collocate a portable FRM $PM_{2.5}$ air sampling instrument with an established routine air monitoring instrument, operate both monitors in exactly the same manner and then compare the results of this instrument against the routine sampler at the site. This evaluation is discussed in Section 16.

2.2.4 Reports

All concentration data will require data assessments to evaluate the attainment of the DQOs, and reports of these assessments or reviews. The following types of reports, as discussed in Section 16, should include:

Data quality assessment (DQA) -is the scientific and statistical evaluation to determine if data are of the right type, quality and quantity to support their intended use (DQOs). QA/QC data can be statistically assessed at various levels of aggregation to determine whether the DQOs have been attained. Data quality assessments of precision, bias and accuracy can be aggregated at the following three levels:

- **Monitor**- monitor/method designation
- **Reporting Organization**- monitors in a method designation, all monitors
- **National** - monitors in a method designation, all monitors

P & A Reports - These reports are generated annually and evaluate the precision and accuracy data against the acceptance criteria discussed in Section 3.

QA Reports - A QA report provides an evaluation of QA/QC data for a given time period to determine whether the data quality objectives were met. Discussions of QA reports can be found in sections 16 and 18.

Meetings and Calls - Various national meetings and conference calls can be used as assessment tools for improving the network. It is important that information derived from the avenues of communication are appropriately documented (annual QA Reports) .

3. Data Quality Objectives

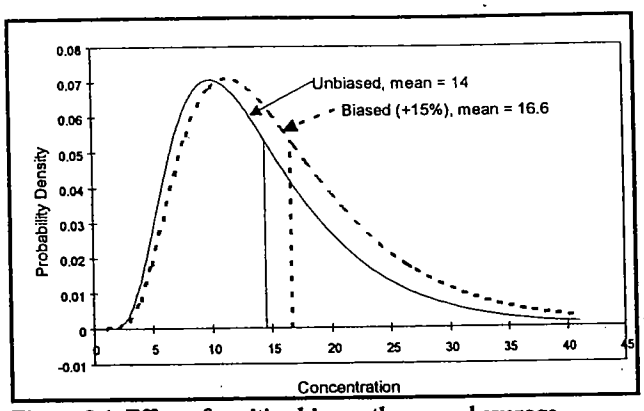


Figure 3.1. Effect of positive biason the annual average estimate, resulting in a false positive decision error

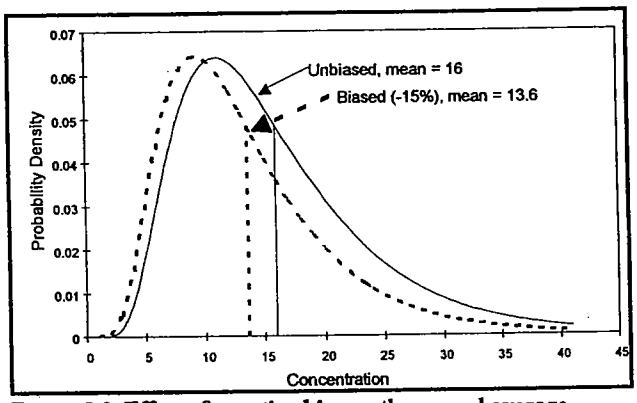


Figure 3.2. Effect of negative bias on the annual average resulting in a false negative decision error

Data collected for the Ambient Air Quality Monitoring Program are used to make very specific decisions that can have an economic impact on the area represented by the data. Data quality objectives (DQOs) are a full set of performance constraints needed to design an environmental data operation (EDO), including a specification of the level of uncertainty that a decision maker (data user) is willing to accept in the data to which the decision will apply. Throughout this document, the term *decision maker* is used. This term represents individuals that are the ultimate users of ambient air data and therefore may be responsible for: setting the NAAQS, developing a quality system, evaluating the data, or declaring an area nonattainment. The DQO will be based on the data requirements of the decision maker. Decision makers need to feel confident that the data used to make environmental decisions are of adequate quality. The data used in these decisions are never error free and always contain some level of uncertainty. Because of these uncertainties or errors, there is a possibility that decision makers may declare an area "nonattainment" when the area is actually in "attainment" (false positive error) or "attainment" when actually the area is in "nonattainment" (false negative error). Figures 3.1 and 3.2 illustrate how false positive and negative errors can affect a NAAQS attainment/nonattainment decision based on an annual mean concentration value of 15. There are serious political, economic and health consequences of making such decision errors. Therefore, decision makers need to understand and set limits on the probabilities of making incorrect decisions with these data.

In order to set probability limits on decision errors, one needs to understand and control uncertainty. Uncertainty is used as a generic term to describe the sum of all sources of error associated with an EDO. Uncertainty can be illustrated as follows:

$$S_o^2 = S_p^2 + S_m^2 \qquad \text{(equation 1)}$$

Where:

S_o= overall uncertainty
S_p= population uncertainty (spatial and temporal)
S_m= measurement uncertainty (data collection)

The estimate of overall uncertainty is an important component in the DQO process. Both population and measurement uncertainties must be understood.

Population uncertainties - The most important data quality attribute of any ambient air monitoring network is representativeness. This term refers to the degree in which data accurately and precisely represent a characteristic of a population, parameter variation at a sampling point, a process condition, or an environmental condition[9]. Population uncertainty, the spatial and temporal components of error, can effect representativeness. These uncertainties can be controlled through the selection of appropriate boundary conditions (the area and the time period) to which the decision will apply, and the development of a proper statistical sampling design (see Section 6). Appendix H of the QAD document titled *EPA Guidance for Quality Assurance Project Plans*[32] provides a very good dissertation on representativeness. It does not matter how precise or unbiased the measurement values are if a site is unrepresentative of the population it is presumed to represent. Assuring the collection of a representative air quality sample depends on the following factors:

- selecting a network size that is consistent with the monitoring objectives and locating representative sampling sites
- determining restraints on the sampling sites that are imposed by meteorology, local topography, emission sources, and the physical constraints and documenting these
- planning sampling schedules that are consistent with the monitoring objectives

Measurement uncertainties are the errors associated with the EDO, including errors associated with the field, preparation and laboratory measurement phases. At each measurement phase, errors can occur, that in most cases, are additive. The goal of a QA program is to control measurement uncertainty to an acceptable level through the use of various quality control and evaluation techniques. In a resource constrained environment, it is most important to be able to calculate/evaluate the total measurement system uncertainty (S_m) and compare this to the DQO. If resources are available, it may be possible to evaluate various phases (field, laboratory) of the measurement system.

Three data quality indicators are most important in determining total measurement uncertainty:

- **Precision** - a measure of mutual agreement among individual measurements of the same property usually under prescribed similar conditions. This is the random component of error. Precision is estimated by various statistical techniques using some derivation of the standard deviation.

- **Bias** - the systematic or persistent distortion of a measurement process which causes error in one direction. Bias will be determined by estimating the positive and negative deviation from the true value as a percentage of the true value.

- **Detectability** - The determination of the low range critical value of a characteristic that a method specific procedure can reliably discern.

Accuracy has been a term frequently used to represent closeness to "truth" and includes a combination of precision and bias error components. This term has been used throughout the CFR and in some of the sections of this document. If possible, it is recommended that an attempt be made to distinguish measurement uncertainties into precision and bias components.

3.1 The DQOs Process

The DQO process is used to facilitate the planning of EDOs. It asks the data user to focus their EDO efforts by specifying the use of the data (the decision), the decision criteria, and the probability they can accept making an incorrect decision based on the data. The DQO process:

- establishes a common language to be shared by decision makers, technical personnel, and statisticians in their discussion of program objectives and data quality
- provides a mechanism to pare down a multitude of objectives into major critical questions
- facilitates the development of clear statements of program objectives and constraints which will optimize data collection plans
- provides a logical structure within which an iterative process of guidance, design, and feedback may be accomplished efficiently

The DQO process contains the following steps:

- the problem to be resolved
- the decision
- the inputs to the decision
- the boundaries of the study
- the decision rule
- the limits on uncertainty
- study design optimization

The DQO Process is fully discussed in the document titled *Guidance for the Data Quality Objectives Process EPA QA/G4*[39], and is available on the EPA QA Division Homepage *(http://es.epa.gov/ncerqa/qa/)*. The EPA QA Division also provides a software program titled *Data Quality Objectives (DQO) Decision Error Feasibility Trials (DEFT)*. This software can help individuals develop appropriate sampling designs based upon the outputs of the DQO Process.

3.2 Ambient Air Quality DQOs

As indicated above, the first step in the DQO process is to identify the problems that need to be resolved. The objectives (problems) of the Ambient Air Quality Monitoring Program as mentioned in Section 2 are:

1. To judge compliance with and/or progress made towards meeting the NAAQS.
2. To activate emergency control procedures that prevent or alleviate air pollution episodes as well as develop long term control strategies.
3. To observe pollution trends throughout the region, including non-urban areas.
4. To provide a data base for research and evaluation of effects: urban, land-use, and transportation planning; development and evaluation of abatement/control strategies; and development and validation of diffusion models.

These different objectives could potentially require different DQOs, making the development of DQOs complex. However, if one were to establish DQOs based upon the objective requiring the most stringent data quality requirements, one could assume that the other objectives could be met. Therefore, the DQOs have been initially established based upon ensuring that decision makers can make attainment/nonattainment decisions in relation to the NAAQS within a specified degree of certainty.

Appendix 3 will eventually contain information on the DQO process for each criteria pollutant. Since the Ambient Air Quality Monitoring Network was established prior to the development of the DQO Process, a different technique was used to establish data quality acceptance levels[27]. Therefore, all criteria pollutants are being reviewed in order to establish DQOs using the current DQO process.

3.3 Measurement Quality Objectives

Once a DQO is established, the quality of the data must be evaluated and controlled to ensure that it is maintained within the established acceptance criteria. Measurement quality objectives are designed to evaluate and control various phases (sampling, preparation, analysis) of the measurement process to ensure that total measurement uncertainty is within the range prescribed by the DQOs. MQOs can be defined in terms of the following data quality indicators:

Precision - defined above

Bias - defined above.

Representativeness - defined above

Detectability- defined above

Completeness - a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions. Data completeness requirements are included in the reference methods (40 CFR Pt. 50).

Comparability - a measure of confidence with which one data set can be compared to another.

For each of these attributes, acceptance criteria can be developed for various phases of the EDO. Various parts of 40 CFR [21-24] have identified acceptance criteria for some of these attributes. In theory, if these MQOs are met, measurement uncertainty should be controlled to the levels required by the DQO. Tables of the most critical MQOs can be developed. Table 3-1 is an example of an MQO table for carbon monoxide. MQO tables for the remaining criteria pollutants can be found in Appendix 3.

Table 3-1 Measurement Quality Objectives - Parameter CO

Measurement Quality Objectives - Parameter CO (Nondispersive Infrared Photometry)				
Requirement	**Frequency**	**Acceptance Criteria**	**Reference**	**Information/Action**
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.8	
Shelter Temperature **Temperature range** **Temperature control**	Daily Daily	20 to 30 C. < ± 2 C	40 CFR, Pt. 53.20 Vol II, S 7.1 [1/]	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dewpoint. Shelter should have a 24- hour temperature recorder.Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Equipment CO analyzer Flow controllers Flowmeters	Purchase specification	Reference or equivalent method Flow rate regulated to ± 1% Accuracy ± 2%	40 CFR, Pt 50, App C " "	
Detection Limit Noise Lower detectable level	Purchase specification	0.5 ppm 1.0 ppm	40 CFR, Pt 53.20 & 23 "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria.
Completeness 8-hour average	hourly	75 % of hourly averages for the 8-hour period	40 CFR, Pt 50.8	
Compressed Gases Dilution gas (zero air) Gaseous standards	Purchase specification Purchase specification	< 0.1 ppm CO NIST Traceable (e.g., EPA Protocol Gas)	40 CFR, Pt 50, App C " EPA-600/R97/12	Return cylinder to supplier. Carbon monoxide in nitrogen or air EPA Protocol Gases have a 36-month certification period and must be recertified to extend the certification.

Measurement Quality Objectives - Parameter CO (Nondispersive Infrared Photometry)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Calibration Multipoint calibration (at least 5 points)	Upon receipt, adjustment, or 1/ 6 months	All points within ± 2% of full scale of best-fit straight line	Vol II, S 12.6 Vol II, MS.2.6.1	Zero gas and at least four upscale calibration points. Points outside acceptance criterion are repeated. If still outside criterion, consult manufacturers manual and invalidate data to last acceptable calibration.
Zero/span check-level 1	1/ 2 weeks	Zero drift ± 2 to 3 ppm Span drift ± 20 to 25 %	Vol II, S 12.6 "	**If calibration updated at each zero/span**, invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration.
		Zero drift ± 1 to 1.5 ppm Span drift ± 15%	Vol II, S 12.6 "	**If fixed calibration used to calculate data**, invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration.
Flowmeters	1/3 months	Accuracy ± 2 %	Vol II, App 12	Flowmeter calibration should be traceable to NIST standards.
Performance Evaluation (NPAP)	1/year at selected sites	Mean absolute difference 15%	Vol II, S 16.3	Use information to inform reporting agency for corrective action and technical systems audits
State audits	1 /year	State requirements	Vol II, pp 15, S 3	
Precision Single analyzer Reporting organization	½ weeks 1/3 months	None 95% CI ± 15%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 5	Concentration = 8 to 10 ppm. Aggregation of a quarters measured precision values.
Accuracy **Single analyzer** **Reporting organization**	25 % of sites quarterly (all sites yearly)	None 95% CI ± 20%	40 CFR, Pt 58, App A	Four concentration ranges. If failure, recalibrate and reanalyze. Repeated failure requires corrective action.

1/ - reference refers to the QA Handbook for Air Pollution Measurement Systems Volume II . The use of "S" refers to sections within the handbook. The use of "MS" refers to sections of the method for the particular pollutant.

4. Personnel Qualifications, Training and Guidance

4.1 Personnel Qualifications

Personnel assigned to ambient air monitoring activities are expected to have met the educational, work experience, responsibility, personal attributes and training requirements for their positions. In some cases, certain positions may require certification and or recertification. These requirements should be outlined in the position advertisement and in personal position descriptions. Records on personnel qualifications and training should be maintained and should be accessible for review during audit activities. These records should be retained as described in Section 5.

4.2 Training

Adequate education and training are integral to any monitoring program that strives for reliable and comparable data. Training is aimed at increasing the effectiveness of employees and their organization. As part of a quality assurance program, 40 CFR Part 58 App A[14] requires the development of operational procedures for training. These procedures should include information on:

- personnel qualifications- general and position specific
- training requirements - by position
- frequency of training

Appropriate training should be available to employees supporting the Ambient Air Quality Monitoring Program, commensurate with their duties. Such training may consist of classroom lectures, workshops, teleconferences and on-the-job training.

4.2.1 Suggested Training

Over the years, a number of courses have been developed for personnel involved with ambient air monitoring and quality assurance aspects. Formal QA/QC training is offered through the following organizations:

- Air Pollution Training Institute (APTI) *http://www.epa.gov/oar/oaq.apti.html*
- Air & Waste Management Association (AWMA) *http://www2.awma.org*
- American Society for Quality Control (ASQC) *http://www.asqc.org/products/educat.html*
- EPA Institute
- EPA Quality Assurance Division (QAD) *http://es.epa.gov/ncerqa/qa/*
- EPA Regional Offices

In addition, OAQPS uses contractors and academic institutions to develop and provide training for data collection activities that support regulatory efforts throughout OAQPS, as well as the States and Regions. The OAQPS QA Program maintains a list of available courses.

Table 4-1 provides a suggested sequence of core QA-related ambient air monitoring courses for ambient air monitoring staff, and QA managers (marked by asterisk). The suggested course sequences assume little or no experience in QA/QC or air monitoring. Persons having experience in the subject matter described in the

courses would select courses according to their appropriate experience level. Courses not included in the core sequence would be selected according to individual responsibilities, preferences, and available resources.

Table 4-1. Suggested Sequence of Core QA-related Ambient Air Training Courses for Ambient Air Monitoring and QA Personnel

Sequence	Course Title (SI = self instructional)	Source
1*	Air Pollution Control Orientation Course (Revised), SI:422	APTI
2*	Principles and Practices of Air Pollution Control, 452	APTI
3*	Orientation to Quality Assurance Management	QAD
4*	Introduction to Ambient Air Monitoring (Under Revision 7/98), SI:434	APTI
5*	General Quality Assurance Considerations for Ambient Air Monitoring (Under Revision 9/98), SI:471	APTI
6*	Quality Assurance for Air Pollution Measurement Systems (Under Revision 8/98), 470	APTI
7*	Data Quality Objectives Workshop	QAD
8*	Quality Assurance Project Plan	QAD
9	Atmospheric Sampling (Under Revision 7/98), 435	APTI
10	Analytical Methods for Air Quality Standards, 464	APTI
11	Chain Of Custody Procedures for Samples and Data, SI:443	APTI
*	Data Quality Assessment	QAD
*	Management Systems Review	QAD
*	Beginning Environmental Statistical Techniques (Revised), SI:473A	APTI
*	Introduction to Environmental Statistics, SI:473B	APTI
*	Quality Audits for Improved Performance	AWMA
*	Statistics for Effective Decision Making	ASQC

* Courses recommended for QA Managers

4.3 Regulations and Guidance

Information on the proper implementation of the Ambient Air Quality Monitoring QA Program has been developed at three levels, as indicated in Figure 4.1. The top two levels (shaded) provide standards, regulations and guidance that form the basis for implementation documents for specific projects. A discussion of the information in these levels follow.

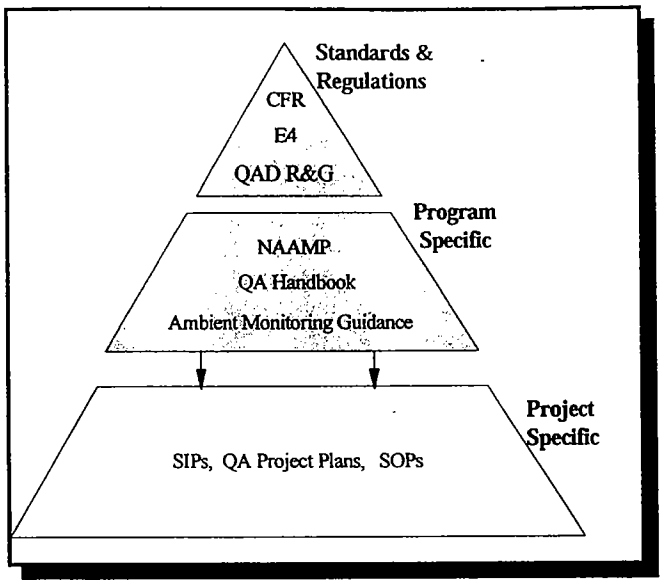


Figure 4.1 Hierarchy of regulations and guidance

4.3.1 Standards and Regulations

At the highest level, standards and regulations determine what QA is required for the monitoring program and therefore sets the stage for program and project specific guidance. The standards and regulations pertinent to the Ambient Air Quality Monitoring Program include:

CFR - The CFR series provides the mandate for monitoring and the minimum requirements for the quality system. It also requires the development of QA Project Plans for any environmental data operations.

E4 - E4 refers to the document *American National Standard-Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs (ANSI/ASQC E4-1994)*[9]. This document describes a basic set of mandatory specifications and non-mandatory guidelines by which a quality system for programs involving environmental data collection can be planned, implemented, and assessed. The EPA QA Order (5360.1 CHG 1) adheres to E4 under the authority of the Office of Management and Budget.

QAD guidance and regulations- QAD refers to the EPA QA Division, the organization within the EPA that is responsible for the "Mandatory QA Program". QAD is responsible for developing QA and QC requirements and for overseeing Agency-wide implementation of the EPA Quality System. QAD has developed a series of regulation/guidance documents that describe how to plan implement and assess environmental data operations. Figure 4.2 describes the documents and the stages in the EDO in which they apply. Many of these documents and can be downloaded from the Internet *(http://es.epa.gov/ncerqa/qa/)*.

4.3.2 Program Specific Guidance

Based upon the standards and regulations, the Office of Air Quality Planning and Standards, ORD, and other organizations implementing air monitoring have developed guidance specific to the Ambient Air Quality Monitoring Program. This Handbook provides the majority of the guidance necessary for the State and local agencies to develop QA project plans specific to their data collection needs. Other guidance has been developed specific to a part of the measurement system (i.e., calibration techniques) or to specific methods. A listing of this guidance is included in Appendix 2. It is anticipated that the majority of these documents will be available through the Internet, most likely on the AMTIC bulletin board

4.3.3 Project Specific

The term "project specific" refers to the environmental data operations that occur at each State and local organization operating a monitoring network. An environmental data operation refers to the work performed to obtain, use, or report information pertaining to environmental processes and conditions[9].

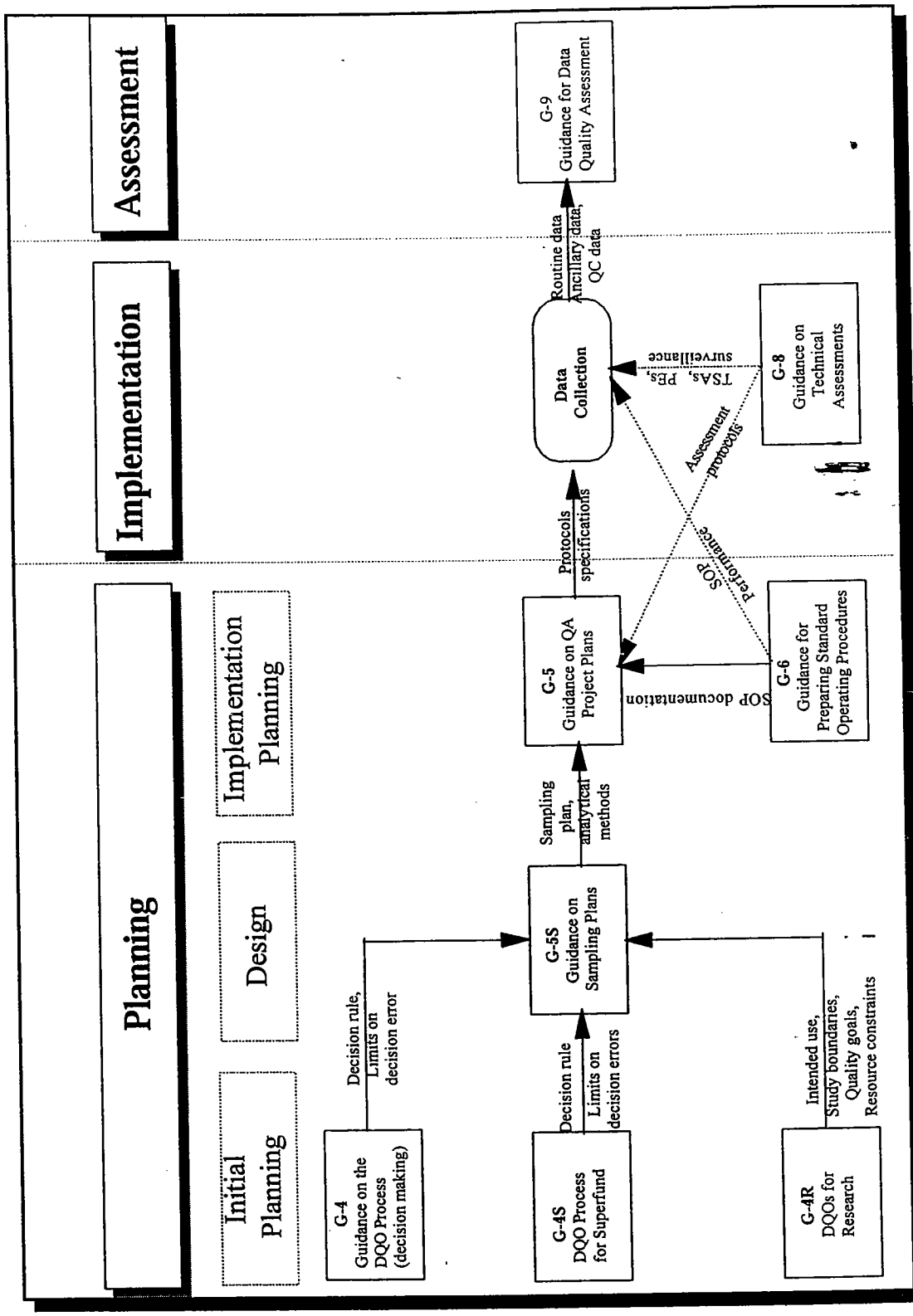


Figure 4.2 EPA QA Division Guidance Documents

5. Documentation and Records

Organizations that perform EDOs and management activities must establish and maintain procedures for the timely preparation, review, approval, issuance, use, control, revision and maintenance of documents and records. A document, from a records management perspective, is a volume that contains information which describes, defines, specifies, reports, certifies, or provides data or results pertaining to environmental programs. As defined in the Federal Records Act of 1950 and the Paperwork Reduction Act of 1995 (now 44 U.S.C. 3101-3107), records are: "...books, papers, maps, photographs, machine readable materials, or other documentary materials, regardless of physical form or characteristics, made or received by an agency of the United States Government under Federal Law or in connection with the transaction of public business and preserved or appropriate for preservation by that agency or its legitimate successor as evidence of the organization, functions, policies, decisions, procedures, operations, or other activities of the Government or because of the informational value of data in them.... " This section will provide guidance of documentation and records for the Ambient Air Quality Monitoring Program.

Table 5-1 Types of Information that Should be Retained Through Document Control

Categories	Record/Document Types
Management and Organization	State Implementation Plan Reporting agency information Organizational structure of monitoring program Personnel qualifications and training Quality management plan Document control plan Support contracts
Site Information	Network description Site characterization file Site maps/pictures
Environmental Data Operations	QA Project Plans Standard operating procedures (SOPs) Field and laboratory notebooks Sample handling/custody records Inspection/maintenance records
Raw Data	Any original data (routine and QC)
Data Reporting	Air quality index report Annual SLAMS air quality information Data/summary reports Journal articles/papers/presentations
Data Management	Data algorithms Data management plans/flowcharts
Quality Assurance	Control charts Data quality assessments QA reports System audits Network reviews

Table 5-1 represents the categories and types of records and documents which are applicable to document control. Information on key documents in each category follow. It should be noted that the list contains documents that may not be applicable to particular organizations and therefore is not meant to be a list of required documentation. This list should also not be construed as the definitive list of record and document types.

Statute of Limitations -

As stated in 40 CFR part 31.42, in general, all information considered as documentation and records should be retained for 3 years from the date the grantee submits its final expenditure report unless otherwise noted in the funding agreement. However, if any litigation, claim, negotiation, audit or other action involving the records has been started before the expiration of the 3-year period, the records must

be retained until completion of the action and resolution of all issues which arise from it, or until the end of the regular 3-year period, whichever is later.

Management and Organization

Documentation for many of the document types listed in Table 5-1 for this category can be found in a single document, a quality management plan, which is a blueprint for how an organizations quality management objectives will be attained. The EPA QA Division provides requirements for quality management plans that State and local organizations may find helpful[33].

Site Information

Site information provides vital data about each monitoring site. Historical site information can help determine and evaluate changes in measurement values at the site. The quality assurance project plan should include specific documentation of site characteristics for each monitoring station. This information will assist in providing objective inputs into the evaluation of data gathered at that site. Typically, the site identification record should include:

1. Data acquisition objective (e.g., air quality standards monitoring).
2. Station type.
3. Instrumentation checklist (manufacturer's model number, pollutant measurement technique, etc.).
4. Sampling system.
5. Spatial scale of the station (site category--i.e., urban/industrial, suburban/commercial, etc.; physical location--i.e., address, AQCR, UTM coordinates, etc.).
6. Influential pollutant sources (point and area sources, proximity, pollutant density, etc.).
7. Topography (hills, valleys, bodies of water, trees; type and size, proximity, orientation, etc. picture of a 360° view from the probe of the monitoring site).
8. Atmospheric exposure (unrestricted, interferences, etc.).
9. Site diagram (sample flowsheet, service lines, equipment configuration, etc.).
10. Site audits.

Environmental Data Operations

A quality assurance program associated with the collection of ambient air monitoring data must include an effective procedure for preserving the integrity of the data. Ambient air test results and, in certain types of tests, the sample itself may be essential elements in proving the compliance status of a facility; that is, it may be necessary to introduce the sample or the test results as evidence in an enforcement proceeding. These will not be admitted as evidence unless it can be shown that they are representative of the conditions that existed at the time that the test was conducted. Therefore, each step in the testing and analysis procedure must be carefully monitored and documented. There are basically four elements in the evidentiary phase of an overall quality assurance program:

1. Data collection - includes testing, preparation and identification of the sample, strip charts, or other data.
2. Sample handling - includes protection from contamination and tampering during transfer between individuals and from the sampling site to the evidence locker (i.e., chain of custody).
3. Analysis - includes storage of samples prior to and after analysis as well as data interpretation.
4. Preparation and filing of test report - includes evidentiary requirements and retention of records.

Failure to include any one of these elements in the collection and analysis of ambient air monitoring data may render the results of the program inadmissible as evidence, or may seriously undermine the credibility of any report based on these data.

Environmental data operations include all the operations required to successfully measure and report a value within the data quality objectives. Documentation for environmental data operations would include:

- **QA Project Plans** - Documents how environmental data operations are planned, implemented, and assessed during the life cycle of a program, project, or task[32,34]. See below.
- **Standard operating procedures (SOPs)**-Written documents that detail the method for an operation, analysis, or action with thoroughly prescribed techniques and steps[42]. See Section 9 and below.
- **Field and laboratory notebooks**- Any documentation that may provide additional information about the environmental data operation (e.g., calibration notebooks, temperature records, site notes, maintenance records etc.). See below
- **Sample handling/custody records**- Records tracing sample handling from the site through analysis, including transportation to facilities, sample storage, and handling between individuals within facilities. Section 12 provides more information on this activity.

Quality Assurance Project Plans--

As mentioned in the assistance agreement sections of 40 CFR parts 30.54 (Non-State an Local Gov.) and 31.45 (State and Local Gov.) quality assurance programs must be established. In addition to the grant requirements, 40 CFR Part 58 Appendix A[14] states that each quality assurance program must be described in detail in accordance with the *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations*[34].

Standard operating procedures--

Standard operating procedures are written documents that detail the method for an operation, analysis, or action with thoroughly prescribed techniques and steps. It is officially approved as the method for all routine activities, especially those that are involved in the environmental data operations, which generally involve repetitious operations performed in a consistent manner. SOPs should be written by individuals performing the procedures that are being standardized. Individuals with appropriate training and experience with the process need to review the SOPs, and the SOPs should be approved by the supervisor of the personnel responsible for writing the document. For documentation purposes, the approving official should sign and date the title page of the SOP. More details of SOPs are discussed in Section 9

Field and Laboratory Notebooks–

Manual recording of data are sometimes required for ambient air tests. Standardized forms should be utilized to ensure that all necessary information is obtained. These forms should be designed to clearly identify the process tested, the date and time, location of the test station, and operating personnel. This information may determine the credibility of the data and should not be erased or altered. Any errors should be crossed out with a single line, and the correct value recorded above the crossed-out number.

Do not discard original field records; copies are not normally admissible as evidence. For neatness, the field data may be transcribed or copied for incorporation in a final report, but the originals should be kept on file. Since these records may be subpoenaed, it is important that all field notes be legible.

Raw Data

Raw data includes any original factual information from a measurement activity or study recorded in laboratory work sheets, records, memoranda, notes, or exact copies thereof and that are necessary for the reconstruction and evaluation of the report of the activity or study. Raw data may include photographs, microfilm or microfiche copies, computer printouts, magnetic media, including dictated observations, and recorded data from automated instruments. For automated information systems, raw data is considered the original observations recorded by the information system that are needed to verify, calculate, or derive data that are or may be reported. Organizations should critically review the Ambient Air Quality Monitoring Program and create a list of what the organization considers raw data and provide a means to store this information in a manner that is readily accessible.

Data Reporting

In addition to samples and field records, the report of the analysis itself may serve as material evidence. Just as the procedures and data leading up to the final report are subject to the rules of evidence, so is the report. Written documents, generally speaking, are considered as hearsay, and are not admissible as evidence without a proper foundation. A proper foundation consists of introducing testimony from all persons having anything to do with the major portions of the test and analysis. Thus the field operator, all persons having custody of the samples, and the analyst would be required to lay the foundation for the introduction of the test report as evidence.

To ensure compliance with legal rules, all test reports should be filed in a safe place by a custodian having this responsibility. Although the field notes and calculations are not generally included in the summary report, these materials may be required at a future date to bolster the acceptability and credibility of the report as evidence in an enforcement proceeding. Therefore, the full report including all original notes and calculation sheets should be kept in the file. Signed receipts for all samples, strip charts, or other data, should also be filed.

The original of a document is the best evidence, and a copy is not normally admissible as evidence. Microfilm, snap-out carbon copies, and similar contemporary business methods of producing copies are acceptable in many jurisdictions if unavailability of the original is adequately explained and if the copy was made in the ordinary course of business.

In summary, although all original calculations and test data need not be included in the final report, they should be kept in the agency's files. It is a good rule to file all reports together in a secure place. Keeping these documents under lock and key will ensure that the author can testify at future court hearings that the report has not been altered.

Data Management

Much of the data collected for the Ambient Air Quality Monitoring Program will be collected through the use of automated systems. These systems must be effectively managed and documented by using a set of

guidelines and principles by which adherence will ensure data integrity. Discussions of data management activities and the requirements for documentation can be found in section 15.

Quality Assurance

Quality assurance information is necessary to document the quality of data. This information should be retained in a manner that it can be associated with the routine data that it represents. QA Information include:

- **Control charts** - Use of control charts is explained in section 12.
- **Data quality assessments (DQAs)**- These assessments are a statistical and scientific evaluation of the data set to determine the validity and performance of the data collection design and to determine the adequacy of the data set for its intended use. Further discussion on DQAs can be found in section 16.
- **Quality Reports** - Reports pertaining to the quality of data, usually related to some aggregate (quarterly, yearly etc.) focusing on measurement quality attributes and data quality objectives, are discussed in Sections 3 and 18.
- **Evaluation/Audits**- Assessments of various phases of the environmental data operation are discussed in section 16.

6. Sampling Process Design

The selection of a specific monitoring site includes four major activities :

1. Developing and understanding the monitoring objective and appropriate data quality objectives.
2. Identifying the spatial scale most appropriate for the monitoring objective of the site.
3. Identifying the general locations where the monitoring site should be placed.
4. Identifying specific monitoring sites.

This section describes the general concepts for establishing the State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), Photochemical Assessment Monitoring Stations (PAMS), and open path monitoring. Additional details can be found in 40 CFR Part 58[23] and the *PAMS Implementation Manual*[77].

Air quality samples are generally collected for one or more of the following purposes:

- to judge compliance with and/or progress made towards meeting ambient air quality standards
- to activate emergency control procedures that prevent or alleviate air pollution episodes
- to observe pollution trends throughout the region, including nonurban areas
- to provide a data base for research evaluation of effects: urban, land-use, and transportation planning; development and evaluation of abatement strategies; and development and validation of diffusion models

Compliance Monitoring

The information required for selecting the number of samplers and the sampler locations include isopleth maps, population density maps, and source locations. The following are suggested guidelines:

- the priority area is the zone of highest pollution concentration within the region; one or more stations are to be located in this area
- close attention should be given to densely populated areas within the region, especially when they are in the vicinity of heavy pollution
- the quality of air entering the region is to be assessed by stations situated on the periphery of the region; meteorological factors (e.g., frequencies of wind directions) are of primary importance in locating these stations
- sampling should be undertaken in areas of projected growth to determine the effects of future development on the environment
- a major objective of surveillance is evaluation of progress made in attaining the desired air quality; for this purpose, sampling stations should be strategically situated to facilitate evaluation of the implemented control tactics
- some information of air quality should be available to represent all portions of the regions

Some stations will be capable of fulfilling more than one of the functions indicated; for example, a station located in a densely populated area can indicate population exposures and can also document the changes in pollutant concentrations resulting from mitigation strategies used in the area.

Emergency Episode Monitoring

For episode avoidance purposes, data are needed quickly--in no less than a few hours after the pollutant contacts the sensor. While it is possible to obtain data rapidly by on-site manual data reduction and telephone reporting, there is a trend towards using automated monitoring networks. The severity of the problem, the size of the receptor area, and the availability of resources all influence both the scope and sophistication of the monitoring system.

It is necessary to use continuous air samplers because of the short durations of episodes and the control actions taken must be based on real-time measurements that are correlated with the decision criteria. Based on episode alert criteria and mechanisms now in use, 1-h averaging times are adequate for surveillance of episode conditions. Shorter averaging times provide information on data collecting excursions, but they increase the need for automation because of the bulk of data obtained. Longer averaging times (>6 hours) are not desirable because of the delay in response that these impose. After an alert is announced, data are needed quickly so that requests for information on the event can be provided.

Collection and analysis must be accomplished rapidly if the data are to be useful immediately. Collection instruments must be fully operable at the onset of an episode. For the instrument to be maintained in peak operating condition, either personnel must be stationed at the sites during an episode or automated equipment must be operated that can provide automatic data transmission to a central location.

Monitoring sites should be located in areas where human health and welfare are most threatened:

- in densely populated areas
- near large stationary sources of pollution
- near hospitals
- near high density traffic areas
- near homes for the aged

A network of sites is useful in determining the range of pollutant concentrations within the area, but the most desirable monitoring sites are not necessarily the most convenient. Public buildings such as schools, firehouses, police stations, hospitals, and water or sewage plants should be considered for reasons of access, security and existing communications.

Trends Monitoring

Trends monitoring is characterized by locating a minimal number of monitoring sites across as large an area as possible while still meeting the monitoring objectives. The program objective is to determine the extent and nature of the air pollution and to determine the variations in the measured levels of the atmospheric contaminants in respect to the geographical, socio-economic, climatological and other factors. The data are useful in planning epidemiological investigations and in providing the background against which more intensive community and statewide studies of air pollution can be conducted.

Urban sampling stations are usually located in the most densely populated areas of the region. In most regions, there are several urban sites. Non-urban stations encompass various topographical categories such as farmland, desert, forest, mountain and coast. Non-urban stations are not selected specifically to be "clean air" control sites for urban areas, but they do provide a relative comparison between some urban and nearby non-urban areas.

In interpreting trends data, limitations imposed by the network design must be considered. Even though precautions are taken to ensure that each sampling site is as representative as possible of the designated area, it is impossible to be certain that measurements obtained at a specific site are not unduly influenced by local factors. Such factors can include topography, structures, sources of pollution in the immediate vicinity of the site, and other variables; the effects which cannot always be accurately anticipated, but nevertheless, should be considered in network design. Comparisons among pollution levels for various areas are valid only if the sites are representative of the conditions for which the study is designed.

Research Monitoring

Air monitoring networks related to health effects are composed of integrating samplers both for determining pollutant concentrations for $\leq$ 24 hours and for developing long term ($\geq$ 24 hour) ambient air quality standards. The research requires that monitoring points be located so that the resulting data will represent the population group under evaluation. Therefore, the monitoring stations are established in the centers of small well-defined residential areas within a community. Data correlations are made between observed health effects and observed air quality exposures.

Requirements for aerometric monitoring in support of health studies are as follows:

- the station must be located in or near the population under study
- pollutant sampling averaging times must be sufficiently short to allow for use in acute health effect studies that form the scientific basis for short-term standards
- sampling frequency, usually daily, should be sufficient to characterize air quality as a function of time
- the monitoring system should be flexible and responsive to emergency conditions with data available on short notice

6.1. Monitoring Objectives and Spatial Scales

With the end use of the air quality samples as a prime consideration, the SLAMS/NAMS networks should be designed to determine one of six basic monitoring objectives listed below:

1. Highest concentrations expected to occur in the area covered by the network.
2. Representative concentrations in areas of high population density.
3. Impact on ambient pollution levels of significant sources or source categories.
4. General background concentration levels.
5. Extent of regional pollutant transport among populated areas, and in support of secondary standards.
6. Welfare-related impacts in more rural and remote areas.

These six objectives indicate the nature of the samples that the monitoring network will collect which must be representative of the spatial area being studied. In the case of PAMS, the design criteria are site specific, and therefore, there are specific monitoring objectives associated with each location for which PAMS stations are required (see Table 6-4).

Sampling equipment requirements are generally divided into three categories, consistent with the desired averaging times:

1. **Continuous**- Pollutant concentrations determined with automated methods, and recorded or displayed continuously.
2. **Integrated**- Pollutant concentrations determined with manual or automated methods from integrated hourly or daily samples on a fixed schedule.
3. **Static**- Pollutant estimates or effects determined from long-term (weekly or monthly) exposure to qualitative measurement devices or materials.

Air monitoring sites that use automated equipment to continually sample and analyze pollutant levels may be classified as primary. Primary monitoring stations are generally located in areas where pollutant concentrations are expected to be among the highest and in areas with the highest population densities; thus, they are often used in health effects research networks. These stations are also designed as part of the air pollution episode warning system.

The goal in siting stations is to correctly match the spatial scale represented by the sample of monitored air with the spatial scale most appropriate for the monitoring objective of the station. The representative measurement scales of greatest interest are shown below:

Micro	Concentrations in air volumes associated with area dimensions ranging from several meters up to about 100 meters
Middle	Concentrations typical of areas up to several city blocks in size with dimensions ranging from about 100 meters to 0.5 kilometer
Neighborhood	Concentrations within some extended area of the city that has relatively uniform land use with dimensions in the 0.5 to 4.0 kilometers range
Urban	Overall, citywide conditions with dimensions on the order of 4 to 50 kilometers. This scale would usually require more than one site for definition
Regional	Usually a rural area of reasonably homogeneous geography and extends from tens to hundreds of kilometers
National/Global	Concentrations characterizing the nation and the globe as a whole

Table 6-1 illustrates the relationships among the four basic monitoring objectives and the scales of representativeness that are generally most appropriate for that objective. Appendix 6-A provides more detailed spatial characteristics for each pollutant while Table 6-2 provides a summary for SLAMS, NAMS, PAMS and open path sites.

Table 6-1 Relationship Among Monitoring Objectives and Scales of Representativeness

Monitoring Objective	Appropriate Siting Scale
Highest Concentration	Micro, middle, neighborhood, sometimes urban
Population	Neighborhood, urban
Source impact	Micro, middle, neighborhood
General/background	Neighborhood, regional
Regional Transport	Urban./regional
Welfare-related	Urban/regional

There is the potential for using open path monitoring for microscale spatial scales. For microscale areas, however, siting of open path analyzers must reflect proper regard for the specific monitoring objectives and

for the path-averaging nature of these analyzers. Specifically, the path-averaging nature of open path analyzers could result in underestimations of high pollutant concentrations at specific points within the measurement path for other ambient air monitoring situations. In open path monitoring, monitoring path lengths must be commensurate with the intended scale of representativeness and located carefully with respect to local sources or potential obstructions. For short-term/high-concentration or source-oriented monitoring, the monitoring path may need to be further restricted in length and be oriented perpendicular to the wind direction(s) determined by air quality modeling leading to the highest concentration, if possible. Alternatively, multiple paths may be used advantageously to obtain both wider area coverage and peak concentration sensitivity.

Table 6-2 Summary of Spatial Scales for SLAMS, NAMS PAMS and Open Path (OP) Sites

Spatial Scale	Scale Applicable for SLAMS							Scales Required for NAMS							PAMS	OP
	SO_2	CO	O_3	NO_2	Pb	PM_{10}	$PM_{2.5}$	SO_2	CO	O_3	NO_2	Pb	PM_{10}	$PM_{2.5}$		
Micro		*			*	*	*		*			*	*	*[1]		
Middle	*	*	*	*	*	*	*					*	*	*[1]		*
Neighborhood	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Urban	*		*	*	*	*	*			*	*			*[2]	*	*
Regional	*		*		*	*	*							*[2]		*

[1]- Only permitted if representative of many such microscale environments in a residential district (for middle scale, at least two)
[2] -Either urban or regional scale for regional transport sites

6.1.1 Monitoring Boundaries

The standards refer to several boundaries that are defined below. These definitions are derived from the document entitled *Guidance for Network Design and Optimum Site Exposure for $PM_{2.5}$ and PM_{10}*.

Metropolitan Statistical Area (MSA)- are designated by the U.S. Office of Management and Budget (OMB) as having a large population nucleus, together with adjacent communities having a high degree of economic and social integration with that nucleus. MSA boundaries correspond to portions of counties that often include urban and nonurban areas. MSAs are useful for identifying which parts of a state have sufficient populations to justify the installation of a compliance monitoring network. Their geographical extent may be too big for defining the boundaries of Metropolitan Planning Areas and Community Monitoring Zones.

Primary Metropolitan Statistical Area (PMSA)- are single counties or groups of counties that are the component metropolitan portions of a mega-metropolitan area. PMSAs are similar the MSAs with the additional characteristic of having a degree of integration with surrounding metropolitan areas.

Consolidated Metropolitan Statistical Area (CSA)- are a group of PMSAs having significant economic and social integration.

New England County Metropolitan Statistical Area (NECMSA)- is a county-based alternative for the city- and town-based New England MSAs and CMSAs.

Monitoring Planning Area (MPA)- are defined by SIPs as the basic planning unit for $PM_{2.5}$ monitoring. A MPA is a contiguous geographic area with established, well defined boundaries. MPAs may cross state lines and can be further subdivided into Community Monitoring Zones. A MPA does not necessarily correspond to the boundaries within which pollution control strategies will be applied. MPAs will normally contain at least 200,000 people, though portions of a state not associated with MSAs can be considered as a single MSA. Optional MPAs may be designated for other areas of a state. MPAs in MSAs are completely covered by one or more Community Monitoring Zones.

Community Monitoring Zone (CMZ)- When spatial averaging is utilized for making comparisons to the annual $PM_{2.5}$ NAAQS, CMZs must be defined in the monitoring network description. This averaging approach is specified in 40 CFR part 50 Appendix N. A CMZ should characterize an area of relatively similar annual average air quality (i.e., the average concentrations at individual sites should not exceed the spatial average by more than 20%). CMZs have dimensions of 4-50 km with boundaries defined by political demarcations with population attributes. They could be smaller in densely populated areas with large pollutant gradients. Each CMZ would ideally equal the collective zone of representation of one or more community-oriented monitors within that zone. The CMZ, applicable only to $PM_{2.5}$, is intended to represent the spatial uniformity of $PM_{2.5}$ concentrations. In practice, more than one monitor may be needed with each CMZ to evaluate the spatial uniformity of $PM_{2.5}$ concentrations and to accurately calculate the spatial average for comparison with the annual $PM_{2.5}$ NAAQS. When spatial averaging is used, each MPA would be completely covered by one or more contiguous CMZs.

6.2 Site Location

Four criteria should be considered, either singly or in combination when locating sites, depending on the sampling objective. Orient the monitoring sites to measure the following:

1. Impacts of known pollutant emission categories on air quality.
2. Population density relative to receptor-dose levels, both short and long term.
3. Impacts of known pollutant emission sources (area and point) on air quality.
4. Representative area-wide air quality.

To select locations according to these criteria, it is necessary to have detailed information on the location of sources of emissions, geographical variability of ambient pollutant concentrations, meteorological conditions and population density. Therefore, selection of the number, locations and types of sampling stations is a complex process. The variability of sources and their intensities of emissions, terrains, meteorological conditions and demographic features requires that each network be developed individually. Thus, selection of the network will be based upon the best available evidence and on the experience of the decision team. The sampling site selection process involves considerations of the following factors:

<u>Economics</u> - The amount of resources required for the entire data collection activity, including instrumentation, installation, maintenance, data retrieval, data analysis, quality assurance and data interpretation.

<u>Security</u> - Experience has shown that in some cases, a particular site may not be appropriate for the establishment of an ambient monitoring station simply due to problems with the security of the equipment in a certain area. If the problems cannot be remedied via the use of standard security measures such as lighting, fences, etc., then attempts should be made to locate the site as near to the identified sector as possible while maintaining adequate security.

Logistics - Logistics is the process of dealing with the procurement, maintenance and transportation of material and personnel for a monitoring operation. This process requires the full knowledge of all aspects of the data collection operation including:

Planning	*Staffing*
Reconnaissance	*Procurement of goods and services*
Training	*Communications*
Scheduling	*Inventory*
Safety	

Atmospheric considerations - Atmospheric considerations may include spatial and temporal variabilities of the pollutants and their transport. Effects of buildings, terrain, and heat sources or sinks on the air trajectories can produce local anomalies of excessive pollutant concentrations. Meteorology must be considered in determining not only the geographical location of a monitoring site but also such factors as height, direction, and extension of sampling probes. The following meteorological factors can greatly influence the dispersal of pollutants:

Wind speed affects the travel time from the pollutant source to the receptor and the dilution of polluted air in the downwind direction. The concentrations of air pollutants are inversely proportional to the wind speed.

Wind direction influences the general movements of pollutants in the atmosphere. Review of available data can indicate mean wind direction in the vicinity of the major sources of emissions.

Wind variability refers to the random motions in both horizontal and vertical velocity components of the wind. These random motions can be considered atmospheric turbulence, which is either mechanical (caused by structures and changes in terrain) or thermal (caused by heating and cooling of land masses or bodies of water). If the scale of turbulent motion is larger than the size of the pollutant plume, the turbulence will move the entire plume and cause looping and fanning; if smaller, it will cause the plume to diffuse and spread out.

If the meteorological phenomena impact with some regularity, data may need to be interpreted in light of these atmospheric conditions. Other meteorological condition to consider are atmospheric stability and lapse rate.

A useful way of displaying wind data is a wind rose diagram constructed to show the distribution of wind speeds and directions. The wind rose diagram shown in Figure 6.1 represents conditions as they converge on the center from each direction of the compass. More detailed guidance for meteorological considerations is available[49]. Relevant weather information such as stability-wind roses are usually available from local National Weather Service stations. For PAMS monitoring, in many areas, there are three types of high ozone days: overwhelming transport, weak transport (or mixed transport and stagnation) and stagnation. The wind rose concept to site monitors is only applicable to the transport types, but not applicable to the stagnation type. In general, transport types dominate north of 40°N, stagnation types dominate the Ohio River Valley and northern Gulf Coast, and a mixture of the two is observed in the rest of the eastern United States. In areas where stagnation dominates the high ozone days, a well-defined primary wind direction

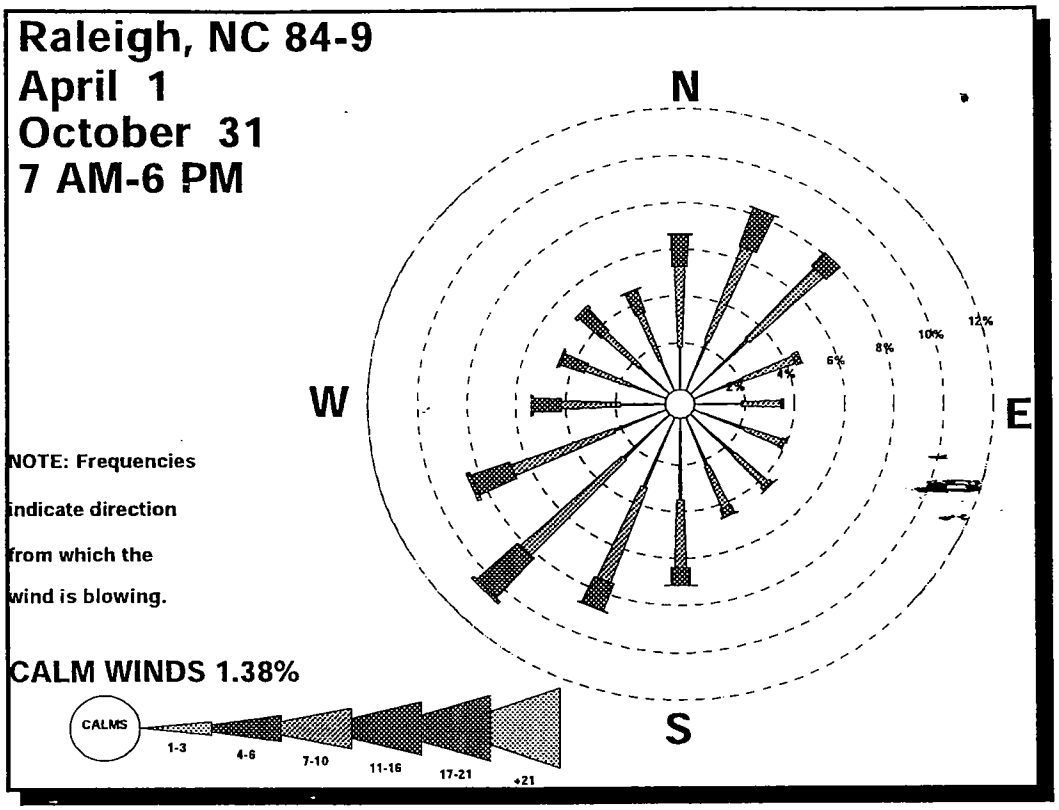


Figure 6.1 Wind rose pattern

(PWD) may not be available. If no well-defined PWD can be resolved, the major axes of the emissions sources should be used as substitutes for the PWDs and the PAMS monitors should be located along these axes.

Meteorological conditions, particularly those that can affect light transmission, should also be considered in selecting the location for open path analyzers (*e.g.*, the influence of relative humidity on the creation of fog, the percentage of heavy snow, and the possible formation of haze, etc.). The percent fog, percent snow fall, percent haze, and hourly visibility (from nearest airport) may impact data completeness. Although sites with high relative humidity may have data capture rates around 90 percent, sites with relative humidity greater than 80 percent more than 20 percent of the time should be carefully assessed for data completeness, or avoided. Similarly, severe fog, snow fall, or haze that affects visibility can affect data completeness and should be kept to less than 20 percent of the time. The time of day or season when such conditions occur should also be determined to ensure that representative data from various time periods and seasons are collected. No more than 20 percent of data in any time period should be lost as a result of the aforementioned meteorological conditions. Sometimes, high data capture at locations with frequent fog or other obscurant conditions can be enhanced by using a shorter path length of 50 to 100 meters. However, this can be done only for microscale sites. Meteorological data considerations therefore should include the following measurements: (1) hourly precipitation amounts for climatological comparisons, (2) hourly relative humidity, (3) percent haze, and (4) airport visibility.

<u>Topography</u> Both the transport and the diffusion of air pollutants are complicated by topographical features. Minor topographical features may exert small influences; major features, such as deep river valleys

or mountain ranges, may affect large areas. Before final site selection, review the topography of the area to ensure that the purpose of monitoring at that site will not be adversely affected. Table 6-3 summarizes important topographical features, their effects on air flow, and some examples of influences on monitoring site selection. Land use and topographical characterization of specific areas can be determined from U.S. Geological Survey (USGS) maps as well as from land use maps.

Table 6-3 Relationships of Topography, Air Flow, and Monitoring Site Selection

Topographical feature	Influence on air flow	Influence on monitoring site selection
Slope/Valley	Downward air currents at night and on cold days; up slope winds on clear days when valley heating occurs. Slope winds and valley channeled winds; tendency toward down-slope and down-valley winds; tendency toward inversions	Slopes and valleys as special sites for air monitors because pollutants generally are well dispersed; concentration levels not representative of other geographic areas; possible placement of monitor to determine concentration levels in a population or industrial center in valley
Water	Sea or lake breezes inland or parallel to shoreline during the day or in cold weather; land breezes at night.	Monitors on shorelines generally for background readings or for obtaining pollution data on water traffic
Hill	Sharp ridges causing turbulence; air flow around obstructions during stable conditions, but over obstructions during unstable conditions	Depends on source orientation; upwind source emissions generally mixed down the slope, and siting at foot of hill not generally advantageous; downwind source emissions generally down washed near the source; monitoring close to a source generally desirable if population centers adjacent or if monitoring protects workers
Natural or manmade obstruction	Eddy effects	Placement near obstructions not generally representative in readings

Pollutant Considerations A sampling site or an array of sites for one pollutant may be appropriate for another pollutant species because of the configuration of sources, the local meteorology, or the terrain. Pollutants undergo changes in their compositions between their emission and their detection; therefore, the impact of that change on the measuring system should be considered. Atmospheric chemical reactions such as the production of O_3 in the presence of NO_x and hydrocarbons (HCs) and the time delay between the emission of NO_x and HCs and the detection peak of O_3 values may require either a sampling network for the precursors of O_3 and/or a different network for the actual O_3 measurement.

The success of the PAMS monitoring program is predicated on the fact that no site is unduly influenced by any one stationary emissions source or small group of emissions sources. Any significant influences would cause the ambient levels measured by that particular site to mimic the emissions rates of this source or sources rather than following the changes in nonattainment area-wide emissions as intended by the Rule. For purposes of this screening procedure, if more than 10% of the typical "lower end" concentration measured in an urban area is due to a nearby source of precursor emissions, then the PAMS site must be relocated or a more refined analysis conducted than is presented here. Detailed procedures can be found in the *PAMS Implementation Manual*[77].

None of the factors mentioned above stand alone. Each is dependent in part on the others. However, the objective of the sampling program must be clearly defined before the selection process can be initiated, and the initial definition of priorities may have to be reevaluated after consideration of the remaining factors and before the final site selection. While the interactions of the factors are complex, the site selection problems can be resolved. Experience in the operation of air quality measurement systems; estimates of air quality,

field and theoretical studies of air diffusion; and considerations of atmospheric chemistry and air pollution effects make up the required expertise needed to select the optimum sampling site for obtaining data representative of the monitoring objectives.

6.2.1 PAMS Site descriptions

The PAMS network array for an area should be fashioned to supply measurements which will assist States in understanding and solving ozone nonattainment problems. EPA has determined that for the larger areas, the minimum network which will provide data sufficient to satisfy a number of important monitoring objectives should consist of five sites as described in Table 6-4

Table 6-4 Site Descriptions of PAMS Monitoring Sites

Site #	Meas. Scale	Description
1	Urban	**Upwind and background characterization** to identify those areas which are subjected to overwhelming incoming transport of ozone. The #1 Sites are located in the predominant morning upwind direction from the local area of maximum precursor emissions and at a distance sufficient to obtain urban scale measurements. Typically, these sites will be located near the upwind edge of the photochemical grid model domain.
2	Neighborhood	**Maximum ozone precursor emissions impacts** located immediately downwind (using the same morning wind direction as for locating Site #1) of the area of maximum precursor emissions and are typically placed near the downwind boundary of the central business district (CBD) or primary area of precursor emissions mix to obtain neighborhood scale measurements.
2a	Neighborhood	**Maximum ozone precursor emissions impacts -second-most predominant morning wind direction**
3	Urban	**Maximum ozone concentrations** occurring downwind from the area of maximum precursor emissions. Locations for #3 Sites should be chosen so that urban scale measurements are obtained. Typically, these sites are located 10 to 30 miles from the fringe of the urban area
4	Urban	**Extreme downwind monitoring** of transported ozone and its precursor concentrations exiting the area and will identify those areas which are potentially contributing to overwhelming ozone transport into other areas. The #4 Sites are located in the predominant afternoon downwind direction from the local area of maximum precursor emissions at a distance sufficient to obtain urban scale measurements. Typically, these sites will be located near the downwind edge of the photochemical grid model domain.

There are three fundamental criteria to consider when locating a final PAMS site: sector analysis, distance, and proximate sources [77]. These three criteria are considered carefully by EPA when approving or disapproving a candidate site for PAMS

6.3 Monitor Placement

SLAMS/NAMS

Final placement of the monitor at a selected site depends on physical obstructions and activities in the immediate area, accessibility/availability of utilities and other support facilities in correlation with the defined purpose of the specific monitor and its design. Because obstructions such as trees and fences can significantly alter the air flow, monitors should be placed away from obstructions. It is important for air flow around the monitor to be representative of the general air flow in the area to prevent sampling bias. Detailed information on urban physiography (e.g., buildings, street dimensions) can be determined through

visual observations, aerial photography and surveys. Such information can be important in determining the exact locations of pollutant sources in and around the prospective monitoring site areas.

Network designers should avoid sampling locations that are unduly influenced by down wash or ground dust (e.g., a rooftop air inlet near a stack or a ground- level inlet near an unpaved road); in these cases, the sample intake should either be elevated above the level of the maximum ground turbulence effect or placed at a reasonable distance from the source of ground dust.

Depending on the defined monitoring objective, the monitors are placed according to exposure to pollution. Due to the various physical and meteorological constraints discussed above, tradeoffs will be made to locate a site in order to optimize representativeness of sample collection. The consideration should include categorization of sites relative to their local placements. Suggested categories relating to sample site placement for measuring a corresponding pollution impact are identified in Table 6-5.

Table 6-5 Relationships of Topography, Air Flow, and Monitoring Site Selection

Station Category	Characterization
A (ground level)	Heavy pollutant concentrations, high potential for pollutant buildup. A site 3 to 5 m (10-16 ft) from major traffic artery and that has local terrain features restricting ventilation. A sampler probe that is 3 to 6 m (10-20 ft) above ground.
B (ground level)	Heavy pollutant concentrations, minimal potential for a pollutant buildup. A site 3 to 15 m (15-50 ft) from a major traffic artery, with good natural ventilation. A sampler probe that is 3 to 6 m (10-20 ft) above ground.
C (ground level)	Moderate pollutant concentrations. A site 15 to 60 m (5-200 ft) from a major traffic artery. A sampler probe that is 3 to 6 m (10-20 ft) above ground.
D (ground level)	Low pollutant concentrations. A site 60 $\geq$ m ($\geq$ 200 ft) for a traffic artery. A sampler probe that is 3 to 6 m (10-20 ft) above ground.
E (air mass)	Sampler probe that is between 6 and 45 m (20-150 ft) above ground. Two subclasses: (1) good exposure from all sides (e.g., on top of building) or (2) directionally biased exposure (probe extended from window).
F (source-oriented)	A sampler that is adjacent to a point source. Monitoring that yields data directly relatable to the emission source.

6.3.1 Concurrent Open Path Monitoring

In addition to requirements for establishing a new site, 40 CFR Part 58, Appendix D[17] addresses requirements for changing to an open path monitor at an existing SLAMS site. Changes must be made with careful consideration given to the impact of the change on the network/site's ability to meet the intended goals. Appendix D[17] requires that the effects of the change on the monitoring data be quantified, if possible, or at least characterized. Appendix D[17] requires concurrent, nominally collocated monitoring in all cases where an open path analyzer is intended to replace a criteria pollutant point monitor which meets either of the following: (1) data collected at the site represent the maximum concentration for a particular nonattainment area, or (2) data collected at the site are currently used to characterize the development of a nonattainment area State implementation plan (SIP). The recommended period of concurrent monitoring is one year (or one season of maximum pollutant concentration) with a maximum term indexed to the subject pollutant NAAQS compliance interval (e.g., three calendar years for O_3). These requirements are intended to provide a bridge between point and open path air monitoring data to evaluate and promote continuity in understanding of the historical representation of the database.

Sites at which open path analyzers are likely to be used to measure NO_2 and O_3 are generally going to be neighborhood scales of representativeness or larger. Since NO_2 and O_3 concentration levels at such sites are likely to be homogeneous, concurrent monitoring is not likely to be useful. However, concurrent monitoring would be required if data from the site were used for attainment designations. In the future, monitoring efforts for SO_2 are likely to concentrate on assessing potential short-term (5-minute average) SO_2 source-related impacts and be conducted at source-oriented micro- to middle-scale sites. For such situations, concurrent monitoring of SO_2 may be useful. Additional information on procedures for locating open path sites can be found in Appendix 6-B

6.4 Minimum Network Requirements

Table 6-6 lists the appropriate numbers of stations for each NAMS, as determined by population and concentrations categories, for SO_2 and PM_{10} as specified in 40 CFR part 58 Appendix D[17]. Tables 6-7 and 6-8 identify the numbers of core SLAMs and NAMS goals for the $PM_{2.5}$ Network.

Table 6-6 NAMS Station Number Criteria

		Approximate number of Stations per area			
Pollutant	**Population Category**		**High Conc.**	**Medium Conc.**	**Low Conc.**
CO	>500,000	≥2	NA	NA	NA
Pb	>500,000	≥2	NA	NA	NA
NO_2	>1,000,000	≥2	NA	NA	NA
O_3	>200,000	≥2	NA	NA	NA
PM_{10} and SO_2	> 1,000,000	--	6-10	4-8	2-4
	500,000-1,000,000	--	4-8	2-4	1-2
	650,000-500,000	--	3-4	1-2	0-1
	100,000-650,000	--	1-2	0-1	0

In addition to requiring reasonably consistent methodologies for sampling ozone precursors and meteorological parameters, 40 CFR 58[24] (and subsequently 40 CFR 58, Appendix D), specifies minimum network requirements and sampling frequencies. For clarity, Table 2 of Appendix D[17] of the codified Rule has been reformatted and follows as Table 6-9. More detailed explanations can be found in the *PAMS Implementation Manual*[77].

Table 6-7 $PM_{2.5}$ Core SLAMS Sites Related to MSA

MSA Population	Min Required No. of Core Sites[1]
>1 Million	3
>2 Million	4
>4 Million	6
>6 Million	8
>8 Million	10

[1] Core SLAMS at PAMS are in addition to this number

Table 6-8 Goals for the Number of $PM_{2.5}$ NAMS by Region

EPA Region	Number of NAMS	EPA Region	Number of NAMS
1	15 - 20	6	25 - 35
2	20 - 30	7	10 - 15
3	20 - 25	8	10 - 15
4	35 - 50	9	25 - 40
5	35 - 50	10	10 - 15

Table 6-9 PAMS Minimum Network Requirements

MINIMUM NETWORK REQUIREMENTS

POPULATION OF MSA/CMSA	FREQ TYPE	SITE LOCATION
LESS THAN 500,000	A or C	(1)
	A/D or C/F	(2)
500,000 TO 1,000,000	A or C	(1)
	B/E	(2)
	A or C	(3)
1,000,000 TO 2,000,000	A or C	(1)
	B/E	(2)
	B/E	(2)
	A or C	(3)
GREATER THAN 2,000,000	A or C	(1)
	B/E	(2)
	B/E	(2)
	A or C	(3)
	A or C	(4)

VOC SAMPLING FREQUENCY REQUIREMENTS

Type	Requirement
A	8 3-Hour Samples Every Third Day 1 24-Hour Sample Every Sixth Day
B	8 3-Hour Samples Everyday 1 24-Hour Sample Every Sixth Day (year-round)
C	8 3-Hr Samples 5 Hi-Event/Previous Days & Every 6th Day 1 24-Hour Sample Every Sixth Day

CARBONYL SAMPLING FREQUENCY REQUIREMENTS

Type	Requirement
D	8 3-Hour Samples Every Third Day
E	8 3-Hour Samples Everyday
F	8 3-Hr Samples 5 Hi-Event/Previous Days & Every 6th Day

MINIMUM PHASE-IN

YEARS AFTER PROMULGATION	NUMBER OF SITES OPERATING	OPERATING SITE LOCATION RECOMMENDATION
1	1	2
2	2	2,3
3	3	1,2,3
4	4	1,2,3,4
5	5	1,2,2,3,4

6.5 Sampling Schedules

Current Federal regulations specify the frequency of sampling for criteria pollutants to meet minimum State implementation plan (SIP) surveillance requirements. Continuous sampling is specified except for 24-hour measurements of PM_{10}, $PM_{2.5}$ (see below) Pb, and TSP and 24-hour integrated values of SO_2 and NO_2.

The 24-hour samples PM_{10}, Pb, and TSP should be taken from midnight (local standard time) to midnight and thus represent calendar days to permit the direct use of sampling data in standard daily meteorological summaries. The frequency of sampling is minimally every six days and the specific day of the week is idendtified based upon the national sampling schedule.

The following are recommended frequencies for noncontinuous hi-vol and impinger sampling to adequately define SO_2, and NO_2 levels:

1. The most polluted sites in an urban area should be sampled at frequencies greater than the minimum requirements.
2. Sites where the highest 24-hour and annual averages are expected should yield the most frequent particulate samples.
3. Areas of maximum SO_2 and NO_2 concentrations should be sampled using continuous monitors in place of SO_2/ NO_2 impingers if possible.
4. Noncritical sites (sites with other than maximum concentration) can be sampled intermittently. Intermittent sampling calls for adopting a systematic sampling schedule that considers statistical relationships for characterizing an air pollutant for a given time period and area (see items 6 and 7 below). Any schedule which provides 61 samples/yr and 5/quarter (in accordance with item 6 below) is satisfactory, but not as convenient as the systematic schedule of every 6th day, for example.
5. Downwind sites monitoring SO_2, NO_2, and particulate matter from isolated point sources should use continuous instruments for gaseous pollutants, and should sample at least once every 6 days for particulate matter.
6. The minimum numbers of samples required for appropriate summary statistics should be taken. At least 75% of the total possible observations must be present before summary statistics are calculated. The exact requirements follow:

Time Interval	Minimum number of observations/averages
3-h running average	3 consecutive hourly observations
8-h running average	6 hourly observations
64 h	18 hourly observations
Monthly	61 daily averages
Quarterly	3 consecutive monthly averages
Yearly	9 monthly averages with at least 6 monthly averages/quarter

For intermittent sampling data, there must be at least five observations/quarter; if one month has no observations, the remaining two months must have at least two.

7. If validation procedures indicate that the criteria in item 6 are not fulfilled (the minimum numbers must be valid observations), the sampling frequency should be increased during the period in which corrective measures are being pursued.

More extensive treatments of sampling frequencies, as related to data analysis, are in references 7, 50 and 55. Section 4.3 of 40 CFR 58, Appendix D[17], stipulates that the PAMS monitoring should be conducted annually throughout the months of June, July and August as a minimum. In most States, these months

incorporate the periods when peak ozone values are likely to occur. EPA, however, encourages the States to extend the PAMS monitoring period whenever feasible to include the entire ozone season or perhaps the entire calendar year. Monitoring which is conducted on an intermittent schedule should be coincident with the previously-established intermittent schedule for particulate matter sampling. The codified ozone monitoring seasons for the PAMS-affected States are displayed in Table 6-10

Table 6-10 Ozone Monitoring Seasons PAMS Affected States

State	Begin Month	End Month	State	Begin Month	End Month
California	January	December	Massachusetts	April	September
Connecticut	April	October	New Hampshire	April	September
Delaware	April	October	New Jersey	April	October
District of Columbia	April	October	New York	April	October
Georgia	April	October	Pennsylvania	April	October
Illinois	April	October	Rhode Island	April	September
Indiana	April	September	Texas AQCR 4, 5, 7, 10, 11	January	December
Louisiana	January	December	Texas AQCR 1, 2, 3, 6, 8, 9, 12	March	October
Maine	April	September	Virginia	April	October
Maryland	April	October	Wisconsin	April 15	October 15

$PM_{2.5}$ Sampling Schedule

Table 6-11 represents the $PM_{2.5}$ sampling schedule as discussed in CFR. The 24-hour sample will be taken from midnight (local standard time) to midnight The frequency of sampling is minimally every six days and the specific day of the week is idendtified based upon the national sampling schedule.

Table 6-11 $PM_{2.5}$ Sampling Schedule

Sampling Frequency	Types of Sites Subject to Sampling Frequency (As per 40 CFR part 58 Section 58.13 and Appendix D)
Daily	At least 2 core PM2.5 sites in each MSA with population > 1M (At least 1 in 3 if collocated with continuous analyzer in priority 2 areas, which are MSAs with > 1 Million people and $PM_{2.5}$ concentrations > 80% of NAAQS)
	At least 2 core PM2.5 sites in each MSA with population between 500K and 1M (At least 1 in 3 if collocated with continuous analyzer)
	1 core PM2.5 site in each PAMS area (daily sampling year round)
	1 site in areas suspected to have conc > 24-hr PM2.5 NAAQS (daily sampling encouraged during seasons of high concentrations, otherwise 1 in 3)
1 in 3	all other SLAMS
1 in 6	SLAMS with Regional Office waiver*
Any	SPMs**

* In accordance with future EPA guidance
** Status of sites is examined during annual network review

7. Sampling Methods

Ambient air sampling is primarily concerned with the atmospheric concentrations of such pollutants as particulates, SO_2, NO_X, CO, and photochemical oxidants. To establish the basic validity of such ambient air monitoring data, it must be shown that:

- the proposed sampling method complies with the appropriate testing regulations
- the equipment is accurately sited
- the equipment was accurately calibrated using correct and established calibration methods
- the organization implementing the data collection operation are qualified and competent

For example, if the only reasonable test site has a less than ideal location, the data collection organization must decide whether a representative sample can be obtained at the site. This determination should be recorded and included in the program's protocol. Although after-the-fact site analysis may suffice in some instances, good quality assurance techniques dictate that this analysis be made prior to expending the resources required to collect the data.

The purpose of this section is to describe the attributes of the sampling system that will ensure the collection of data of a quality acceptable for the Ambient Air Quality Monitoring Program.

7.1 Environmental Control

7.1.1 Monitoring Station Design

State and local agencies should design their monitoring stations with the station operator in mind. Careful thought to safety, ease of access to instruments and optimal work space should be given every consideration. If the station operator has these issues addressed, then he/she will be able to perform their duties more efficiently and diligently. Having the instruments in an area that is difficult to work in creates frustration and prolongs downtime. The goal is to optimize data collection and quality. This must start with designing the shelter and laboratory around staff needs and requirements. The following is a description of the optimal station and laboratory design.

The EPA is aware that monitoring stations may be located in urban areas where space and land are at a premium, especially in large cities that are monitoring for NO_x and CO. In many cases, the monitoring station is located in a building or school that is gracious enough to allow an agency to locate their equipment there. Sometimes, a storage or janitorial closet is all that is available. However, this can pose serious problems. If the equipment is located in a closet, then it is difficult for the agency to control the temperature, humidity, light, vibration and chemicals that the instruments are subjected to. In addition, security can also be an issue if people other than agency staff have access to the equipment. State and local agencies should give serious thought to locating their air monitoring equipment in stand-alone shelters with limited access, or modify existing rooms to the recommended station design if funds and staff time are available.

In general, air monitoring stations should be designed for functionality and ease of access, i.e., instrumentation easily accessed for operation and repair. In addition, the shelter should be rugged enough to withstand any weather that the local area may generate. In the past, small utility trailers were the norm in monitoring shelters. However, in some areas, this will not suffice. Recently, steel and aluminum storage containers are gaining wide acceptance as monitoring shelters. It is recommended that monitoring stations be housed in

shelters that are fairly secure from intrusion or vandalism. All sites should be located in fenced or secure areas with access only through locked gates or secure pathways. The shelter's design dictates that they be insulated (R-19 minimum) to prevent temperature extremes within the shelter. All foundations should be earthquake secured. All monitoring shelters should be designed to control excessive vibrations and external light falling on the instruments, and provide 110/220 VAC voltage throughout the year. When designing a monitoring shelter, make sure that enough electrical circuits are secured for the current load of equipment plus other instruments that may be added later. Figure 7.1 represents one shelter design that has proven adequate.

The first feature of the shelter is that there are two rooms separated by a door. The reasons for this are two-fold. The entry and access should be into the computer/data review area. This allows access to the site without having to open the room that houses the equipment. It also isolates the equipment from cold/hot air that can come into the shelter when someone enters. Also, the Data Acquisition System (DAS)/data review area is isolated from the noise and vibration of the equipment. This area can be a place where the operator can print data, and prepare samples for the laboratory. This also gives the operator an area where cursory data review can take place. If something is observed during this initial review then possible problems can be corrected or investigated at that time. The DAS can be linked through cables that travel through conduit into the equipment area. The conduit is attached to the ceiling or walls and then dropped down to the instrument rack.

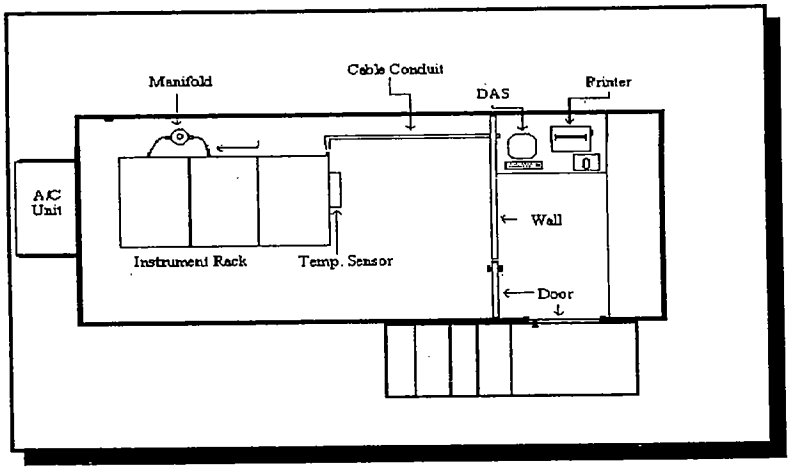


Figure 7.1 Example design for shelter

The air conditioning/heating unit should be mounted to heat and cool the equipment room. When specifying the unit, make sure it will cool the room on the warmest and heat on the coldest days of the year. Also, make sure the electrical circuits are able to carry the load. If necessary, keep the door closed between the computer and equipment room to lessen the load on the heating or cooling equipment.

All air quality instrumentation should be located in an instrument rack or equivalent. The instruments and their support equipment are placed on sliding trays or rails. By placing the racks away from the wall, the rear of the instruments are accessible. The trays or rails allows the site operators access to the instruments without removing them from the racks. Most instrument vendors offer sliding rails as an optional purchase.

7.1.2 Sampling Environment

A proper sampling environment demands control of all physical parameters external to the samples that might affect sample stability, chemical reactions within the sampler, or the function of sampler components. The important parameters to be controlled are summarized in Table 7-1.

Table 7-1 Environment Control Parameters

Parameter	Source of specification	Method of Control
Instrument vibration	Manufacturer's specifications	Design of instrument housings, benches, etc., per manufacturer's specifications.
Light	Method description or manufacturer's specifications	Shield chemicals or instruments that can be affected by natural or artificial light
Electrical voltage	Method description or manufacturer's specifications	Constant voltage transformers or regulators; separate power lines; isolated high current drain equipment such as hi-vols, heating baths, pumps from regulated circuits
Temperature	Method description or manufacturer's specifications	Regulated air conditioning system 24-hour temperature recorder; use electric heating and cooling only
Humidity	Method description or manufacturer's specifications	Regulated air conditioning system; 24-hour temperature recorder

With respect to environmental temperature for designated analyzers, most such analyzers have been tested and qualified over a temperature range of 20°C to 30°C; few are qualified over a wider range. This temperature range specifies both the range of acceptable operating temperatures and the range of temperature change which the analyzer can accommodate without excessive drift. The latter, the range of temperature change that may occur between zero and span adjustments, is the most important. When one is outfitting a shelter with monitoring equipment, it is important to recognize and accommodate the instrument with the most sensitive temperature requirement.

To accommodate energy conservation regulations or guidelines specifying lower thermostat settings, designated analyzers located in facilities subject to these restrictions may be operated at temperatures down to 18°C, provided the analyzer temperature does not fluctuate by more than 10°C between zero and span adjustments. Operators should be alert to situations where environmental temperatures might fall below 18°C, such as during night hours or weekends. Temperatures below 18°C may necessitate additional temperature control equipment or rejection of the area as a sampling site.

Shelter temperatures above 30°C also occur, due to temperature control equipment that is malfunctioning, lack of adequate power capacity, or shelters of inadequate design for the environmental conditions. Occasional fluctuations above 30°C may require additional assurances that data quality is maintained. Sites that continually have problems maintaining adequate temperatures may necessitate additional temperature control equipment or rejection of the area as a sampling site. If this is not an option, a waiver to operate beyond the required temperature range should be sought with the EPA Regional Office, if it can be shown that the site can meet established data quality requirements.

In order to detect and correct temperature fluctuations, a 24-hour temperature recorder at the analyzer site is suggested. These recorders can be connected to data loggers and should be considered official documentation that should be filed (see Section 5). Many vendors offer these type of devices. Usually they are thermocouple/thermistor devices of simple design and are generally very sturdy. Reasons for using electronic shelter temperature devices are two-fold: 1) through remote interrogation of the DAS, the agency can tell if values collected by air quality instruments are valid, and 2) that the shelter temperature is within a safe operating range if the air conditioning/heating system fails.

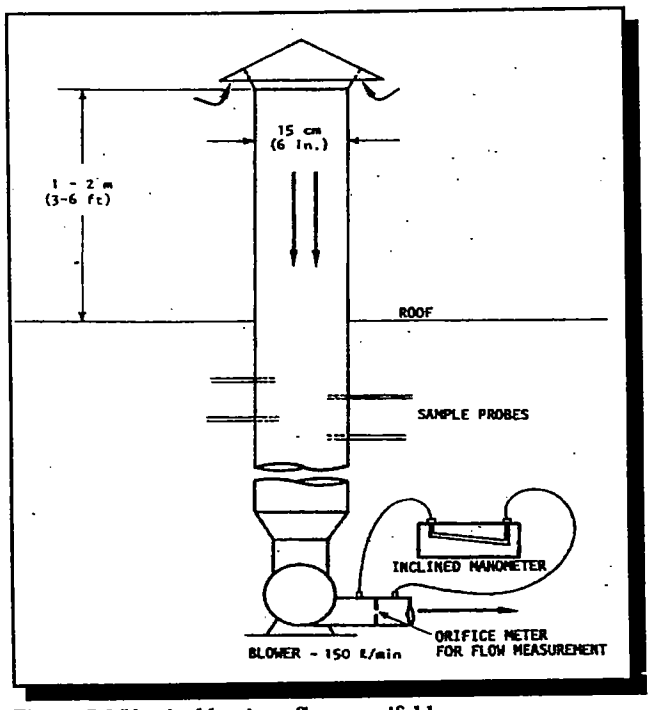


Figure 7.2 Vertical laminar flow manifold

7.2 Sampling Probes And Manifolds

7.2.1 Design of Probes and Manifolds for Automated Methods

Some important variables affecting the sampling manifold design are the diameter, length, flow rate, pressure drop, and materials of construction. Considerations for these parameters are discussed below for both a vertical laminar flow and a conventional manifold design.

Vertical laminar flow design - Figure 7.2 is an example of a vertical laminar flow manifold. By the proper selection of a large diameter vertical inlet probe and by maintaining a laminar flow throughout, the sample air is not permitted to react with the walls of the probe. Numerous materials such as glass, PVC plastic, galvanized steel, and stainless steel, can be used for constructing the probe. Removable sample lines constructed of Teflon or glass can be used to provide each device with sample air.

Inlet line diameters of 15 cm with a flow rate of 150 L/min are necessary if diffusion losses and pressure drops are to be minimized. The sampling rate should be maintained to insure laminar flow conditions. This configuration has the following advantages:

- a 15-cm pipe can be cleaned easily by pulling a cloth through it with a string
- sampling ports can be cut into the pipe at any location and, if unused, can be plugged with stoppers of similar composition
- metal poses no breakage hazard
- there is less potential for sample contamination than there is with smaller tubes

Conventional manifold design - In practice, it may be difficult to achieve vertical laminar flow because of the elbows within the intake manifold system. Therefore, a conventional horizontal manifold system should be constructed of inert materials such as Pyrex glass and/or Teflon, and in modular sections to enable frequent cleaning. The system (Figure 7.3) consists of a vertical "candy cane" protruding through the roof of the shelter with a horizontal sampling manifold connected by a tee to the vertical section. Connected to the other vertical outlet of the tee is a bottle for collecting heavy particles and moisture before they enter the horizontal section. A small blower, 1700 L/min at 0 cm of water at static pressure, is at the exhaust end of the system to provide a flow through the system of approximately 85 to 140 L/min. Particulate monitoring instruments, such as nephelometers, each have separate intake probes that are as short and as straight as possible to avoid particulate losses due to impaction on the walls of the probe.

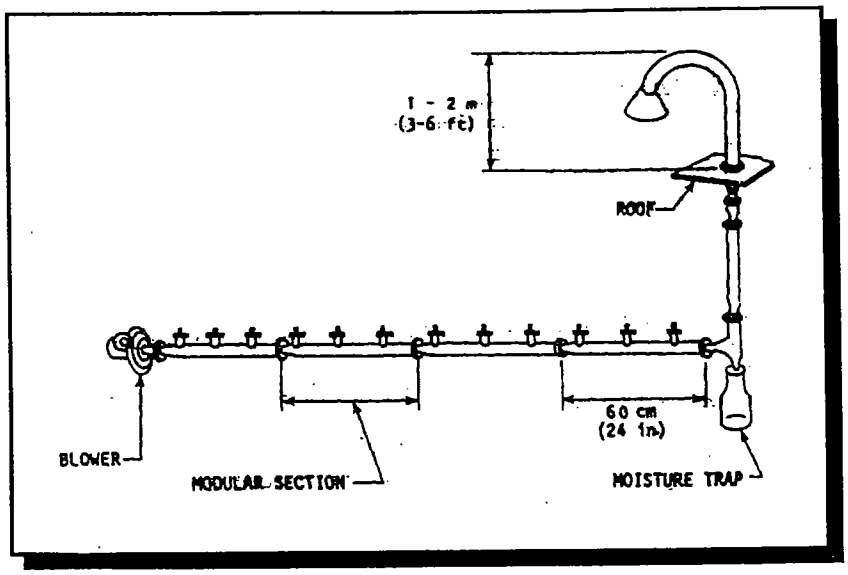


Figure 7.3 Conventional manifold system

Another type of manifold that is being widely used is known as the "ARB" style manifold illustrated in Figure 7.4. This manifold has a reduced profile, i.e., there is less volume in the cane and manifold, therefore, there is less of a need for by-pass flow.

These manifolds allow the user more options than the other conventional manifolds. If the combined flow rates are high enough with the instruments at the monitoring location, by-pass flow devices such as blower motors are not required.

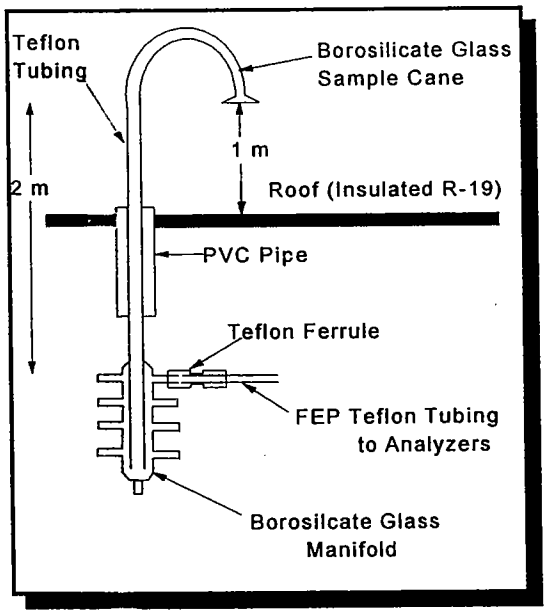


Figure 7.4 Alternate manifold design

Residence time Determination: The residence time of pollutants within the sampling manifold is critical. Residence time is defined as the amount of time that it takes for a sample of air to travel from the opening of the cane to the inlet of the instrument and is required to be less than 20 seconds for reactive gas monitors[18]. It is recommended that the residence time within the manifold and sample lines to the instruments be less than 10 seconds. If the volume of the manifold does not allow this to occur, then a blower motor or other device (vacuum pump) can be used to decrease the residence time. The residence time for a manifold system is determined in the following way. First the volume of the cane, manifold and sample lines must be determined using the following equation:

$$Total\ Volume = Cv + Mv + Lv$$

Where:
Cv = Volume of the sample cane and extensions
Mv = Volume of the sample manifold and trap
Lv = Volume of the instrument lines

Each of the components of the sampling system must be measured individually. To measure the volume of the components, use the following calculation:

$$V = pi * (d/2)^2 * L$$

Where:
V = volume of the component
pi = 3.14159
L = Length of the component
d = inside diameter

Once the total volume is determined, divide the volume by the flow rate of all instruments. This will give the residence time. If the residence time is greater than 10 seconds, attach a blower or vacuum pump to increase the flow rate and decrease the residence time.

It has been demonstrated that there are no significant losses of reactive gas (O_3) concentrations in conventional 13 mm inside diameter sampling lines of glass or Teflon if the sample residence time is 10 seconds or less. This is true even in sample lines up to 38 m in length, which collect substantial amounts of visible contamination due to ambient aerosols. However, when the sample residence time exceeds 20 seconds, loss is detectable, and at 60 seconds the loss is nearly complete.

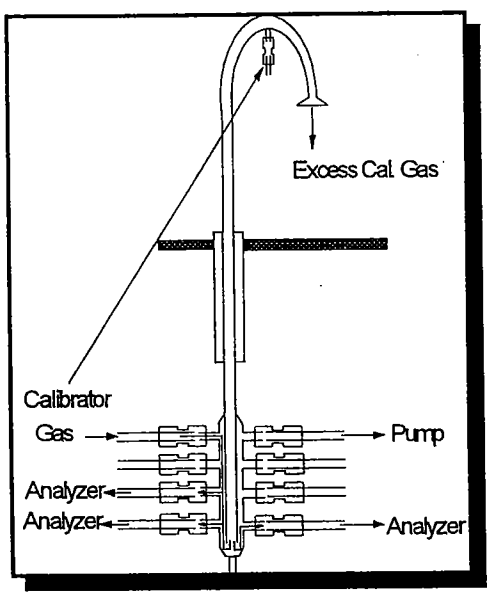


Figure 7.5 Positions of calibration line in sampling manifold

Placement of tubing on the Manifold: If the manifold that is employed at the station has multiple ports (See Figures 7.3 and 7.4) then placement of the instrument lines can be crucial. If a manifold similar to Figure 7.5 is used, it is suggested that instruments requiring lower flows be placed towards the bottom of the manifold. The general rule of thumb states that the calibration line (if used) placement should be in a location so that the calibration gases flow past the instruments before the gas is evacuated out of the manifold. Figure 7.5 illustrates two potential introduction ports for the calibration gas. The port at the elbow of the sampling cane provides more information about the cleanliness of the sampling system.

7.2.2 Placement of Probes and Manifolds

Probes and manifolds must be placed to avoid introducing bias to the sample. Important considerations are probe height above the ground, probe length (for horizontal probes), and physical influences near the probe. Some general guidelines for probe and manifold placement are:

- probes should not be placed next to air outlets such as exhaust fan openings
- horizontal probes must extend beyond building overhangs
- probes should not be near physical obstructions such as chimneys which can affect the air flow in the vicinity of the probe
- height of the probe above the ground depends on the pollutant being measured

In addition, Table 7-2 summarizes the probe and monitoring path siting criteria while Table 7-3 summarizes the spacing of probes from roadways. This information can be found in 40 CFR part 58, Appendix E[18] For PM_{10} and $PM_{2.5}$, Figure 7.6 provides the acceptable areas for micro, middle, neighborhood and urban samplers, with the exception of microscale street canyon sites.

Table 7-2 Summary of Probe and Monitoring Path Siting Criteria

Pollutant	Scale (maximum monitoring path length, meters)	Height from ground to probe or 80% of monitoring path[A] (meters)	Horizontal and vertical distance from supporting structures[B] to probe or 90% monitoring path[A] (meters)	Distance from trees to probe of monitoring path[A] (meters)
SO_2 [C, D, E, F]	Middle (300m) Neighborhood, Urban, and Regional (1 km)	3 - 15	>1	>10
CO [D, E, G]	Micro, Middle (300m) Neighborhood (I km)	3 ± 0.5; 3 - 15	>1	>10
O_3 [C, D, E]	Middle (300m) Neighborhood, Urban, and Regional (1 km)	3 - 15	>1	>10
Ozone precursors for (PAMS) [C, D, E]	Neighborhood, and Urban (1km)	3 - 15	>1	>10
NO_2 [C, D, E]	Middle (300m) Neighborhood, and Urban (1 km)	3 - 15	>1	>10
Pb [C, D, E, F, H]	Micro, Middle Neighborhood, Urban, and Regional (1 km)	2-7 (micro); 2-15 (all other scales)	>2 (all scales, horizontal distance only)	>10 (all scales)
PM_{10} [C, D, E, F, H]	Micro, Middle Neighborhood, Urban, and Regional	2-7 (micro); 2-15 (all other scales)	>2 (all scales, horizontal distance only)	>10 (all scales)
$PM_{2.5}$ [C, D, E, F, H, I]	Micro, Middle Neighborhood, Urban, and Regional	2-7 (micro); 2-15 (all other scales)	>2 (all scales, horizontal distance only)	>10 (all scales)

N/A - Not applicable

[A]- Monitoring Path f open path analyzers is applicable only to middle or neighborhood scale CO monitoring and all applicable scales for monitoring O_2, O_3, O_3 precursors, and NO_2

[B]- When probe is loc ed on a rooftop, this separation distance is in reference to walls, parapets, or penthouses located on roof

[C] Should be > 20 met rs from the dripline of tree(s) and must be 10 meters from the dripline when the trees (s) act as an obstruction

[D] - Distance from sampler, probe, or 90% of monitoring path to obstacle, such as a building, must be at least twice the height the obstacle protrudes above the sampler, probe or monitoring path. Sites not meeting this criterion may be classified as middle scale.

[E] Must have unrestricted air flow 270° around probe or sampler; 180° if the probe is on the side f a building

[F] - The Probe, sampler, or monitoring path should be away from minor sources, such as a furnace or incineration flues. The separation distance is dependent on the height of the minor sources's emission point (such as a flue), the type of fuel or waste bed, and the quality of fuel (sulfur, ash, or lead content). This criterion is designed to avoid undue influences from minor sources.

[G] - For microscale CO monitoring sites, he probe must be >10 meters from a street intersection and preferably at a midblock location

[H] - For collocated Pb an PM-10 samplers, a 2-4 meter separation distance between collocated samplers must be met

[I] - For collocated PM-.5 samplers, a 1-4 meter separation distance between collocated samplers must be met.

Table 7-3 Minimum Separation Distance Between Sampling Probes and Roadways

Roadway ave. daily traffic vehicles per day	Minimum separation distance in meters between roadways and probes or monitoring paths at various scales						
	O_3 Neighbor. & Urban	NO_2 Neighbor. & Urban	CO Neighbor.	Pb Micro	Pb Middle	Pb Neighbor., Urban, Reg.	PAMS
≤ 10,000	10	10	10	5-15	>15-50	>50	> 10
15,000	20	20	25				20
20,000	30	30	45	5-15	>15-75	>75	30
30,000			80				
≥ 40,000				5-15	>15-100	>100	
40,000	50	50	115				50
50,000			135				
≥ 60,000			150				
70,000	100	100					100
≥110,000	250	250					250

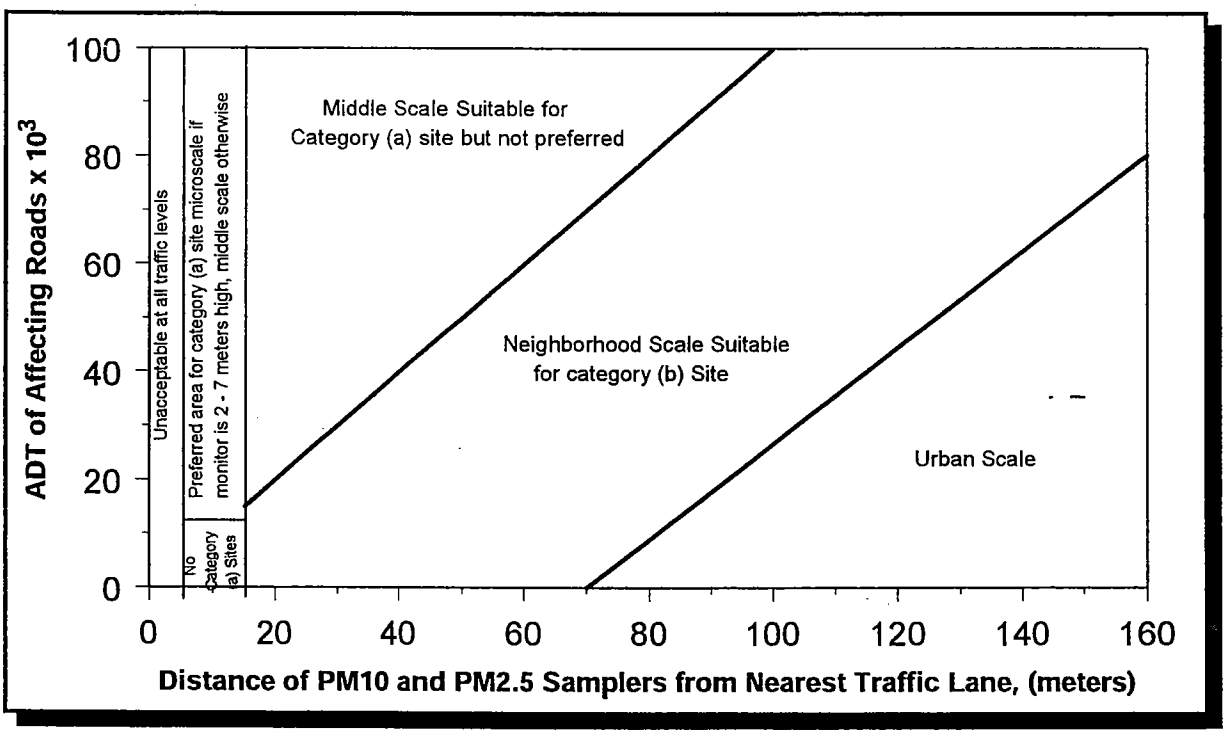


Figure 7.6 Acceptable areas for PM_{10} and $PM_{2.5}$ micro, middle, neighborhood, and urban samplers except for microscale street canyon sites

Open Path Monitoring

To ensure that open path monitoring data are representative of the intended monitoring objective(s), specific path siting criteria are needed. 40 CFR part 58, Appendix E[18], contains specific location criteria applicable to monitoring paths after the general station siting has been selected based on the monitoring objectives, spatial scales of representativeness, and other considerations presented in Appendix D[17]. The new open path siting requirements largely parallel the existing requirements for point analyzers, with the revised provisions applicable to either a "probe" (for point analyzers), a "monitoring path" (for open path analyzers), or both, as appropriate. Criteria for the monitoring path of an open path analyzer are given for horizontal and vertical placement, spacing from minor sources, spacing from obstructions, spacing from trees, and spacing from roadways. These criteria are summarized in Table 7-2.

Cumulative Interferences on a Monitoring Path: To control the sum effect on a path measurement from all the possible interferences which exist around the path, the cumulative length or portion of a monitoring path that is affected by obstructions, trees, or roadways must not exceed 10 percent of the total monitoring path length. This limit for cumulative interferences on the monitoring path controls the total amount of interference from minor sources, obstructions, roadways, and other factors that might unduly influence the open path monitoring data.

Monitoring Path Length: For NO_2, O_3, and SO_2, the monitoring path length must not exceed 1 kilometer for analyzers in neighborhood, urban, or regional scales, or 300 meters for middle scale monitoring sites. These path limitations are necessary in order to produce a path concentration representative of the measurement scale and to limit the averaging of peak concentration values. In addition, the selected path length should be long enough to encompass plume meander and expected plume width during periods when high concentrations are expected. In areas subject to frequent periods of rain, snow, fog, or dust, a shortened monitoring path length should be considered to minimize the loss of monitoring data due to these temporary optical obstructions.

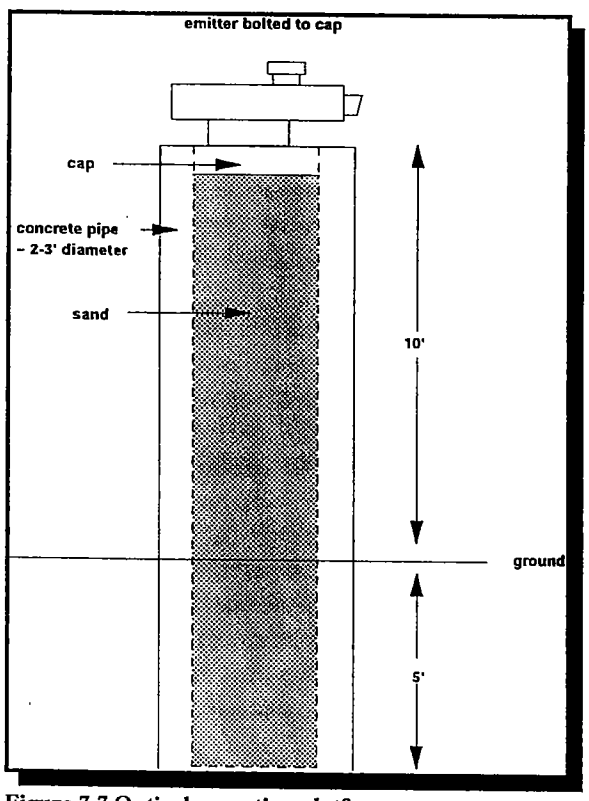


Figure 7.7 Optical mounting platform

Mounting of Components and Optical Path Alignment: Since movements or instability can misalign the optical path, causing a loss of light and less accurate measurements or poor readings, highly stable optical platforms are critical. Steel buildings and wooden platforms should be avoided as they tend to move more than brick buildings when wind and temperature conditions vary. Metal roofing will, for example, expand when heated by the sun in the summer. A concrete pillar with a wide base, placed upon a stable base material, has been found to work well in field studies. A sketch of an optical platform is included in Figure 7.7

7.2.3 Probe and Manifold Maintenance

After an adequately designed sampling probe and/or manifold has been selected and installed, the following steps will help in maintaining constant sampling conditions:

1. Conduct a leak test. For the conventional manifold, seal all ports and pump down to approximately 1.25 cm water gauge vacuum, as indicated by a vacuum gauge or manometer connected to one port. Isolate the system. The vacuum measurement should show no change at the end of a 15-min period.
2. Establish cleaning techniques and a schedule. A large diameter manifold may be cleaned by pulling a cloth on a string through it. Otherwise the manifold must be disassembled periodically and cleaned with distilled water. Soap, alcohol, or other products that may contain hydrocarbons should be avoided when cleaning the sampling train. These products may leave a residue that may affect volatile organic measurements. Visible dirt should not be allowed to accumulate.
3. Plug the ports on the manifold when sampling lines are detached.
4. Maintain a flow rate in the manifold that is either 3 to 5 times the total sampling requirements or at a rate equal the total sampling requirement plus 140 L/min . Either rate will help to reduce the sample residence time in the manifold and ensure adequate gas flow to the monitoring instruments.
5. Maintain the vacuum in the manifold <0.64 cm water gauge. Keeping the vacuum low will help to prevent the development of leaks.

7.2.4 Support Services

Most of the support services necessary for the successful operation of ambient air monitoring networks can be provided by the laboratory. The major support services are the generation of reagent water and the preparation of standard atmospheres for calibration of equipment. Table 7-4 summarizes guidelines for quality control of these two support services.

In addition to the information presented above, the following should be considered when designing a sampling manifold:

- suspending strips of paper in front of the blower's exhaust to permit a visual check of blower operation
- positioning air conditioner vents away from the manifold to reduce condensation of water vapor in the manifold
- positioning sample ports of the manifold toward the ceiling to reduce the potential for accumulation of moisture in analyzer sampling lines, and using borosilicate glass, stainless steel, or their equivalent for VOC sampling manifolds at PAMS sites is to avoid adsorption and desorption reactions of VOC's on FEP Teflon
- if moisture in the sample train poses a problem (moisture can absorb gases, namely NO_x and SO_2) :
  - wrap the manifold and instrument lines with "heat wrap", a product that has heating coils within a cloth covering that allows the manifold to be maintained at a constant temperature.
  - make sure the manifold has a moisture trap and that it is emptied often.
  - use of water resistant particulate filters in-line with the instrument

Table 7-4 Techniques for Quality Control of Support Services

Support Service	Parameters affecting quality	Control techniques
Laboratory and calibration gases	Purity specifications vary among manufacturers	Develop purchasing guides
	Variation among lots	Overlap use of old and new cylinders
	Atmospheric interferences	Adopt filtering and drying procedures
	Composition	Ensure traceability to primary standard
Reagents and water	Commercial source variation	Develop purchasing guides. Batch test for conductivity
	Purity requirements	Redistillation, heating, deionization with ion exchange columns
	Atmospheric interferences	Filtration of exchange air
	Generation and storage equipment	Maintenance schedules from manufacturers

7.3 Reference And Equivalent Methods

For monitoring in a SLAMS or NAMS network, either reference or equivalent methods are usually required. This requirement, and any exceptions, are specified in 40 CFR part 58, Appendix C[16]. In addition, reference or equivalent methods may be required for other monitoring applications, such as those associated with prevention of significant deterioration (PSD). Requiring the use of reference or equivalent methods helps to assure the reliability of air quality measurements including: ease of specification, guarantee of minimum performance, better instruction manuals, flexibility of application, comparability with other data and increased credibility of measurements. However, designation as a reference or equivalent method provides no guarantee that a particular analyzer will always operate properly. Appendices A[14] and B[15] require the monitoring organization to establish an internal QC program. Specific guidance for a minimum QC program is described in Section 10 of this Handbook.

The definitions and specifications of reference and equivalent methods are given in 40 CFR part 53[23]. For most monitoring applications, the distinction between reference and equivalent methods is unimportant and either may be used interchangeably.

Reference and equivalent methods may be either manual or automated (analyzers). For SO_2, particulates, and Pb, the reference method for each is a unique manual method that is completely specified in 40 CFR part 50[21] (appendices A, B, and G respectively); all other approved methods for SO_2 and Pb qualify as equivalent methods. As yet, there is no provision in the regulations for designating equivalent methods for particulates. For CO, NO_2, and O_3, Part 50[21] provides only a measurement principle and calibration procedure applicable to reference methods for those pollutants. Automated methods (analyzers) for these pollutants may be designated as either reference methods or equivalent methods, depending on whether the methods utilize the same measurement principle and calibration procedure specified in Part 50[21] for reference methods. Because any analyzer that meets the requirements of the specified measurement principle and calibration procedure may be designated as a reference method, there are numerous reference

methods for CO, NO_2, and O_3. Further information on this subject is in the preamble to 40 CFR part 53[23]. Part II of this Handbook provides details on many of the current reference or equivalent methods.

Except for the unique reference methods for SO_2, particulates, and Pb specified in 40 CFR Part 50[21], all reference and equivalent methods must be officially designated as such by EPA under the provisions of 40 CFR part 53[23]. Notice of each designated method is published in the *Federal Register* at the time of designation. In addition, a current list of all designated reference and equivalent methods is maintained and updated by EPA whenever a new method is designated. This list can be found on the *AMTIC Bulletin Board (http://www.epa.gov/ttn/amtic)*, obtained from the Quality Assurance Coordinator at any EPA Regional Office, or from the National Environmental Research Laboratory (MD-77, RTP NC 27711). Moreover, any analyzer offered for sale as a reference or equivalent method after April 16, 1976, must bear a label or sticker indicating that the analyzer has been designated as a reference or equivalent method by EPA.

Sellers of designated automated methods must comply with the conditions summarized below:

1. A copy of the approved operation or instruction manual must accompany the analyzer when it is delivered to the ultimate purchaser.
2. The analyzer must not generate any unreasonable hazard to operators or to the environment.
3. The analyzer must function within the limits of the performance specifications in Table 7-5 for at least 1 year after delivery when maintained and operated in accordance with the operation manual.
4. Any analyzer offered or sale as a reference or equivalent method must bear a label or sticker indicating that it has been designated as a reference or equivalent method in accordance with 40 CFR Part 53[23].
5. If such an analyzer has one or more selectable ranges, the label or sticker must be placed in close proximity to the range selector and must indicate which range or ranges have been designated as reference or equivalent methods.
6. An applicant who offers analyzers for sale as reference or equivalent methods is required to maintain a list of purchasers of such analyzers and to notify them within 30 days if a reference or equivalent method designation applicable to the analyzers has been canceled or if adjustment of the analyzers is necessary under 40 CFR part 53.11(b) to avoid a cancellation.

Aside from occasional malfunctions, consistent or repeated noncompliance with any of these conditions should be reported to EPA at the address given previously. In selecting designated methods, remember that designation of a method indicates only that it meets certain minimum standards. Competitive differences still exist among designated analyzers. Some analyzers or methods may have performance, operational, economic or other advantages over others. A careful selection process based on the individual air monitoring application and circumstances is very important.

Some of the performance tests and other criteria used to qualify a method for designation as a reference or equivalent method are intended only as pass/fail tests to determine compliance with the minimum standards. Test data may not allow quantitative comparison of one method with another.

$PM_{2.5}$ Reference and Equivalent Methods

All formal sampler design and performance requirements and the operational requirements applicable to reference methods for $PM_{2.5}$ are specified in Appendix L of 40 CFR Part 50[21] (EPA 1997a). These requirements are quite specific and include explicit design specifications for the type of sampler, the type of

filter, the sample flow rate, and the construction of the sample collecting components. However, various designs for the flow-rate control system, the filter holder, the operator interface controls, and the exterior housing are possible. Hence, various reference method samplers from different manufacturers may vary considerably in appearance and operation. Also, a reference method may have a single filter capability (single sample sampler) or a multiple filter capability (sequential sample sampler), provided no deviations are necessary in the design and construction of the sample collection components specified in the reference method regulation. A $PM_{2.5}$ method is not a reference method until it has been demonstrated to meet all the reference method regulatory requirements and has been officially designated by EPA as a reference method for $PM_{2.5}$.

Equivalent methods for $PM_{2.5}$ have a much wider latitude in their design, configuration, and operating principle than reference methods. These methods are not required to be based on filter collection of $PM_{2.5}$; therefore, continuous or semi-continuous analyzers and new types of $PM_{2.5}$ measurement technologies are not precluded as possible equivalent methods. Equivalent methods are not necessarily required to meet all the requirements specified for reference methods, but they must demonstrate both **comparability** to reference method measurements and similar $PM_{2.5}$ **measurement precision**.

The requirements that some (but not all) candidate methods must meet to be designated by EPA as equivalent methods are specified in 40 CFR Part 53[23]. To minimize the difficulty of meeting equivalent method designation requirements, three classes of equivalent methods have been established in the 40 CFR Part 53[23] regulations, based on a candidate method's extent of deviation from the reference method requirements. All three classes of equivalent methods are acceptable for SLAMS or SLAMS-related $PM_{2.5}$ monitoring. But not all types of equivalent methods may be equally suited to various $PM_{2.5}$ monitoring requirements or applications.

Class I equivalent methods are very similar to reference methods, with only minor deviations, and must meet nearly all of the reference method specifications and requirements. The requirements for designation as Class I equivalent methods are only slightly more extensive than the designation requirements for reference methods. Also, because of their substantial similarity to reference methods, Class I equivalent methods operate very much the same as reference methods.

Class II equivalent methods are filter-collection-based methods that differ more substantially from the reference method requirements. The requirements for designation as Class II methods may be considerably more extensive than for reference or Class I equivalent methods, depending on the specific nature of the variance from the reference method requirements.

Class III equivalent methods cover any $PM_{2.5}$ methods that cannot qualify as reference or Class I or II equivalent methods because of more profound differences from the reference method requirements. This class encompasses $PM_{2.5}$ methods such as continuous or semi-continuous $PM_{2.5}$ analyzers and potential new $PM_{2.5}$ measurement technologies. The requirements for designation as Class III methods are the most extensive, and, because of the wide variety of $PM_{2.5}$ measurement principles that could be employed for candidate Class III equivalent methods, the designation requirements are not explicitly provided in 40 CFR Part 53.

Table 7-5. Performance Specifications for Automated Methods

Performance Parameter	Units	SO_2	O_3	CO	NO_2	Def and test procedure-Sec.
1) Range	ppm	0-0.5	0-0.5	0-50	0-0.5	53.23(a)
2) Noise	ppm	0.005	0.005	0.50	0.005	53.23(b)
3) Lower detectable limit	ppm	0.01	0.01	1.0	0.01	53.23©
4) Interference equivalent Each Interferant Total Interferant	ppm	 ±.02 0.06	 ±.02 0.06	 ±.1.0 1.5	 ±.02 0.04	53.23(d)
5) Zero drift, 14 and 24 hour	ppm	±.02	±.02	±1.0	±.02	53.23(e)
6) Span drift, 24 hour 20% of upper range limit 80% of upper range limit	percent	 ±20.0 ±5.0	 ±20 ±5.0	 ± 10 ±2.5	 ±20 ±5.0	53.23(e)
7) Lag time	minutes	20	20	10	20	53.23(e)
8) Rise Time	minutes	15	15	5	15	53.23(e)
9) Fall Time	minutes	15	15	5	15	53.23(e)
10) Precision 20% of upper range limit 80% of upper range limit	ppm	 0.01 0.015	 0.01 0.01	 0.5 0.5	 0.02 0.03	53.23(e)

8. Sample Handling and Custody

A critical activity within any data collection phase is the process of handling samples in the field, through the transit stages, through storage and through the analytical phases. Documentation ensuring that proper handling has occurred is part of the custody record.

8.1 Sample Handling

In the Ambient Air Quality Monitoring Program, only the manual methods of lead, particulates (PM_{10} and $PM_{2.5}$), and PAMS samples are handled. In particular, one must pay particular attention to the handling of filters for $PM_{2.5}$. It has been suggested that the process of filter handling may be where the largest portion of measurement error occurs. Due to the manner in which concentrations are determined, it is critical that samples are handled as specified in SOPs. The various phases of sample handling include:

- labeling,
- sample collection, and
- transportation.

8.1.1 Sample Labeling and Identification

Care must be taken to properly mark all samples and monitoring device readings to ensure positive identification throughout the test and analysis procedures. The rules of evidence used in legal proceedings require that procedures for identification of samples used in analyses form the basis for future evidence. An admission by the laboratory analyst that he/she cannot be positive whether he/she analyzed sample No. 6 or sample No. 9, for example, could destroy the validity of the entire test report.

Positive identification also must be provided for any filters used in the program. If ink is used for marking, it must be indelible and unaffected by the gases and temperatures to which it will be subjected. Other methods of identification can be used (bar coding), if they provide a positive means of identification and do not impair the capacity of the filter to function.

Each sampling transport container should have a unique identification to preclude the possibility of interchange. The number of the container should be subsequently recorded on the analysis data form. Figure 8.1 shows a standardized identification sticker which may be used. Additional information may be added as required, depending on the particular monitoring program.

Samples must be properly handled to ensure that there is no contamination and that the sample analyzed is actually the sample taken under the conditions reported. For this reason, samples should be kept in a secure place between the time they are collected and the time they are analyzed. It is highly recommended that all samples be secured until discarded. These security measures should be documented by a written record signed by the handlers of the sample.

Strip charts from automated analyzers must also be clearly and unambiguously identified. The information must be placed upon each strip chart so as not to interfere with any of the data on the chart. If the strip chart is very long, the information should be placed at periodic intervals on the chart. The markings should be indelible and permanently affixed to each strip chart.

(Name of Sampling Organization)

Sample ID No: _____

Sample Type: _____

Date Collected: _____

Site Name: _____

Site Address: _____

Sampler: _____

Figure 8.1 Example sample label

8.1.2 Sample Collection

To reduce the possibility of invalidating the results, all collected samples must be carefully removed from the monitoring device and placed in sealed, nonreactive containers. The best method of sealing depends on the container; in general, the best way is to simply use a piece of tape to preclude accidental opening of the container and to act as a sufficient safeguard where all other aspects of the chain-of-custody procedure are observed. However, when there is any possibility of temporary access to the samples by unauthorized personnel, the sample containers or envelopes should be sealed with a self-adhesive sticker which has been signed and numbered by the operating technician. This sticker must adhere firmly to ensure that it cannot be removed without destruction. The samples should then be delivered to the laboratory for analysis. It is recommended that this be done on the same day that the sample is taken from the monitor. If this is impractical, all the samples should be placed in a carrying case (preferably locked) for protection from breakage, contamination, and loss.

8.1.3 Transportation

In transporting samples and other monitoring data, it is important that precautions be taken to eliminate the possibility of tampering, accidental destruction, and/or physical and chemical action on the sample. Attributes that can effect the integrity of samples include temperature extremes, air pressure (air transportation) and the physical handling of samples (packing, jostling, etc.). These practical considerations must be dealt with on a site-by-site basis and should be documented in the organizations QAPP and site specific SOPs .

The person who has custody of the samples, strip charts, or other data must be able to testify that no tampering occurred. Security must be continuous. If the samples are put in a vehicle, lock the vehicle. After delivery to the laboratory, the samples must be kept in a secured place.

To ensure that none of the sample is lost in transport, mark all liquid levels on the side of the container with a grease pencil. Thus, any major losses which occur will be readily ascertainable.

When using passivated stainless steel canisters for PAMS, the canister pressure, upon receipt, should be recorded and compared to the final sample collection pressure to indicate canister leakage and sample loss.

8.2 Chain Of Custody

If the results of a sampling program are to be used as evidence, a written record must be available listing the location of the data at all times. This chain-of custody record is necessary to make a prima facie showing of the representativeness of the sampling data. Without it, one cannot be sure that the sampling data analyzed was the same as the data reported to have been taken at a particular time. The data should be handled only by persons associated in some way with the test program. A good general rule to follow is "the fewer hands the better," even though a properly sealed sample may pass through a number of hands without affecting its integrity.

Each person handling the samples or strip charts must be able to state from whom the item was received and to whom it was delivered. It is recommended practice to have each recipient sign a chain-of-custody form for the sampling data. Figure 8.2 is an example of a form which may be used to establish the chain of custody. This form should accompany the samples or strip charts at all times from the field to the laboratory. All persons who handle the data should sign the form.

When using the U.S. Postal Service to transport sampling data, only certified or registered mail should be used, and a return receipt should be requested. When using the United Parcel Service, or similar means of shipment, information describing the enclosed sampling data should be placed on the bill of lading. Similarly, when using next-day services, a copy of the receipt, including the air bill number, should be kept as a record. The package should be marked "Deliver to Addressee Only," and it should be addressed to the specific person authorized to receive the package.

W.O. No	Project Name	Sample Type	Number & Type of Container						Remarks
Samplers: (Signature)									

Sta. No.	Date	Time	Station Description								

Relinquished By: (signature)	Date	Time	Received By: (signature)	(Print)	Comments

Figure 8.2 Example field chain of custody form

Once the samples arrive at their destination, the samples should first be checked to ensure that their integrity is intact. Any samples whose integrity are questionable should be flagged and these flags should be "carried" along with the data until the validity of the samples can be proven. This information can be included in the remark section of Figure 8.2 or documented on another form. A chain of custody form should be used to track the handling of the samples through various stages of storage, processing and analysis at the laboratory. Figure 8.3 is an example of a laboratory chain of custody form.

Laboratory/Plant: _____

Sample Number	Number of Container	Sample Description

Person responsible for samples Time: Date:

Sample Number	Relinquished By:	Received By:	Time:	Date:	Reason for change in custody

Figure 8.3 Example laboratory chain of custody form

9. Analytical Methods

The choice of methods used for any EDO should be influenced by the DQO. From the DQO and an understanding of the potential population uncertainty, one can then determine what measurement uncertainty is tolerable and select the method most appropriate in meeting that tolerance. Methods are usually selected based upon their performance characteristics (precision, bias, limits of detection), ease of use, and their reliability in field and laboratory conditions.

Since both field and analytical procedures have been developed for the criteria pollutants in the Ambient Air Quality Monitoring Program, and can be found in Part II of this document, this section will discuss the general concepts of standard operating procedures and good laboratory practices as they relate to the reference and equivalent methods.

1 Standard Operating Procedures

In order to perform sampling and analysis operations consistently, standard operating procedure (SOPs) must be written as part of the QAPP. Standard operating procedures (SOPs) are written documents that detail the method for an operation, analysis, or action with thoroughly prescribed techniques and steps and is officially approved as the method for performing certain routine or repetitive tasks[9].

SOPs should ensure consistent conformance with organizational practices, serve as training aids, provide ready reference and documentation of proper procedures, reduce work effort, reduce error occurrences in data, and improve data comparability, credibility, and defensibility. They should be sufficiently clear and written in a step-by-step format to be readily understood by a person knowledgeable in the general concept of the procedure. Elements to include in SOPs are:

1. Scope and Applicability
2. Summary of Method
3. Definitions
4. Health and Safety Warnings
5. Cautions
6. Interferences
7. Personnel Qualifications
8. Apparatus and Materials
9. Instrument or Method Calibration
10. Sample Collection
11. Handling and Preservation Sample Preparation and Analysis
12. Troubleshooting
13. Data Acquisition, Calculations & Data Reduction
14. Computer Hardware & Software (used to manipulate analytical results and report data)
15. Data Management and Records Management

SOPs should follow the guidance document *Guidance for the Preparation of Standard Operating Procedures* EPA QA/G-6[42]. Copies of this document are available through the QAD office as well as the QAD Homepage *(http://es.epa.gov/ncerqa)*.

Many of these operational procedures listed above are included in the EPA reference and equivalent methods, and EPA guidance documents. However, it is the organization's responsibility to develop its own unique written operational procedures applicable to air quality measurements made by the organization.

SOPs should be written by individuals performing the procedures that are being standardized. SOPs for the Ambient Air Quality Monitoring Program environmental data operations must be included in QAPPs, either by reference or by inclusion of the actual method. If a method is referenced, it must be stated that the method is followed exactly or an addendum that explains changes to the method must be included in the QAPP. If a modified method will be used for an extended period of time, the method should be revised to include the changes to appropriate sections. In general, approval of SOPs occur during the approval of the QAPP. Individuals with appropriate training and experience with the particular SOPs in the QAPP need to review the SOPs.

9.2 Good Laboratory Practices

Good laboratory practices (GLPs) refer to general practices that relate to many, if not all of the measurements made in a laboratory. They are usually independent of the SOP and cover subjects such as maintenance of facilities, records, sample management and handling, reagent control, and cleaning of laboratory glassware[99]. In many cases the activities mentioned above may not be formally documented because they are considered common knowledge. Although not every activity in a laboratory needs to be documented, the activities that could potentially cause unnecessary measurement uncertainties, or have caused significant variance or bias, should be cause to generate a method.

In 1982, the Organization for Economic Co-operation and Development (OECD) developed principles of good laboratory practice. The intent of GLP is to promote the quality and validity of test data by covering the process and conditions under which EDOs are planned, performed, monitored, recorded and reported. The principles include[97] :

- test facility organization and personnel
- quality assurance program
- facilities
- apparatus, material and reagents
- test systems
- test and reference substances
- standard operating procedures
- performance of the study
- reporting of study results
- storage and retention of records and material

9.3 Laboratory Activities

For ambient air samples to provide useful information or evidence, laboratory analyses must meet the following four basic requirements:

1. Equipment must be frequently and properly calibrated and maintained (Section 12).
2. Personnel must be qualified to make the analysis (Section 4).
3. Analytical procedures must be in accordance with accepted practice (Section 9.1 above).
4. Complete and accurate records must be kept (Section 5).

As indicated, these subjects are discussed in other sections of this document. For the Ambient Air Quality Monitoring Program, laboratory activities are mainly focused on the pollutants associated with manual measurements; basically lead, particulate matter, and PAMS (VOCs). However, many laboratories also prepare reference material, test or certify instruments, and perform other activities necessary to collect and report measurement data. Each laboratory should define these critical activities and ensure there are consistent methods for their implementation.

10. Quality Control

Quality Control (QC) is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer[9]. QC is both corrective and proactive in establishing techniques to prevent the generation of unacceptable data, and so the policy for corrective action should be outlined. In the case of the Ambient Air Quality Monitoring Program, QC activities are used to ensure that measurement uncertainty, as discussed in Section 4, is maintained within acceptance criteria for the attainment of the DQO. Figure 10.1 describes the process of accepting routine data, which includes implementing and evaluating QC activities. The QAD document titled *EPA Guidance for Quality Assurance Project Plans*[31] provides additional guidance on this subject. This document is available on the EPA QA Division Homepage *(http://es.epa.gov/ncerqa/qa/)*.

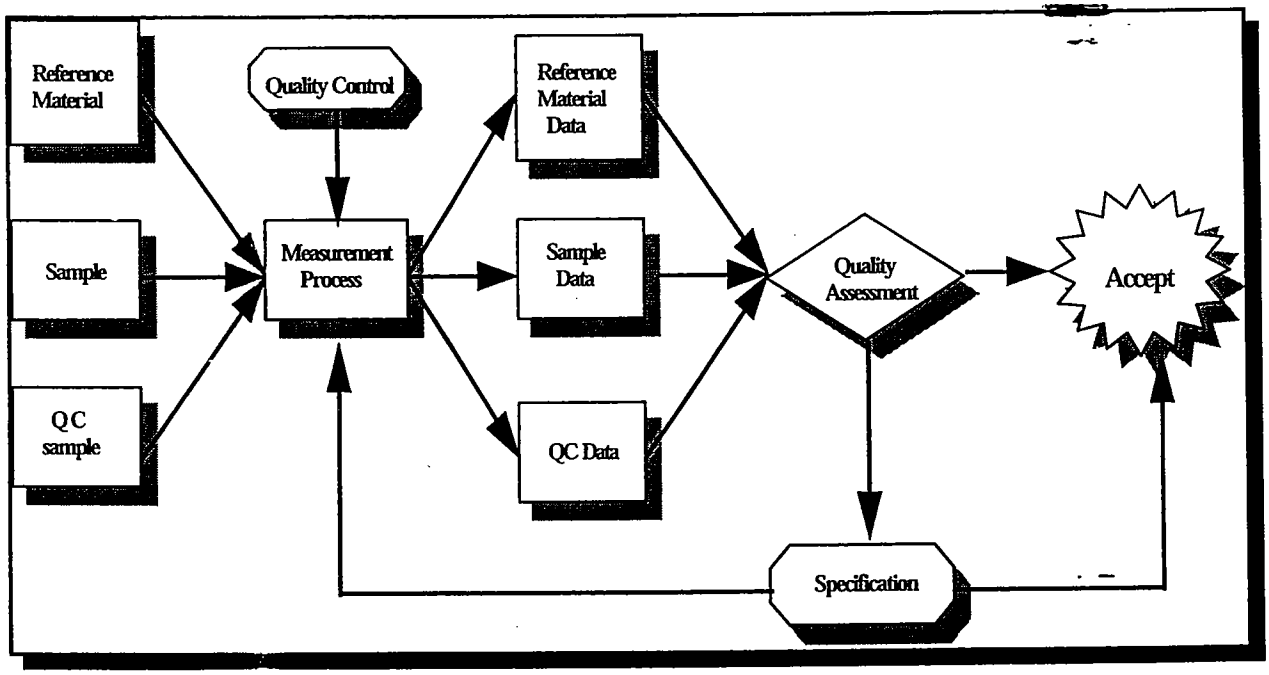


Figure 10.1 Flow diagram of the acceptance of routine data values

There is a wide variety of techniques that fall under the category of QC. Figure 10.2 lists a number of these activities. Figures 10.1 and 10.2 illustrate the types QC and quality assessment activities used to assess data quality. For the Ambient Air Quality Monitoring Program, 40 CFR Part 58 Appendix A[14], and the federal reference and equivalent methods in Part II of this document discuss a number of QC checks that are to be used. The MQO tables included in Appendix 3 also identify the most critical QC samples. However, it is the responsibility of the State and local organizations through the development of their QAPP and quality system to develop and document the:

- QC techniques
- frequency of the check and the point in the measurement process in which the check is introduced
- traceability of standards
- matrix of the check sample
- level of concentration of analyte of interest

- actions to be taken in the event that a QC check identifies a failed or changed measurement system
- formulae for estimating data quality indicators
- procedures for documenting QC results, including control charts
- description of how the data will be used to determine that measurement performance is acceptable

Tables 10-1 and 10-2 provide an example of the QC criteria established for the $PM_{2.5}$ network. Some of the elements identified above are included in this table.

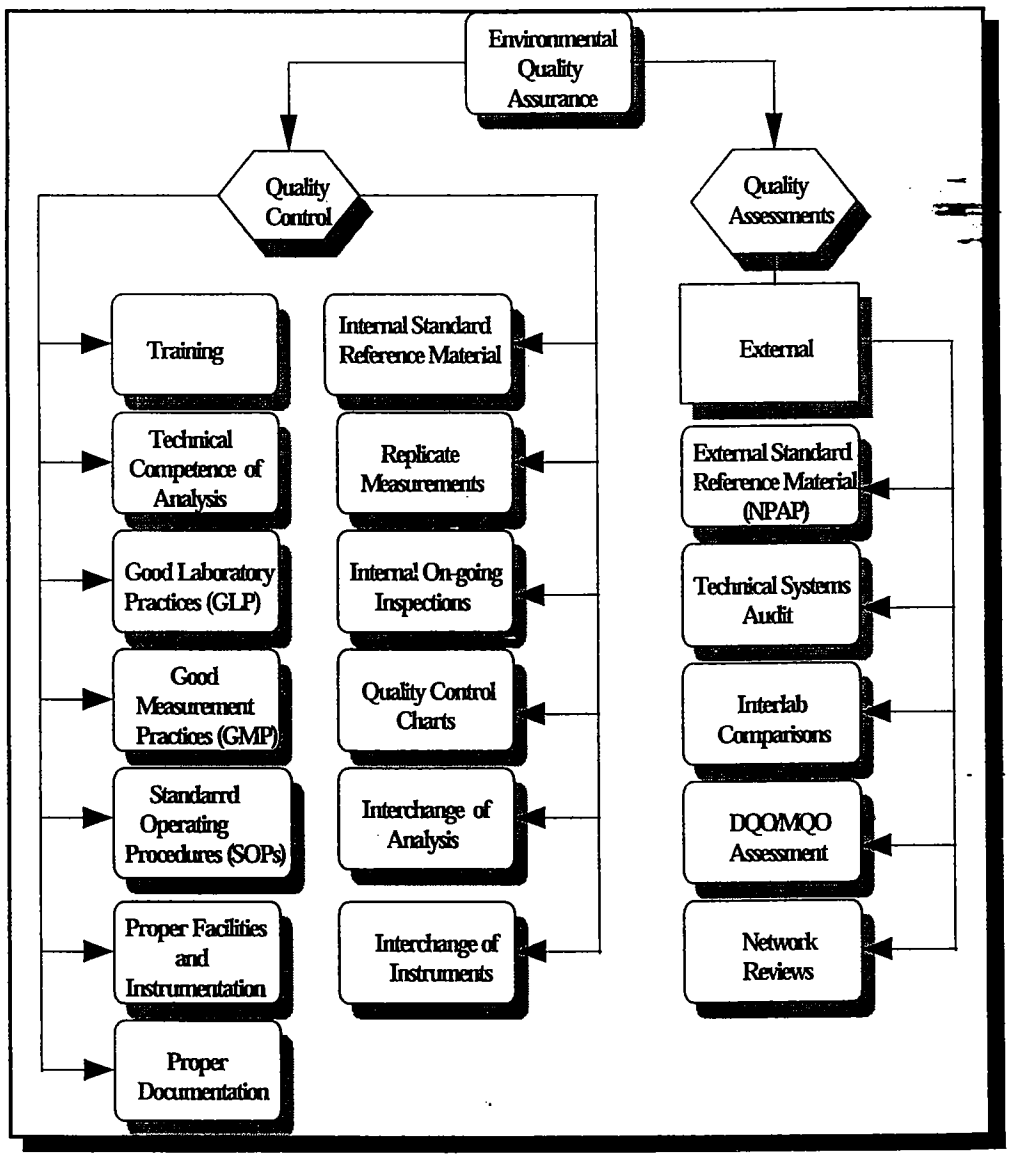


Figure 10.2 Types of quality control and quality assessment activities

Table 10-1 $PM_{2.5}$ Field QC Checks

Requirement	Frequency	Acceptance Criteria	CFR Reference	2.12 Reference	Information Provided
Calibration Standards					
Flow Rate Transfer Std.	1/yr	±2% of NIST-traceable Std.	Part 50, App.L Sec 9.1, 9.2	Sec. 6.3	Certification of Traceability
Field Thermometer	1/yr	± 0.1° C resolution	not described	Sec 4.2 and 8.3	Certification of Traceability
		± 0.5° C accuracy	not described	"	
Field Barometer	1/yr	± 1 mm Hg resolution	not described	"	Certification of Traceability
		± 5 mm Hg accuracy	not described	"	
Calibration/Verification					
Flow Rate (FR) Calibration	If multi-point failure	± 2% of transfer standard	Part 50, App.L, Sec 9.2	Sec 6.3 and 6.6	Calibration drift and memory effects
FR multi-point verification	1/yr	± 2% of transfer standard	Part 50, App.L, Sec 9.2.5	Sec 8.3	Calibration drift and memory effects
One point FR verification	1/4 weeks	± 4% of transfer standard		Sec 8.3	Calibration drift and memory effects
External Leak Check	every 5 sampling events	80 mL/min	Part 50, App.L, Sec 7.4	Sec. 8.3	Sampler function
Internal Leak Check	every 5 sampling events	80 mL/min	"	Sec. 8.3	Sampler function
Temperature Calibration	If multi-point failure	± 2% of standard	Part 50, App.L, Sec 9.3	Sec. 6.4	Calibration drift and memory effects
Temp multi-point verification	on installation, then 1/yr	± 2 C of standard	Part 50, App.L, Sec 9.3	Sec. 6.4 and 8.2	Calibration drift and memory effects
One- point temp Verification	1/4 weeks	± 4 C of standard	"	Sec. 6.4 and 8.2	Calibration drift and memory effects
Pressure Calibration	on installation, then 1/yr	±10 mm Hg	"	Sec. 6.5	Calibration drift and memory effects
Pressure Verification	1/4 weeks	±10 mm Hg	"	Sec. 8.2	Calibration drift and memory effects
Clock/timer Verification	1/ 4 weeks	1 min/mo	Part 50, App.L, Sec 7.4	not described	Verification of to assure proper function
Blanks					
Field Blanks	See 2.12 reference	±30 ug	Part 50, App.L Sec 8.2	Sec. 7.10	Measurement system contamination
Precision Checks					
Collocated samples	every 6 days	CV ≤ 10%	Part 58, App.A, Sec 3.5, 5.5	Sec. 10.3	Measurement system precision
Accuracy					
Flow rate audit	1/2wk (automated)	± 4% of transfer standard	Part 58, App A, Sec 3.5.1	Sec. 8.1	Instrument bias/accuracy
	1/3mo (manual)				
External Leak Check	4/yr	< 80 mL/min		"	Sampler function
Internal Leak Check	4/yr	< 80 mL/min	not described	"	Sampler function
Temperature Check	4/yr	± 2 C	not described	"	Calibration drift and memory effects
Pressure Check	4/yr (?)	±10 mm Hg	not described	"	Calibration drift and memory effects
Audits *(external assessments)*					
FRM Performance audit	25% of sites 4/yr	± 10%	Part 58, App A, Sec 3.5.3	Sec 10.3	Measurement system bias
Flow rate audit	1/yr	± 4% of audit standard	not described	Sec 10.2	External verification bias/accuracy
External Leak Check	1/yr	< 80 mL/min	not described		Sampler function
Internal Leak Check	1/yr	< 80 mL/min	not described		Sampler function
Temperature Audit	1/yr	± 2 C	not described		Calibration drift and memory effects
Pressure Audit	1/yr	±10 mm Hg	not described		Calibration drift and memory effects

Table $10_{-2\ PM2.5}$ Laboratory QC Checks

Requirement	Frequency	Acceptance Criteria	QA Guidance Document 2.12 Reference	Information Provided
Blanks				
Lot Blanks	3-lot	±15 ug difference	2.12 Sec. 7	Filter stabilization/equilibrium
Lab Blanks	3 per batch	±15 ug difference	Part 50, App.L Sec 8.2 2.12 Sec. 7.10	Laboratory contamination
Calibration/Verification				
Balance Calibration	1/yr	Manufacturers spec.	2.12 sec 7.2	Verification of equipment operation
Lab Temp. Calibration	3 mo	± 2 C	QAPP Sec. 13/16	Verification of equipment operation
Lab Humidity Calibration	3 mo	±2%	QAPP Sec. 13/16	Verification of equipment operation
Accuracy				
Balance Audit	1/year	±15 g for unexposed filters	2.12 Sec 10.2	Laboratory technician operation
Balance Check	beginning, every 10th samples, end	≤3 ug	2.12 Sec. 7.8	Balance accuracy/stability
Calibration standards				
Working Mass Stds.	3-6 mo.	25 ug	2.12 Sec 4.3 and 7.3	Standards verification
Primary Mass Stds.	1/yr	25 ug	"	Primary standards verification
Precision				
Duplicate filter weighings	1 per weighing session	±15 ug difference	2.12 Tab 7-1 QAPP Sec. 13/16	Weighing repeatability/filter stability

Other elements of an organization's QAPP that may contain related sampling and analytical QC requirements include:

- **Sampling Design,** which identifies the planned field QC samples as well as procedures for QC sample preparation and handling;
- **Sampling Methods Requirements**, which includes requirements for determining if the collected samples accurately represent the population of interest;
- **Sample Handling and Custody Requirements**, which discusses any QC devices employed to ensure samples are not tampered with (e.g., custody seals) or subjected to other unacceptable conditions during transport;
- **Analytical Methods Requirements**, which includes information on the subsampling methods and information on the preparation of QC samples (e.g., blanks and replicates); and
- **Instrument Calibration and Frequency**, which defines prescribed criteria for triggering recalibration (e.g., failed calibration checks).

10.1 Use of Computers for Quality Control

With the wide range of economical computers now available, consideration should be given to a computer system that can process and output the information in a timely fashion. Such a computer system should be able to:

- compute calibration equations
- compute measures of linearity of calibrations (e.g., standard error or correlation coefficient)
- plot calibration curves
- compute zero/span drift results
- plot zero/span drift data
- compute precision and accuracy results
- compute control chart limits
- plot control charts
- automatically flag out-of-control results
- maintain and retrieve calibration and performance records

11. Instrument Equipment Testing, Inspection, and Maintenance

Implementing an ambient air monitoring network, with the various types of equipment needed, is no easy task. It is important that all equipment used to produce data are tested, inspected, and maintained in sound condition. Every piece of equipment has an expected life span. Through proper testing, inspection and maintenance programs, organizations can be assured that equipment is capable of operating at acceptable performance levels.

Some procedures for equipment testing, inspection and maintenance are explained below or in other sections. Due to the enormous amount of equipment that potentially could be used in the Ambient Air Monitoring Program, this section can not provide guidance on each type of equipment. In most cases, the manufacturers of the equipment provide inspection and maintenance information in the operating manuals. What is important is that State and local organizations, in the development of the QAPP and a quality system, should address the scheduling and documentation of routine testing, inspection and maintenance. Many organizations develop detailed maintenance documents for ambient air monitoring; some for each monitoring site. Elements to include in testing, inspection and maintenance documents would include:

- equipment lists - by organization or station
- spare equipment/parts lists - by equipment, including suppliers
- inspection/maintenance frequency - by equipment
- testing frequency and source of the test concentrations or equipment
- equipment replacement schedules
- sources of repair- by equipment
- service agreements that are in place
- monthly check sheets and entry forms for documenting testing, inspection, maintenance performed

Testing, inspection and maintenance procedures should be available at each monitoring station.

11.1 Instrumentation

11.1.1 Analyzers

Except for the specific exceptions described in Appendix C of Part 58[16], monitoring methods used for SLAMS monitoring must be a reference or equivalent method, designated as such by the 40 CFR Part 53[23] (see Section 7.3). Among reference and equivalent methods, a variety of analyzer designs and features are available. For some pollutants, analyzers employing different measurement principles are available, and some analyzer models provide a higher level of performance than others that may only meet the minimum performance specifications (see Table 7-5). Accordingly, in selecting a designated method for a particular monitoring application, consideration should be given to such aspects as:

- the suitability of the measurement principle
- analyzer sensitivity
- susceptibility to interferences that may be present at the monitoring site
- requirements for support gases or other equipment
- reliability
- maintenance requirements
- initial as well as operating costs

- features such as internal or fully automatic zero and span checking or adjustment capability, etc.

References 60, 68 69, 70 and 95 may be helpful in evaluating and selecting automated analyzers. It is important that the purchase order for a new reference or equivalent analyzer specify the designation by the EPA and document the required performance specifications, terms of the warranty, time limits for delivery and for acceptance testing, and what happens in the event that the analyzer delivered falls short of the requirements[60]. Upon receiving the new analyzer, the user should carefully read the instruction or operating manual provided by the manufacturer of the analyzer. The manufacturer's manual should contain information or instructions concerning:

- unpacking and verifying that all component parts were delivered
- checking for damage during shipment
- checking for loose fittings and electrical connections
- assembling the analyzer
- installing the analyzer
- calibrating the analyzer
- operating the analyzer
- preventive maintenance schedule and procedures
- trouble shooting
- list of expendable parts

Following analyzer assembly, an initial verification that the instrument is calibrated should be performed to determine if the analyzer is operating properly. Analyzer performance characteristics such as response time, noise, short-term span and zero drift, and precision should be checked during the initial calibration or measured by using abbreviated forms of the test procedures provided in 40 CFR Part 53[23]. Acceptance of the analyzer should be based on results from these performance tests[60]. Once accepted, reference and equivalent analyzers are warranted by the manufacturer to operate within the required performance limit for one year[23].

11.1.2 Support Instrumentation

Experience of the State and local staff plays the major role in the selection of support equipment. Preventive maintenance, ease of maintenance, and general reliability play a crucial role in the selection of support equipment. The following examples show some support equipment and some typical features to look for when selecting this equipment.

- **Calibration Standards:** Calibration standards are normally two types: Mass Flow Controlled (MFC) or permeation devices. See Appendix 12 for details on these type of devices. Normally, it is recommended that they are 110 VAC, compatible with DAS systems for automated calibrations and have true transistor-transistor logic (TTL).
- **Data Acquisition Systems (DAS):** It is recommended that DAS have 16 bit logic, have modem capabilities, allow remote access and control and be able to initiate automated calibrations.
- **Analog Chart Recorders:** It is recommended that chart recorders be able to have multi-pen capablities, accept multi-voltage inputs (i.e, be able to accept 1, 5 or 10 volt inputs) and be programmable.
- **Instrument Racks:** Instrument racks should be constructed of steel and be able to accept sliding trays or rails. Open racks help to keep instrument temperature down and allow air to circulate through easily.

- **Zero Air Systems:** Zero air systems should be able to deliver 10 liters/min of air that is free of contaminants, be free of ozone, NO, NO_2, SO_2 to 0.001 ppm and CO and Hydrocarbons to 0.1 ppm. There are many commercially available systems. However, simple designs can be obtained by using a series of canisters. See Section 12 for more guidance on zero air.

11.1 3 Laboratory Support

State and local agencies should employ full laboratory facilities. These facilities should be equipped with all equipment to test, repair, troubleshoot and calibrate all analyzers and support equipment necessary to operate the Ambient Air Monitoring Networks. In some cases, a State or local agency may have a central laboratory.

The laboratory should be designed to accommodate the air quality lab/shop and PM_{10} and $PM_{2.5}$ filter rooms, and enforcement instrumentation support activities. The air quality portion consists of several benches flanked by instrument racks. One bench and rack are dedicated to ozone traceability. The other instrument racks are designated for calibration and repair. A room should be set aside to house spare parts and extra analyzers.

A manifold/sample cane should be mounted behind the bench. If possible, mount a sample cane through the roof to allow any analyzers that are being tested to sample outside air. Any excess calibration gas can be exhausted to the atmosphere. It is recommended that the pump room be external to the building to eliminate noise.

Each bench area should have an instrument rack that is attached to the bench. The instrument rack should be equipped with sliding trays or rails that allow easy installation of instruments. If instrumentation needs to be repaired and then calibrated, this can be performed on the bench top or within the rack. Analyzers then can be allowed to warm up and be calibrated by a calibration unit. Instruments that are to be tested are connected to the sample manifold and allowed to sample air in the same manner as if the analyzer is being operated within a monitoring station. The analyzer's analog voltage is connected to a DAS and chart recorder and allowed to operate. If intermittent problems occur, then they can be observed on the chart recorder. The analyzer can be allowed to operate over several days to see if the anomaly or problem reappears. If it does, there is a chart record of the problem. If the instrument rack has a DAS and calibrator, nightly auto calibrations can be performed to see how the analyzer reacts to known gas concentrations. In addition, the ozone recertification bench and rack are attached to a work bench. The rack should house the ozone primary standard, and the ozone transfer standards that are being checked for recertification. Zero air is plumbed into this rack for the calibration and testing of ozone analyzers and transfer standards.

11.2 Preventive Maintenance

Every State and local agency should develop a preventive maintenance program. Preventive maintenance is what its name implies; maintaining the equipment within a network to prevent downtime and costly repairs. Preventive maintenance is an ongoing portion of quality control. Since this is an ongoing process, it normally is enveloped into the daily routines. In addition to the daily routines, there are monthly, quarterly, semi-annually, and annually scheduled activities that must be performed.

Preventive maintenance is the responsibility of the station operators and the supervisory staff. It is important that the supervisor reviews the preventive maintenance work, and continually checks the schedule. The supervisor is responsible for making sure that the preventive maintenance is being accomplished in a

timely manner. Preventive maintenance is not a static process. Procedures must be updated for many reasons, including but not limited to new models or types of instruments and new or updated methods. Each piece of equipment (analyzers and support equipment) should have a bound notebook that contains all preventive maintenance and repair data for that particular instrument. This notebook should stay with the instrument wherever it travels.

The preventive maintenance schedule is changed whenever an activity is moved or is completed. For instance, if a multipoint calibration is performed in February instead of the March date, then the six month due date moves from August to September. The schedule is constantly in flux because repairs must be followed by calibrations or verifications. On a regular basis, the supervisor should review the preventive maintenance schedule with the station operators.

11.2.1 Instrumentation Log

Each instrument and support equipment (with the exception of the instrument racks) should have a Instrumentation Repair Log. The log can be a folder or bound notebook that contains the repair and calibration history of that particular instrument. Whenever multipoint calibrations, instrument maintenance, repair, or relocation occur, detailed notes are written in the instrumentation log. The log contains the most recent multipoint calibration report, a preventive maintenance sheet, and the acceptance testing information. If an instrument is malfunctioning and a decision is made to relocate that instrument, the log travels with that device. The log can be reviewed by staff for possible clues to the reasons behind the instrument malfunction. In addition, if the instrument is shipped to the manufacturer for repairs, the log always travels with the instrument. This helps the non-agency repair personnel with troubleshooting instrument problems.

11.2.2 Station Maintenance

Station maintenance is a portion of preventive maintenance that does not occur on a routine basis. These tasks usually occur on an "as needed" basis. The station maintenance items are checked monthly or whenever an agency knows that the maintenance needs to be performed. Examples of some station maintenance items include:

- floor cleaning
- shelter inspection
- air conditioner repair
- AC filter replacement
- weed abatement
- roof repair
- general cleaning

11.2.3 Station Log

The station log is a chronology of the events that occur at the monitoring station. The log is an important part of the equation because it contains the narrative of problems and solutions to problems. The site log notes should be written in a narrative rather than technical details. The technical details belong in the instrumentation log. The items that belong in the station log are:

- the date, time, and initials of the person(s) who have arrived at the site
- brief description of the weather (i.e., clear, breezy, sunny, raining)
- brief description of exterior of the site. Any changes that might affect the data, for instance, if someone is parking a truck or tractor near the site, this may explain high NOx values, etc.
- any unusual noises, vibrations or anything out of the ordinary
- description of the work accomplished at the site (i.e., calibrated instruments, repaired analyzer)
- detailed information about the instruments that may be needed for repairs or troubleshooting

11.2.4 Routine Operations

Routine operations are the checks that occur at specified periods of time during a monitoring station visit. The duties are the routine day-to-day operations that must be performed in order to operate a monitoring network at optimal levels. Some typical routine operations are detailed in Table 11-1.

Table 11-1 Routine Operations

Item	Each Visit	Weekly	Monthly
Print Data	X		
Mark Charts	X		
Check Exterior		X	
Change Filters.		X	
Drain Compressor		X	
Leak Test		X	
Check Desiccant			X
Inspect tubing			X
Inspect manifold and cane			X
Check electrical connections			X

In addition to these items, the exterior of the building, sample cane, meteorological instruments and tower, entry door, electrical cables and any other items deemed necessary to check should be inspected for wear, corrosion and weathering. Costly repairs can be avoided in this manner.

12. Instrument Calibration and Frequency

Prior to the implementation of a sampling and analysis program, a variety of sampling and analysis equipment must be calibrated. All data and calculations involved in these calibration activities should be recorded in a calibration log book. It is suggested that this log be arranged so that a separate section is designated for each apparatus and sampler used in the program.

In some cases, reagents are prepared prior to sampling. Some of these reagents will be used to calibrate the equipment, while others will become an integral part of the sample itself. In any case, their integrity must be carefully maintained from preparation through analysis. If there are any doubts about the method by which the reagents for a particular test were prepared or about the competence of the laboratory technician preparing these items, the credibility of the ambient air samples and the test results will be diminished. It is essential that a careful record be kept listing the dates the reagents were prepared, by whom, and their locations at all times from preparation until actual use. Prior to the test, one individual should be given the responsibility of monitoring the handling and the use of the reagents. Each use of the reagents should be recorded in a field or lab notebook.

Calibration of an analyzer establishes the quantitative relationship between actual pollutant concentration input (in ppm, ppb, ug/m^3, etc.) and the analyzer's response (chart recorder reading, output volts, digital output, etc.). This relationship is used to convert subsequent analyzer response values to corresponding pollutant concentrations. Since the response of most analyzers has a tendency to change somewhat with time (drift), the calibration must be updated (or the analyzer's response must be adjusted) periodically to maintain a high degree of accuracy. Each analyzer should be calibrated as directed by the analyzer's operation or instruction manual and in accordance with the general guidance provided here. For reference methods for CO, NO_2, and O_3, detailed calibration procedures may also be found in the appropriate appendix to 40 CFR Part 50[21]. Additional calibration information is contained in References 29, 30, 76, 77, 100 and 111 and in Part II.

Calibrations should be carried out at the field monitoring site by allowing the analyzer to sample test atmospheres containing known pollutant concentrations. The analyzer to be calibrated should be in operation for at least several hours (preferably overnight) prior to the calibration so that it is fully warmed up and its operation has stabilized. During the calibration, the analyzer should be operating in its normal sampling mode, and it should sample the test atmosphere through all filters, scrubbers, conditioners, and other components used during normal ambient sampling and through as much of the ambient air inlet system as is practicable. All operational adjustments to the analyzer should be completed prior to the calibration (see section 12.7). Analyzers that will be used on more than one range or that have autoranging capability should be calibrated separately on each applicable range.

Calibration documentation should be maintained with each analyzer and also in a central backup file. Documentation should be readily available for review and should include calibration data, calibration equation(s) (and curve, if prepared), analyzer identification, calibration date, analyzer location, calibration standards used and their traceabilities, identification of calibration equipment used, and the person conducting the calibration.

12.1 Calibration Standards

In general, ambient monitoring instruments should be calibrated by allowing the instrument to sample and analyze test atmospheres of known concentrations of the appropriate pollutant in air. All such (non-zero) test concentrations must be, or be derived from, local or working standards (e.g., cylinders of compressed gas or permeation devices) that are certified as traceable to a NIST primary standard. "Traceable" is defined in 40 CFR Parts 50[21] and 58[24] as meaning *" ... that a local standard has been compared and certified, either directly or via not more than one intermediate standard, to a primary standard such as a National Institute of Standards and Technology Standard Reference Material (NIST SRM) or a USEPA/NIST-approved Certified Reference Material (CRM)"*. Normally, the working standard should be certified directly to the SRM or CRM, with an intermediate standard used only when necessary. Direct use of a CRM as a working standard is acceptable, but direct use of an NIST SRM as a working standard is discouraged because of the limited supply and expense of SRM's. At a minimum, the certification procedure for a working standard should:

- establish the concentration of the working standard relative to the primary standard
- certify that the primary standard (and hence the working standard) is traceable to an NIST primary standard
- include a test of the stability of the working standard over several days
- specify a recertification interval for the working standard

Certification of the working standard may be established by either the supplier or the user of the standard.

Test concentrations of ozone must be traceable to a primary standard UV photometer as described in 40 CFR Part 50 Appendix D[17]. Reference 67 describes procedures for certifying transfer standards for ozone against UV primary standards.

Test concentrations at zero concentration are considered valid standards. Although zero standards are not required to be traceable to a primary standard, care should be exercised to ensure that zero standards are indeed adequately free of all substances likely to cause a detectable response from the analyzer. Periodically, several different and independent sources of zero standards should be compared. The one that yields the lowest response can usually (but not always) be assumed to be the "best zero standard". If several independent zero standards produce exactly the same response, it is likely that all the standards are adequate.

The accuracy of flow measurements is critically important in many calibration procedures. Flow or volume measuring instruments should be calibrated and certified at appropriate intervals (usually 3 to 6 months) against NIST or other authoritative standards such as a traceable bubble flow meter or gas meter. Flow rate verifications, calibrations, acceptance criteria, methods, and frequencies are discussed in individual methods found in Part II of this Volume of the Handbook.

12.2 Multi-point Calibrations

Multi-point calibrations consist of three or more test concentrations, including zero concentration, a concentration between 80% and 90% of the full scale range of the analyzer under calibration, and one or more intermediate concentrations spaced approximately equally over the scale range. Multi-point calibrations are used to establish or verify the linearity of analyzers upon initial installation, after major repairs and at specified frequencies. Most modern analyzers have a linear or very nearly linear response with concentration. If a non-linear analyzer is being calibrated, additional calibration points should be included to adequately define the calibration relationship, which should be a smooth curve. Multi-point calibrations are likely to be more accurate than two-point calibrations because of the averaging effect of the multiple points and because an error in the generation of a test concentration (or in recording the analyzer's response) is more likely to be noticed as a point that is inconsistent with the others. For this reason, calibration points should be plotted or evaluated statistically as they are obtained so that any deviant points can be investigated or repeated immediately.

Most analyzers have zero and span adjustment controls, which should be adjusted based on the zero and highest test concentrations, respectively, to provide the desired scale range within the analyzer's specifications (see section 12.5). For analyzers in routine operation, unadjusted ("as is") analyzer zero and span response readings should be obtained prior to making any zero or span adjustments . $NO/NO_2/NO_x$ analyzers may not have individual zero and span controls for each channel; the analyzer's operation/instruction manual should be consulted for the proper zero and span adjustment procedure. Zero and span controls often interact with each other, so the adjustments may have to be repeated several times to obtain the desired final adjustments.

After the zero and span adjustments have been completed and the analyzer has been allowed to stabilize on the new zero and span settings, all calibration test concentrations should be introduced into the analyzer for the final calibration. The final, post-adjusted analyzer response readings should be obtained from the same device (chart recorder, data acquisition system, etc.) that will be used for subsequent ambient measurements. The analyzer readings are plotted against the respective test concentrations, and the best linear (or nonlinear if appropriate) curve to fit the points is determined. Ideally, least squares regression analysis (with an appropriate transformation of the data for non-linear analyzers) should be used to determine the slope and intercept for the best fit calibration line of the form, $y = mx + a$, where y represents the analyzer response, x represents the pollutant concentration, m is the slope, and a is the x-axis intercept of the best fit calibration line. When this calibration relationship is subsequently used to compute concentration measurements (x) from analyzer response readings (y), the formula is transposed to the form, $x = (y - a)/m$.

As a quality control check on calibrations, the standard error or correlation coefficient can be calculated along with the regression calculations. A control chart of the standard error or correlation coefficient could then be maintained to monitor the degree of scatter in the calibration points and, if desired, limits of acceptability can be established.

12.3 Level 1 Zero and Span Calibration

A level 1 zero and span calibration is a simplified, two-point analyzer calibration used when analyzer linearity does not need to be checked or verified. Sometimes when no adjustments are made to the analyzer, the level 1 calibration may be called a zero/span check, in which case it must not be confused with a level 2 zero/span check (see 12.4). Since most analyzers have a reliably linear or near-linear output response with concentration, they can be adequately calibrated with only two concentration standards (two-point calibration). Furthermore, one of the standards may be zero concentration, which is relatively easily obtained and need not be certified. Hence, only one certified concentration standard is needed for the two-point (level 1) zero and span calibration. Although lacking the advantages of the multi-point calibration, the two-point zero and span calibration can be (and should be) carried out much more frequently. Also, two-point calibrations are easily automated. Frequent checks or updating of the calibration relationship with a 2-point zero and span calibration improves the quality of the monitoring data by helping to keep the calibration relationship more closely matched to any changes (drift) in the analyzer response.

As with any calibration, the analyzer should be operating in its normal sampling mode, and generally the test concentrations should pass through as much of the inlet and sample conditioning system as is practicable. For NO_2, SO_2, and particularly for O_3, wet or dirty inlet lines and particulate filters can cause changes in the pollutant concentration. For PAMS, sample inlet lines to the analyzer should be kept as short as possible. Efforts should be made, at least periodically, to introduce the span calibration concentration into the sampling system as close to the outdoor sample inlet point as possible. The calibration response under these conditions can then be compared to the response when the span concentration is introduced at the analyzer, downstream of the sample inlet components, as a check of the entire sample inlet system. Some CO analyzers may be temporarily operated at reduced vent or purge flows, or the test atmosphere may enter the analyzer at a point other than the normal sample inlet provided that such a deviation from the normal sample mode is permitted by the analyzer's operation or instruction manual and the analyzer's response is not likely to be altered by the deviation. Any such operational modifications should be used with caution, and the lack of effect should be verified by comparing test calibrations made before and after the modification. The standards used for a level 1 zero and span calibration must be certified traceable as described previously under Section 12.1. The span standard should be a concentration between about 70% and 90% of the analyzer's full scale measurement range. Adjustments to the analyzer may be made during the zero and span calibration. However, it is strongly recommended that unadjusted (i.e., "as is") analyzer response readings be obtained before any adjustments are made to the analyzer. As described later, these unadjusted zero and span readings provide valuable information for: (1) confirming the validity of (or invalidating) the measurements obtained immediately preceding the calibration, (2) monitoring the analyzer's calibration drift, and (3) determining the frequency of recalibration. Accordingly, the following procedure for a zero and span calibration is recommended:

1. Disconnect the analyzer's inlet from the ambient intake and connect it to a calibration system. Leave the analyzer in its normal sampling mode, and make no other adjustments to the analyzer (except as mentioned previously for some CO analyzers).
2. Sample and measure the span test concentration and record the unadjusted, stable ("as is") span response reading (S'). NOTE: All analyzer response readings should be recorded in the analyzer's normal output units, e.g., millivolts, percent of scale, etc. (the same units used for the calibration curve). If these units are concentration units they should be identified as "indicated" or "uncorrected" to

differentiate them from the "actual" concentration units that are used for reporting actual ambient concentration measurements.

3. Sample and measure the zero test concentration standard and record the unadjusted, stable zero reading (Z').
4. Perform any needed analyzer adjustments (flow, pressure, etc.) or analyzer maintenance.
5. If adjustment of the zero is needed (see sections 12.5 and 12.6) or if any adjustments have been made to the analyzer, adjust the zero to the desired zero reading. Record the adjusted, stable zero reading (Z). Note that if no zero adjustment is made, the Z=Z'. Offsetting the zero reading (e.g., to 5% of scale) may help to observe any negative zero drift that may occur. If an offset (A) is used, record the non-offset reading, that is, record Z-A.
6. Sample and measure the span test concentration. If span adjustment is needed (see sections 12.5 and 12.6), adjust the span response to the desired value, allowing for any zero offset used in the previous step. Record the final adjusted, stable span reading (S). If no span adjustment is made and no offset is used, then S = S'.
7. If any adjustments made to the zero, span, or other parameters or if analyzer maintenance was carried out, allow the analyzer to restabilize at the new settings, then recheck the zero and span readings and record new values for Z and S, if necessary.

If the calibration is updated for each zero/span calibration (see section 12.9), the new calibration relationship should be plotted using the Z and S readings, or the intercept and slope should be determined as follows:

$$I = intercept = Z$$

$$M = slope = \frac{S - Z}{span\ concentration}$$

12.3.1 Documentation

All level 1 zero or span calibrations should be documented in a chronological format. Documentation should include analyzer identification, date, standard used and its traceability, equipment used, the individual conducting the span calibration, the unadjusted zero and drift span responses, and the adjusted zero and span responses. Again, quality control charts are an excellent form of documentation to graphically record and track calibration results. See Section 12.6 for a discussion on control chats. Level 1 zero and span documentation should be maintained both in a central file and at the monitoring site.

12.4 Level 2 Zero and Span Check

A level 2 zero and span check is an "unofficial" check of an analyzer's response. It may include dynamic checks made with uncertified test concentrations, artificial stimulation of the analyzer's detector, electronic or other types of checks of a portion of the analyzer, etc. Level 2 zero and span checks are not to be used as a basis for analyzer zero or span adjustments, calibration updates, or adjustment of ambient data. They are intended as quick, convenient checks to be used between zero and span calibrations to check for possible analyzer malfunction or calibration drift. Whenever a level 2 zero and span check indicates a possible calibration problem, a level 1 zero and span (or multipoint) calibration should be carried out before any corrective action is taken.

If a level 2 zero and span check is to be used in the quality control program, a "reference response" for the check should be obtained immediately following a zero and span (or multipoint) calibration ~~while~~ the analyzer's calibration is accurately known. Subsequent level 2 check responses should then ~~be~~ compared to the most recent reference response to determine if a change in response has occurred. For automatic level 2 zero and span checks, the first scheduled check following the calibration should be used for the reference response. It should be kept in mind that any level 2 check that involves only part of the analyzer's system cannot provide information about the portions of the system not checked and therefore cannot be used as a verification of the overall analyzer calibration.

12.5 Physical Zero and Span Adjustments

Almost all ambient monitoring instruments have physical means by which to make zero and span adjustments. These adjustments are used to obtain the desired nominal scale range (within the instruments' specifications), to provide convenient (nominal) scale units, and to periodically adjust the instruments' response to correct for calibration drift. **Note**: $NO/NO_2/NO_X$ analyzers may not have individual zero and span controls for each channel. If that is the case, the zero and span controls must be adjusted only under the conditions specified in the calibration procedure provided in the analyzer's operation/instruction manual.

Precise adjustment of the zero and span controls may not be possible because of: (1) limited resolution of the controls, (2) interaction between the zero and span controls, and (3) possible delayed reaction to adjustment or a substantial stabilization period after adjustments are made. Precise adjustments may not be necessary because calibration of the analyzer following zero and span adjustments will define the precise response characteristic (calibration curve). Accordingly, zero and span adjustments must always be followed by a calibration. Allow sufficient time between the adjustments and the calibration for the analyzer to fully stabilize. This stabilization time may be substantial for some analyzers. Also, obtain unadjusted response readings before adjustments are made, as described in the previous section on level 1 zero and span calibration.

Zero and span adjustments do not necessarily need to be made at each calibration. In fact, where only relatively small adjustments would be made, it is probably more accurate not to make the adjustments because of the difficulty of making precise adjustments mentioned earlier. An appropriate question, then, is how much zero or span drift can be allowed before a physical zero or span adjustment should be made to an analyzer?

Ideally, all ambient measurements obtained from an analyzer should be calculated or adjusted on the basis of the most recent (zero and span or multipoint) calibration or on the basis of both the previous and subsequent calibrations (see section 12.9). In this case, considerable drift (i.e., deviation from an original or nominal response curve) can be allowed before physical adjustments must be made because the calibration curve used to calculate the ambient measurements is kept in close agreement with the actual analyzer response. The chief limitations are the amount of change in the effective scale range of the analyzer that can be tolerated and possible loss of linearity in the analyzer's response due to excessive deviation from the design range. Cumulative drifts of up to 20% or 25% of full scale from the original or nominal zero and span values may not be unreasonable, subject to the limitations mentioned above.

In situations where it is not possible to update the calibration curve used to calculate the ambient readings after each zero and span calibration, then the ambient readings must be calculated from the most recent multipoint calibration curve or from a fixed nominal or "universal" calibration curve (section 12.9). In this case the zero and span calibrations serve only to measure or monitor the deviation (drift error) between the actual analyzer response curve and the calibration curve used to calculate the ambient measurements. Since this error must be kept small, physical zero and span adjustments are much more critical and should be made before the error becomes large. More information on drift limits and determining when physical zero and span adjustments are needed is contained in the next section on frequency of calibration.

12.6 Frequency of Calibration and Analyzer Adjustment

As previously indicated, a multipoint calibration should be carried out on new analyzer(s), or after major repairs, to establish analyzer linearity. It is also appropriate to carry out a multipoint calibration on each analyzer in routine operation at least twice per year to reverify linearity, although an annual multipoint audit may serve in lieu of one of these. Nonlinear analyzers may require more frequent multipoint calibration if they cannot be calibrated adequately with 2-point calibrations. Specific requirements for calibration can be found in the guidance methods (Part II) and summarized in Appendix 3.

The calibrations referred to below would normally be 2-point zero and span (level 1) calibrations. However, a multi-point calibration can always substitute for a 2-point calibration. An analyzer should be calibrated (or recalibrated):

- upon initial installation
- following physical relocation
- after any repairs or service that might affect its calibration
- following an interruption in operation of more than a few days
- upon any indication of analyzer malfunction or change in calibration
- at some routine interval (see below)

Analyzers in routine operation should be recalibrated periodically to maintain close agreement between the calibration relationship used to convert analyzer responses to concentration measurements and the actual response of the analyzer. The frequency of this routine periodic recalibration is a matter of judgment and is a tradeoff among several considerations, including: the inherent stability of the analyzer under the prevailing conditions of temperature, pressure, line voltage, etc. at the monitoring site; the cost and inconvenience of

carrying out the calibrations; the quality of the ambient measurements needed; the number of ambient measurements lost during the calibrations; and the risk of collecting invalid data because of a malfunction or response problem with the analyzer that wouldn't be discovered until a calibration is carried out.

When a new monitoring instrument is first installed, level 1 zero and span calibrations should be very frequent, perhaps daily or 3 times per week, because little or no information is available on the drift performance of the analyzer. Information on another unit of the same model analyzer may be useful; however, individual units of the same model may perform quite differently. After enough information on the drift performance of the analyzer has been accumulated, the calibration frequency can be adjusted to provide a suitable compromise among the various considerations mentioned above. However, prudence suggests that the calibration frequency should not be less than every two weeks. If a biweekly frequency is selected and the level 1 zero/span calibration is carried out on the same day as the one-point precision check required in Subsection 3 of Appendices A and B of Part 58[24], the precision check must be done first.

To facilitate the process of determining calibration frequency, it is strongly recommended that control charts be used to monitor the zero and span drift performance of each analyzer. Control charts can be constructed in different ways, but the important points are to visually represent and statistically monitor zero and span drift, and to be alerted if the drift becomes excessive so that corrective action can be taken. Examples of simple zero and span control charts are shown in Figure 12.1. Such control charts make important use of the unadjusted zero and span response readings mentioned in Section 12.3.

In the zero drift chart of Figure 12.1, cumulative zero drift is shown by plotting the zero deviation in ppb for each zero/span calibration relative to a nominal calibration curve (intercept = 0 scale percent, slope = 200 scale percent per ppm for a nominal scale range of 0.5 ppm). This zero deviation may be calculated as follows:

$$D_Z = \frac{Z' - I_o}{m_o} \; X \; 1000 \; ppb/ppm$$

where:

D_Z = zero deviation from the reference calibration (e.g., nominal or original calibration), ppb;

Z' = unadjusted zero reading, e.g., scale percent;

I_o = intercept of reference calibration, e.g., scale percent;

m_o = slope of reference calibration, e.g., scale percent/ppm.

Similarly, cumulative span drift may be shown by plotting the percent deviation in the slope of the calibration curve relative to the reference calibration. This percent deviation in the span slope may be calculated as follows:

$$D_s = \frac{m_c - m_o}{m_o} \; X \; 100 \; percent$$

where:

D_s = span deviation from reference calibration, percent;

m_o= slope of reference calibration, e.g., scale percent/ppm;

m_c= slope of current analyzer calibration

$$slope = \frac{S'-Z'}{C}$$, e.g., scale percent/ppm;

S' = unadjusted span reading, e.g., scale percent;

Z' = unadjusted zero reading, e.g., scale percent;

C = span concentration.

Where physical zero or span adjustments have been made to the analyzer (marked by diamonds along the horizontal axes in Figure 12.1), both the unadjusted (Z', S') and the adjusted readings (Z, S) are plotted (substitute Z for Z' and S for S' in the formulas). The connecting line stops at the unadjusted reading, makes a vertical transition representative of the physical adjustment, then continues from the adjusted reading.

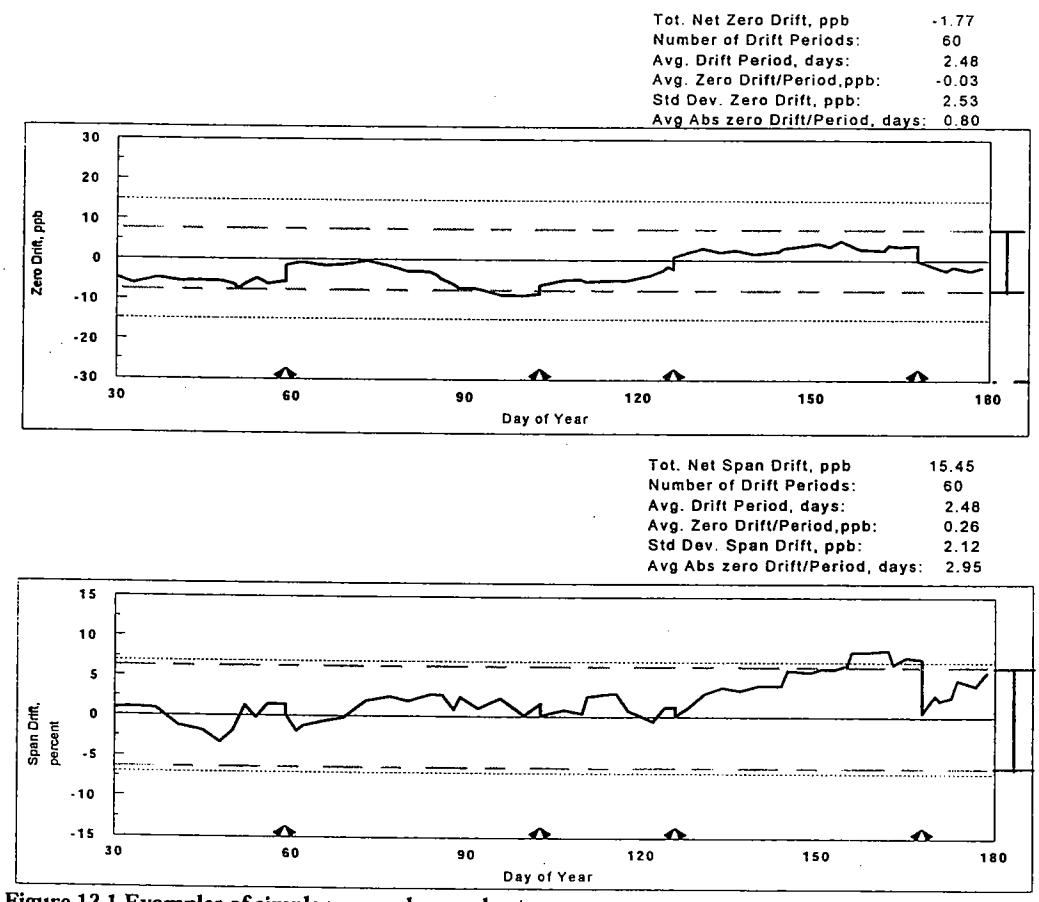


Figure 12.1 Examples of simple zero and span charts

The charts in Figure 12.1 cover a period of 180 days, with zero/span calibration every 2 or 3 days (2.5 days on the average). Practical adjustment limits were set at ±15 ppb for zero and ± 7% for span, (shown as broken lines in Figure 12.1), although most of the span adjustments and all of the zero adjustments were made before these limits were reached. These limits could have been set wider because the calibration slope and intercept used to calculate the ambient readings were updated at each zero/span calibration. Narrower limits may be needed if the calibration curve used to calculate the ambient data is not updated at each zero/span calibration.

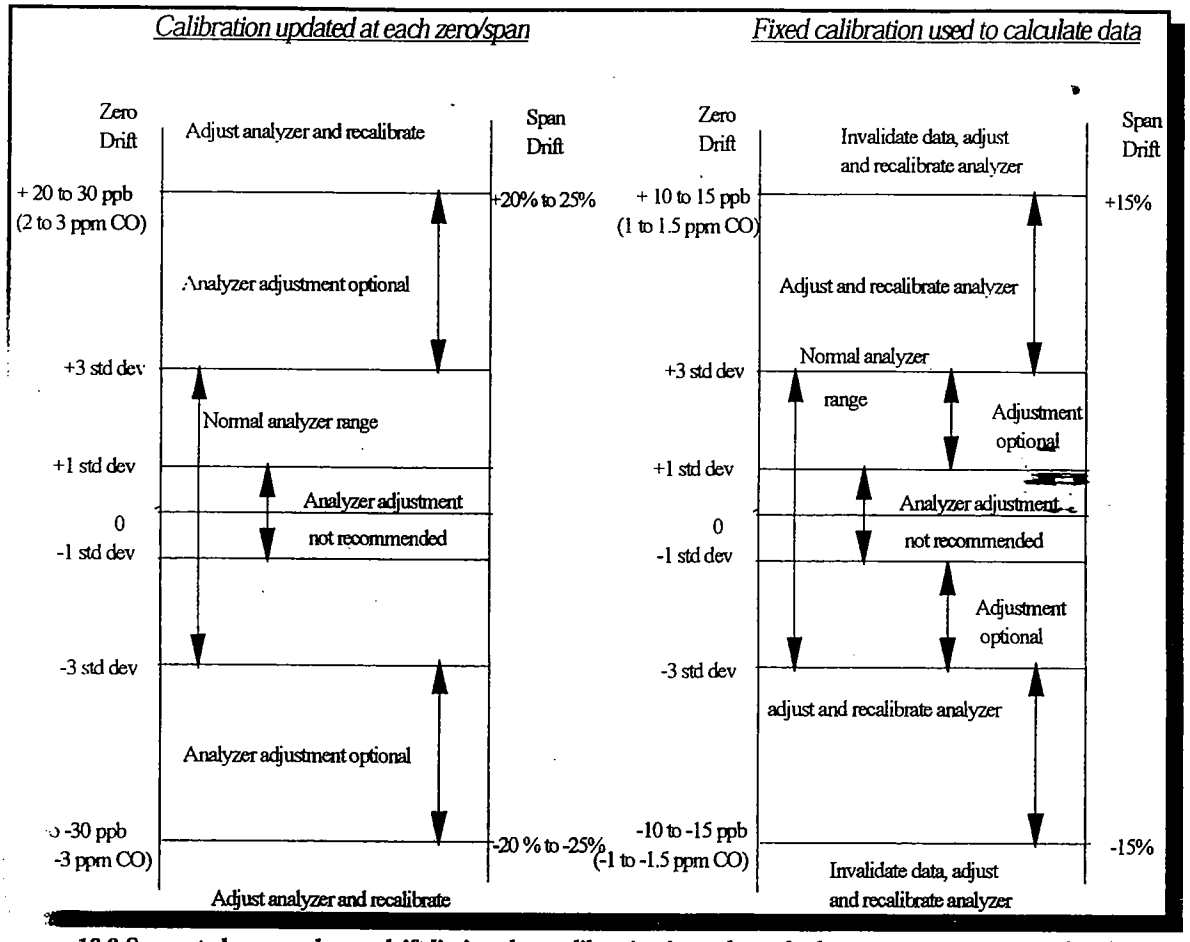
The total net cumulative zero drift over the entire 180 day period (ignoring zero adjustments) was -1.77 ppb, indicating that the analyzer's zero stability was good. Total net cumulative span drift (ignoring span adjustments) was +15.45%, indicating that the analyzer should be watched closely for continued positive span drift. Most of the individual zero and span drifts (i.e., the net change from one zero/span calibration to the next) were small. The average of the absolute values of these individual zero drifts (ignoring zero adjustments) was 0.80 ppb, and the average of the absolute values of the individual span drifts (ignoring span adjustments) was 2.95 percent. In view of these relatively low values, the frequency of zero/span calibrations could be reduced, say to twice a week or every 4 days, particularly if level 2 zero/span checks were used between the level 1 zero/span calibrations. However, such reduced calibration frequency would tend to increase the average error between the actual analyzer response and the calibration curve used to calculate the ambient measurements. Reduced calibration frequency would also increase the risk of collecting invalid data because of potentially increased delay in discovering a malfunction or serious response change. If either of the average zero or average span drift is large, more frequent zero/span calibration should be considered.

A final pair of statistics that should be calculated is the standard deviations of the individual zero and span drifts, respectively (again, ignoring zero and span adjustments). These values (2.53 ppb and 2.12%, respectively, for the charts shown in Figure 12.1) provide a measure of the typical drift performance of the analyzer. A band equal to +3 standard deviations can be established to represent "normal" performance of the analyzer. Such a band is represented on the charts of Figure 12.1 by the I-bands at the right edge of the charts. Any excursion outside of these bands is an indication of a possible performance problem that may need corrective action or additional scrutiny.

In continuous monitoring, the total cumulative drift, average of the absolute values of the individual drifts, and the standard deviation of the individual drifts should be calculated on a running basis over the last 100 or so days. Figure 12.2 summarizes some of the ranges and control chart limits discussed previously. These limits are suggested, but they could be modified somewhat at the discretion of the monitoring agency. There are also other ways to control chart.

12.7 Automatic Self-Adjusting Analyzers

Some air monitoring analyzers are capable of periodically carrying out automatic zero and span calibrations and making their own zero and span self adjustments to predetermined readings. How should such automatic zero/span calibrations be treated? If the automatic zero/span calibration meets all the requirements discussed previously for level 1 zero and span calibrations (i.e., traceable standards that pass through the sample inlet and sample conditioning system) and both the adjusted and unadjusted zero and span response readings can be obtained from the data recording device, then the calibration may be treated



re 12.2 Suggested zero and span drift limits when calibration is used to calculate measurements is updated at zero/span calibration and when fixed calibration is used to calculate measurements.

as alid zero/span calibration as discussed in this section. If the automatic calibrations do not qualify as le l calibrations (because the zero and span readings cannot be read from the strip chart for example), t he analyzer must receive manual zero/span calibrations as if it had no automatic capabilities. In this c the automatic zero and span adjustments should be ignored, except that manual calibrations should be s ated in time as much as possible from the occurrence of the automatic calibrations for maximal benefit. It y sometimes happen that automatic and manual calibrations interact, producing a detrimental effect on th nonitoring data. If so, the automatic calibrations should be discontinued or adjusted to avoid co inuation of the conflict.

12 8 Data Reduction Using Calibration Information

As noted previously, an analyzer's response calibration curve relates the analyzer response to actual concentration units of measure, and the response of most analyzers tends to change (drift) unpredictably with passing time. These two conditions must be addressed in the mechanism that is used to process the raw analyzer readings into final concentration measurements. Four practical methods are described below. They are listed in order of preference, with the first one being the most likely to minimize errors caused by differences between the actual analyzer response and the response curve used to calculate the measurements.

As would be expected, the order also reflects decreasing complexity and decreasing difficulty of implementation. The first 3 methods are best implemented with automatic data processing systems because of the number of calculations required. Methods 3 and 4 could be used on a manual basis and are more labor intensive because of the need for more frequent and precise physical adjustment of analyzer zero and span controls

1) Linear Interpolation--In this method, the (linear) calibration curve used to convert analyzer readings to concentration values is defined by a slope and intercept, which are updated at each calibration. Both unadjusted and adjusted response readings are required for each calibration. Each ambient concentration is calculated from individual slope and intercept values determined by linear interpolation between the adjusted slope and intercept of the most recent previous calibration and the unadjusted slope and intercept of the first subsequent calibration.

Because of the need for subsequent (level 1) calibration information, this method cannot be used for real time calculation of concentration readings. Also, some contingency arrangement (such as method 2) must be employed when a subsequent calibration is missing (e.g., following a disabling malfunction). Physical zero and span adjustments to the analyzer are needed only to maintain an appropriate scale range or to avoid scale nonlinearity due to cumulative drift in excess of design values.

Within these constraints, data invalidation limits should be based on net change from one calibration to the next, rather than on total cumulative drift, because the calibration is continually updated. A significant problem with this method is acquiring the requisite calibration data and making sure it is merged correctly with the ambient data to facilitate the required calculations. Some automated data acquisition systems support this application by making special provisions to acquire and process periodic zero and span data. One way to ensure that the zero/span data are correctly merged with the ambient readings is to code the zero and span values directly into the data set at the location corresponding to the time of calibration, replacing the normal hourly reading that is lost anyway because of the calibration. This data can be marked (such as with a negative sign) to differentiate it from ambient data and later deleted from the final report printout. When zero and span data is acquired automatically by a data acquisition system for direct computer processing, the system must be sufficiently sophisticated to:

- ensure that zero or span data is never inadvertently reported as ambient measurements
- ignore transient data during the stabilization period before the analyzer has reached a stable zero or span response (this period may vary considerably from one analyzer to another)
- average the stable zero and span readings over some appropriate time period so that the zero or span reading obtained accurately represents the analyzers true zero or span response
- ignore ambient readings for an appropriate period of time immediately following a zero or span reading until the analyzer response has restabilized to the ambient-level concentration

2) Step-Change Update--This method is similar to Method 1 above except that the adjusted slope and intercept of the most recent calibration are used to calculate all subsequent ambient readings until updated by another calibration (i.e., no interpolation). No unadjusted zero or span readings are used, and ambient measurements can be calculated in real time if desired. The same comments concerning physical zero and span adjustments and data invalidation limits given for Method 1 apply, as well as the comments concerning zero and span data acquired automatically by a data acquisition system.

3) Major Calibration Update--In this method, the calibration slope and intercept used to calculate ambient measurements are updated only for "major" calibration--i.e., monthly or quarterly multi-point calibrations. All ambient measurements are calculated from the most recent major calibration. Between major calibrations, periodic zero and span calibrations are used to measure the difference between the most recent major calibration and the current instrument response. Whenever this difference exceeds the established zero/span adjustment limits (see sections 12.5 and 12.6), physical zero and/or span adjustments are made to the analyzer to restore a match between the current analyzer response and the most recent major calibration. Neither adjusted nor unadjusted zero or span readings are used in the calculation of the ambient concentrations.

4) "Universal" Calibration--A fixed, "universal" calibration is established for the analyzer and used to calculate all ambient readings. All calibrations are used to measure the deviation of the current analyzer response from the universal calibration. Whenever this deviation exceeds the established zero and span adjustment limits, physical zero and/or span adjustments are made to the analyzer to match the current analyzer response to the universal calibration.

12.9 Validation of Ambient Data Based on Calibration Information

When zero or span drift validation limits (see section 12.6) are exceeded, ambient measurements should be invalidated back to the most recent point in time where such measurements are known to be valid. Usually this point is the previous calibration (or accuracy audit), unless some other point in time can be identified and related to the probable cause of the excessive drift (such as a power failure or malfunction). Also, data following an analyzer malfunction or period of non-operation should be regarded as invalid until the next subsequent (level 1) calibration unless unadjusted zero and span readings at that calibration can support its validity.

13. Inspection/Acceptance for Supplies and Consumables

Pollutant parameters are measured using either wet chemical techniques or physical methods. Chemical analysis always involves the use of consumable supplies that must be replaced on a schedule consistent with their stability and with the rate at which samples are taken. Currently used instruments require adequate supplies of chemicals for operation for 3 months so that the supplier can comply with the delivery schedules. In some cases, analytical reagents for specific air contaminants deteriorate rapidly and need protective storage. The following information may be helpful when considering the use of these consumable items. Much of the information presented below is derived from the document *Quality Assurance Principles for Analytical Laboratories*[36].

13.1 Supplies Management

Control of supplies and consumables is important to the success of the quality assurance program. It is important that specifications for each item are prepared and adhered to during the procurement process. When specifications are prepared, the following points should be considered: identity, purity, potency, source, tests to be conducted for quality and purity, need for further purification, storage and handling procedures, and replacement dates.

As part of supplies management, the following actions are recommended:

- establish criteria and specifications for the important supplies and consumables
- check and test the supplies and consumables against specifications, before placing them in use
- design and maintain a supplies management program to ensure the quality of reagents used in day-to-day operations, paying particular attention to primary reference standards, working standards, and standard solutions
- decide on the kinds of purified water that are necessary, and develop suitable tests and testing intervals to ensure the quality of water used in analytical work and for cleaning glassware
- purchase only Class A volumetric glassware and perform calibrations and recalibrations that are necessary to achieve reliable results
- establish procedures for cleaning and storing glassware with due consideration for the need for special treatment of glassware used in trace analysis
- discard chipped and etched glassware

13.2 Standards and Reagents

In some cases, reagents are prepared prior to sampling. Some of these reagents will be used to calibrate the equipment, while others will become an integral part of the sample itself. In any case, their integrity must be carefully maintained from preparation through analysis. If there are any doubts about the method by which the reagents for a particular test were prepared or about the competence of the laboratory technician preparing these items, the credibility of the ambient air samples and the test results will be diminished. It is essential that a careful record be kept listing the dates the reagents were prepared, by

whom, and their locations at all times from preparation until actual use. Prior to the test, one individual should be given the responsibility of monitoring the handling and the use of the reagents. Each use of the reagents should be recorded in a field/laboratory notebook.

Chemical reagents, solvents and gases are available in various grades. Reagents can be categorized into the following 6 grades[36]:

1. **Primary standard** - Each lot is analyzed, and the percentage of purity is certified.
2. **Analyzed reagents**- Can fall into 2 classes: a) each lot is analyzed and the percentages of impurities are reported; and b) conformity with specified tolerances is claimed, or the maximum percentages of impurities are listed.
3. **USP and NF Grade**- These are chemical reference standards where identity and strength analysis are ensured.
4. **"Pure," "c.p.," "chemically pure," "highest purity"** - These are qualitative statements for chemicals without numerical meaning
5. **"Pure," "purified," "practical grades"** - These are usually intended as starting substances for laboratory syntheses.
6. **Technical or commercial grades** - These are chemicals of widely varying purity.

Part II of this document, which contains the reference and equivalent methods, define the grades and purities needed for the reagents and gases required in the Ambient Air Quality Monitoring Program.

All reagent containers should be properly labeled either with the original label or at a minimum, the reagent, date prepared, expiration date, strength and preparer. Leftover reagents used during preparation or analysis should never be returned to bottles.

13.2.1 Primary Reference Standards

A primary reference standard can be defined as a homogenous material with specific properties such as identity, unity, and potency, that has been measured and certified by a qualified and recognized organization[36], such as the NIST) standard reference materials (SRMs). NIST maintains a catalog of SRMs that can be accessed through the Internet *(http://www.nist.gov)*. Primary reference standards are usually quite expensive and are often used to calibrate, develop or assay working or secondary standards.

It is important that primary reference standards are maintained, stored and handled in a manner that maintains their integrity. These samples should be kept under secure conditions and records should be maintained that document chain of custody information.

13.2.2 Standard Solutions

Most laboratories maintain a stock of standard solutions. The following information on these solutions should be kept in a log book:

- identity of solution
- strength
- method of preparation (reference to SOP)
- standardization calculations
- recheck of solution for initial strength
- date made/expiration date
- initials of the analyst

As mentioned above, all standard solutions should contain appropriate labeling as to contents and expiration dates.

13.2.3 Purified Water

Water is one of the most critical but most often forgotten reagent in the laboratory. The water purification process should be documented, from the quality of the starting raw water to the systems used to purify the water including, how the water is delivered, the containers in which it is stored, and the tests and the frequency used to ensure the quality of the water.

13.3 Volumetric Glassware

Use of the appropriate glassware is important since many preparation and analysis require the development of reagents, standards, dilutions and controlled delivery systems. It is suggested that "Class A" glassware be used in all operations requiring precise volumes. SOPs requiring volumetric glassware should specify the size/type required for each specific operation.

13.4 Filters

Filters are used for the manual methods for the criteria pollutants PM_{10}, $PM_{2.5}$, and Pb. No commercially available filter is ideal in all respects. The sampling program should determine the relative importance of certain filter evaluation criteria (e.g., physical and chemical characteristics, ease of handling, cost). The reference methods for the PM_{10}, $PM_{2.5}$, and Pb present detailed acceptance criteria for filters; some of the basic criteria that must be met regardless of the filter type follows:

- Visual inspection for pinholes, tears, creases, or other flaws which may affect the collection efficiency of the filter which may be consistent through a batch. This visual inspection would also be made prior to filter installation and during laboratory pre- and post-weighings to assure the

integrity of the filter is maintained and therefore, the ambient air sample obtained with each filter adequately represents the sampled pollutant conditions.

- Collection efficiency - Greater than 99% as measured by DOP test (ASTM 2988) with 0.3 micrometer particles at the sampler's operating face velocity.

- Integrity - (pollutant specific) measured as the concentration equivalent corresponding to the difference between the initial and final weights of the filter when weighed and handled under simulated sampling conditions (equilibration, initial weighing, placement on inoperative sampler, removal from a sampler, re-equilibration, and final weighing).

- Alkalinity - Less than 0.005 milliequivalent/gram of filter following at least 2 months storage at ambient temperature and relative humidity.

<u>Note</u>: Some filters may not be suitable for use with all samplers. Due to filter handling characteristics or rapid increases in flow resistance due to episodic loading, some filters, although they meet the above criteria, may not be compatible with the model of sampler chosen. It would be prudent to evaluate more than one filter type before purchasing large quantities for network use. In some cases EPA Headquarters may have national contracts for acceptable filters which will be supplied to State and local organizations.

14. Data Acquisition and Information Management

14.1 General

Success of the Ambient Air Quality Program objectives rely on data and their interpretation. It is critical that data be available to users and that these data are:

- reliable
- of known quality
- easily accessible to a variety of users
- aggregated in a manner consistent with it prime use

In order to accomplish this activity, information must be collected and managed in a manner that protects and ensures its integrity.

Most of the data collected from the Ambient Air Monitoring Program will be collected through automated systems at various facilities. These systems must be effectively managed by using a set of guidelines and principles by which adherence will ensure data integrity. The EPA has a document entitled Good Automated Laboratory Practices (GALP)[38]. The GALP defines six data management principles:

1. DATA: The system must provide a method of assuring the integrity of all entered data. Communication, transfer, manipulation, and the storage/recall process all offer potential for data corruption. The demonstration of control necessitates the collection of evidence to prove that the system provides reasonable protection against data corruption.

2. FORMULAE: The formulas and decision algorithms employed by the system must be accurate and appropriate. Users cannot assume that the test or decision criteria are correct; those formulas must be inspected and verified.

3. AUDIT: An audit trail that tracks data entry and modification to the responsible individual is a critical element in the control process. The trail generally utilizes a password system or equivalent to identify the person or persons entering a data point, and generates a protected file logging all unusual events.

4. CHANGE: A consistent and appropriate change control procedure capable of tracking the system operation and application software is a critical element in the control process. All software changes should follow carefully planned procedures, including a pre-install test protocol and appropriate documentation update.

5. STANDARD OPERATING PROCEDURES (SOPs): Control of even the most carefully designed and implemented systems will be thwarted if appropriate procedures are not followed. The principles implies the development of clear directions and Standard Operating Procedures (SOPs); the training of all users; and the availability of appropriate user support documentation.

6. DISASTER: Consistent control of a system requires the development of alternative plans for system failure, disaster recovery, and unauthorized access. The control principle must extend to planning for reasonable unusual events and system stresses.

The principles listed above apply to both the local and central information management systems. In order to address these principles the following elements will be discussed:

Personnel	Quality Assurance
Facilities	Equipment
Security	Standard Operating Procedures
Software	Data Entry
Raw Data	Data transfer
Records/Archive	Reporting

14.1.1 Personnel

Each organization responsible for data on automated systems should identify a person within the organization responsible for this information management system. This person should have adequate education, training, and experience to enable him/her to perform the assigned system functions. This person should be identified in the organizational structure in the QAPP. To assist or assure user competence, users should be provided with clear standard operating procedures (SOPs) to enable them to perform the assigned functions and sufficient training to clarify these SOPs.

Once an information management system is in place, data should be made available to the system in a timely manner. Personnel responsible for local and central systems should be of sufficient number for the timely and proper implementation of the information management system.

14.1.2 Quality Assurance

As part of the quality assurance responsibility, a group/individual needs to be identified whose responsibilities would be primarily those of system and data inspection, audit and review. The objective of QA is to provide proof that the information management system operates in a correct manner consistent with its recommended functions.

14.1.3 Facilities

The facility used to house the information management system should have provisions to regulate the environmental conditions (temperature, humidity, electricity) adequately to protect the systems against data loss. The facility should also have adequate storage capability for the automated information management system and provide for retention of raw data, including archives of computer resident data.

14.1.4 Equipment

Information management system equipment should be of appropriate design and capacity to function according to the specifications. Guidelines for the minimum hardware specifications of the system should be developed. Hardware should be on a maintenance schedule. Backup and recovery procedures should be accomplished on a routine basis and should be incorporated into SOPs.

14.1.5 Security

Information management systems need to be safeguarded against accidental or deliberate:

- **Modification or destruction of data-** This relates to maintaining the integrity of the data which would include developing policy/procedures for computer use (password protection and authorization) data entry (i.e., double entry, verification checks etc.) editing, and transfer.
- **Unavailability of data or services** - Ensuring that data does not get lost (i.e. data backup policies and storage on more than one media or system) or that services are not interrupted (maintenance of hardware, surge protection, backup systems)
- **Unwanted disclosure of data-** This relates to confidentiality and ensuring that secured or confidential data can not accidentally or deliberately be disclosed.

14.1.6 Standard Operating Procedures

Standard operating procedures (SOPs) are protocols for routine activities involved in a data collection activity which generally involve repetitious operations performed in a consistent manner. SOPs should be established for:

- maintaining system security
- defining raw data (distinction between raw and processed data)
- entry of data
- verification of manually or electronically input data
- interpretation of error codes/flags and corrective action
- changing data
- data analysis, processing, transfer, storage, and retrieval
- backup and recovery
- electronic reporting (if applicable)

14.1.7 Software

Software, either developed internally or "off -the-shelf" must accurately perform its intended function. Tests of the software prior to implementation should occur and be documented. Algorithms should be checked

and source code reviewed as part of the process. Source code, including processing comments, should be archived. Procedures for reporting software problems and corrective action should be in place.

14.1.8 Data Entry/Formatting

Organizations using information management systems should ensure that data input is traceable to the person entering it. Also, instruments transmitting data to the system should be identified. It should be possible to trace each record transmitted back to the source instrument, including the date and time of generation.

Any change in data entry after initial entry should have an audit trail which indicates the new value, the old value, a reason for change, and person who entered the change. As part of a organizations QAPP, procedures should exist for validating the data entered manually or automatically.

Since data will be transferred to a central repository, the Aerometric Information Retrieval System (AIRS), any formatting accomplished at the local level that enhances the ease of transferring the data to the central data structure will be most advantageous. The procedures for transmitting data to the AIRS data base can be found in section 14.2 and 14.3.

14.1.9 Raw Data

Raw data are worksheets, records, memoranda, notes, or exact copies thereof, that are the result of original observations and activities of a study and are necessary for the reconstruction and evaluation of that study.... "Raw data" may include photographs, microfilm or microfiche copies, computer printouts, magnetic media, ... and recorded data from automated instruments" (40 CFR 792.3). Data entered into a system directly by keyboard or automatically by lab test devices are considered raw data. Organizations should define raw data above this minimum and make provisions for their storage and retrieval.

14.1.10 Data Transfer

Data transfer is discussed in more detail in Sections 14.2 and 14.3

14.1.11 Records and Archive

As mentioned in Section 5, all raw data, documentation and records should be retained for an appropriate period of time. Correspondence and other documentation relating to interpretation and evaluation of data collected, analyzed, processed or maintained on automated data collection systems should also be retained. Other records to be maintained include but are not limited to:

- software source code
- software and/or hardware acceptance tests
- records

- hardware maintenance records
- records of problems and corrective actions
- records of qa activities (inspections etc.)
- records of backups and recoveries

14.1.12 Reporting

Reporting will be discussed in Section 14.2

14.1.13 Systematic Data Management

An orderly process of data management, based on the analysis of all data handling procedures and their interrelationships, is sometimes referred to as a "systems" approach. This kind of systematic overview of the total data function is accomplished in three phases:

- surveying current and future reporting requirements
- outlining the present routine flow of data within and outside the agency
- redesigning the current system to allow maximum functional overlap of filing and retrieval routines

A survey of current reporting requirements involves summarizing and categorizing the reports currently required and their important data elements. The purpose of this analysis is to identify report elements that require similar input, to allow optimum scheduling, and to differentiate between required reports and those provided as a service. Future reporting requirements will be based on projected legal requirements, projected developments of systems for communicating with various data banks, and projected growth of the air quality surveillance network.

Outlining present data flow requires a review of the origin of each data form, the editing procedures applied, the calculations performed, the application of quality control procedures, and the reports for which each form is used. The purpose of outlining the data flow is to identify data elements that are subjected to similar checks and to similar calculating procedures and to classify them according to their points of origin. Once again, this procedure provides a means of preventing unnecessary duplication.

As a final step in systematic data management, the data system should be continually updated. The following items are suggested for review:

- what operations are duplicated in the system?
- how can the system be changed to eliminate needless duplications?
- how do the manual systems and computerized systems augment each other?
- are the data formats, identification codes, and other elements compatible throughout the system?
- can reporting schedules be changed to minimize the filing and retrieval of each data record?

- can special techniques, such as the use of multi-part forms, be applied to minimize data transposition?
- are filing and retrieval systems sufficiently flexible to allow expansion or upgrading at minimum cost?

14.2 Data Acquisition

All ambient air monitoring data will eventually be transferred and stored in AIRS. As stated in 40 CFR Part 58[24], the State shall report all criteria pollutant data and information specified by the AIRS Users Guide (Volume II, Air Quality Data Coding [3], and Volume III, Air Quality Data Storage[4]) to be coded into the AIRS-AQS Format. The following sections provides some information on these requirements.

14.2.1 Standard Forms for Reporting

Data forms are used to provide a consistent format for recording information that will eventually be entered into an electronic data base. Examples of standard forms and procedures to be followed in completing these forms can be found in the appropriate AIRS AQS manuals[3,4], but any form can be generated by the State and local organization as long as the appropriate data, is submitted to AIRS.

If computer techniques are used for recording results, the computer system must be designed to maintain compatibility between the AIRS station codes and the codes used by the computer program. Whenever station parameters change or when a station is moved, updated site identification information should be submitted to the AIRS.

Identification errors can be avoided by preprinting entry forms with the station identification. If this technique is adopted, control must be employed to be certain that unused forms are discarded and new ones printed when the station identification changes. Preprinting the pollutant I.D. and the proper decimal points (Table 14-1) for that pollutant on the reporting forms can eliminate the problem of misplaced decimals.

Table 14-1 Data Reporting Requirements

Pollutant	Decimal Places	uq/m³	ppm	ppbC*
PM2.5	--	15		
PM10	--	50		
Lead	1	1.5		
Sulfur dioxide	2		0.03	
Nitrogen dioxide	3		0.053	
Carbon monoxide	0		9	
Ozone	2		0.12	
PAMS	2			6.23

* part per billion-carbon

Acceptability limits for start-stop times, flow rate, and other routine system checks performed by the operator should appear on the data recording form as a reminder to the operator. If a value outside these limits of acceptability is recorded, the operator should flag the value for the attention of individuals performing data validation functions.

14.2.2 Data Errors in Intermittent Sampling

The most common errors in recording data in the field are transposition of digits and incorrect placement of decimal points. These errors are almost impossible to detect. The decimal error can be avoided to some extent by providing an operator with the guidelines in Table 14-1 that are listed by the concentrations reported in the AIRS data base.

14.2.3 Data Errors in Continuous Sampling

Data errors in continuous sampling primarily include errors in recording device functioning, errors in strip chart reading for manual techniques or in data transmission for automated techniques of data recording.

<u>Strip chart errors</u> - Errors due to recording device malfunctions of strip charts can occur. General guidelines to avoid errors or loss of data caused by mechanical problems follow:

- perform a daily check to assure an adequate supply of strip chart paper
- check the ink level in the recorder pen to verify that the level is adequate for the next sampling period and that the pen tip is not blocked
- perform a daily check to verify that the pen on the recorder aligns with the baseline of the strip chart during the instrument zero check.
- verify the timing of the strip chart drive against a standard timepiece immediately after installation of the recorder and at intervals dictated by experience with the recorder
- replace recorder pens, and soak in cleaning solution occasionally
- examine the strip chart for apparent evidence of chart drag or malfunction, and mark suspected intervals

When reviewing a strip chart, typical signs of system malfunction are:

- a straight trace for several hours (other than minimum detectable)
- excessive noise as indicated by a wide solid trace, or erratic behavior such as spikes that are sharper than possible with the normal instrument response time (noisy outputs usually result when analyzers are exposed to vibrations)
- a long steady increase or decrease in deflection
- a cyclic pattern of the trace with a definite time period indicating a sensitivity to changes in temperature or parameters other than the pollutant concentration
- periods where the trace drops below the zero baseline (this may result from a larger-than-normal drop in the ambient room temperature or power line voltage)

Void any data for any time interval for which malfunction of the sampling system is detected. Suggestions for minimizing errors in reading strip charts are as follows:

- chart readers should be trained with a standard strip of chart, whose readings have been determined by one or more experienced readers
- when the new reader can perform adequately on the standard strip, then permit him/her to read new sample charts
- an individual should spend only a portion of a day reading strip charts since productivity reliability are expected to decrease after a few hours
- a senior technician should verify a percentage (5-10%) of the reduced strip chart values. If minimum performance criteria established for a particular network are not being met, additional training is indicated
- use a chart reader to reduce technician fatigue and to achieve accuracy and consistency in data reduction

14.2.4 Automated Data Acquisition Requirements

The use of a data logging device to automate data handling from a continuous sensor is not a strict guarantee against recording errors. Internal validity checks are necessary to avoid serious data recording errors. This section provides information on Data Acquisition Systems (DAS), a term signifying any system that collects, stores, summarizes, reports, prints, calculates or transfers data. The transfer is usually from an analog or digital format to a digital medium. In addition, this section will discuss limitations with data collected with DAS. Uncertainty of data will be discussed and how to ascertain the quality of the data.

DAS have been available to air quality professionals since the early 1980s. The first systems were single and multi-channel systems that collected data on magnetic media. This media was usually hand transferred to a central location or laboratory for downloading to a central computer. With the advent of digital data transfer from the stations to a central location, the need to hand transfer data has diminished. However, errors in data reporting can occur with strip chart as well as digital data. For DAS, there are two sources of error between the instrument (sensor) and the recording device: 1) the output signal from the sensor, and 2) the errors in recording by the data logger. This section will relate how to ascertain quality data from DAS.

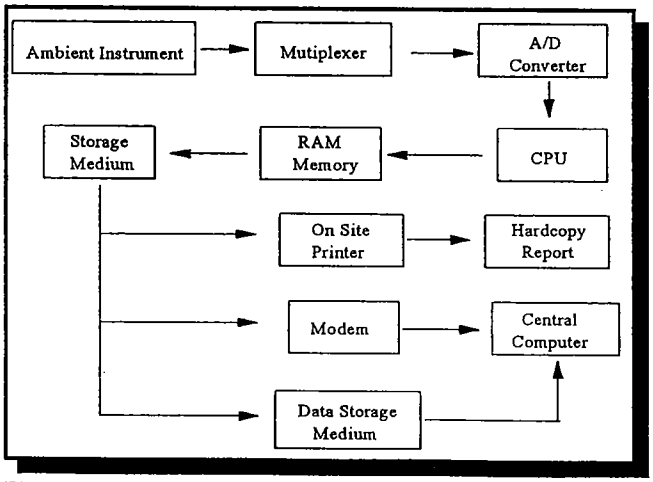


Figure 14.1 DAS flow diagram

14.2.4.1 DAS Data Acquisition Layout and Collection

Figure 14.1 shows the basic transfer of data from the instrument to the final product, a hard copy report or transfer to a central computer. The instrument has a voltage potential that generally is a DC voltage. This voltage varies directly with the concentration collected. Most instruments'

output is a DC voltage in the 0-1 or 0-5 volts range.

- the voltage is measured by the multiplexer which allows voltages from many instruments to be read at the same time.
- the multiplexer sends a signal to the a/d converter which changes the analog voltage to a low amperage digital signal.
- the a/d converter send signals to the central processing unit (cpu) that directs the digital electronic signals to a display or to the random access memory (ram) which stores the short-term data until the end of a pre-defined time period.
- the cpu then shunts the data from the ram to the storage medium which can be magnetic tape, computer hard-drive or computer diskette.
- the computer storage medium can be accessed remotely, or at the monitoring location.

The data transfer can occur via modem to a central computer storage area or printed out as hard copy. In some instances, the data can be transferred from one storage medium (i.e. hard drive to a diskette or tape) to another storage medium.

14.2.4.2 DAS Quality Assurance/Quality Control

Quality assurance aspects of the DAS deal with whether the system is being operated within some given guidance. Usually, this means that the data that is collected on the DAS is the same value that is generated from the analyzer all the way to the AIRS data base. This usually is accomplished by a data trail audit performance audits and calibrations.

Data Trail Audit- The data trail audit consists of following a value or values collected by the DAS to the central data collection site and then eventually to AIRS. A person other than the normal station operator should perform this duty. The following procedure should be followed:

- a data point should be collected from the DAS (usually an hourly value) and be checked on the DAS storage medium against the hard copy report
- the auditor goes to the central computer and checks to see if this hourly value is the same
- if the data has been submitted to airs, then the airs data base should be checked as well

Performance Audit- The performance audit consists of challenging the instrument and DAS to a known audit source gas and observing the final response. The response should correspond to the value of the audit source gas.

Calibrations-The quality control aspects of data collection are well defined in terms of chart recorders. DAS systems are much more complex but the approach to calibration of a DAS is similar to the chart recorder. The calibration of a DAS is performed by inputting known voltages into the DAS and measuring the output of the DAS. The DAS owner's manual should be followed. It is recommended that DAS be calibrated once per year. An example of a calibration technique can be found in Appendix 14.

14.2.4.3 DAS Data Transfer

Data transfer is usually accomplished in three ways: hard copy printout, downloading data from internal storage medium to external storage medium, or digital transfer via the telephone lines.

Hard copy report- Most DAS have the ability to create a hard copy report. Usually, this report is in tabular format showing 1 minute, 5 minute or hourly averages vs. hours in the day. Agencies are encouraged to keep hard copy printouts for several reasons:

- the hard copy report can be reviewed by the station operators during site visits to ascertain the quality of the data
- the hard copy reports can be compared against the strip charts at the site for validation
- notes can be made on the hard copy reports for later review by data review staff
- this creates a "back-up" to the electronically based data

External Storage- This term refers to storing and transferring the data on diskettes or tape. Many DAS have the ability to download data to diskette or cassette tape. The data can then be hand transferred to a central office for downloading and data review.

Digital Transfer- There are many commercially available DAS which allow access to the computer via the telephone and modem. These systems allow fast and effective ways to download data to a central location. The EPA recommends using these systems for the following reasons:

- In case of malfunction of an ambient instrument, the senior staff at the central location can try to diagnose any problems and decide a course of action.
- Downloading the data allows the data processing team to get a head start on reviewing the data.
- When pollution levels are high or forecasted to be high, this allows the pollution forecaster the ability to check trends.

As stated previously, the measurement instruments produce an analog voltage that is collected by a DAS and averaged for a particular time period (e.g., one hour). The data is stored by the DAS and may be retrieved via phone line and modem by a central computer. The data should be stored on a central computer until the end of the month as preliminary data. The station operators/lab technician should print out the data at the monitoring station and submit a report outlining any corrections or changes to the preliminary data that is stored. In addition to the electronic collected data, the analog output of the analyzers should be recorded on chart recorders. This serves as a back-up system in case of DAS failure.

14.2.4.4 DAS Data Review

The data review is an ongoing process that is performed by the station operators (SO) and the data processing team (DP). It would be extremely difficult for the data processing team to review the raw data without the

notations, notes and calibration information that the station operators provide for the group. The review process for the station operator could include:

- (SO) reviewing calibration information, the hourly data, and any flags that could effect data and recording any information on the daily summaries that might be vital to proper review of the data
- (SO)at regular intervals, bringing strip charts, daily summaries, monthly maintenance sheets and site log notes to the laboratory for secondary review
- (SO) at the laboratory, reviewing the data and marking any notations, or invalidations that occurred, providing strip charts, daily summaries, site notes, and monthly maintenance sheets for ready access by the data processing staff
- (DP) reviewing all hand reduced data, calibrations, precision data, station notes, and monthly maintenance sheets for the month; checking a percentage of all calibrations and strip chart data for comparison against the DAS, and if significant differences are observed, determining what corrective action steps are required

14.2.4.5 DAS Data Handling and Reporting

This section presents standard data handling and reporting techniques that should be used by reporting agencies.

Initialization Errors --

All data acquisition systems must be initialized. The initialization consists of an operator "setting up" the parameters so that the voltages produced by the instruments can be read, scaled correctly and reported in the correct units. Errors in initializations can create problems when the data is collected and reported. Read the manufacturer's literature before parameters are collected. If the manufacturer does state how these parameters are collected, request this information The following should be performed when setting up the initializations:

- check the full scale outputs of each parameter.
- calibrations should be followed after each initialization (each channel of a DAS should be calibrated independently) Appendix 14 provides an example of a DAS calibration technique.
- review the instantaneous data stream if possible to see if the DAS is collecting the data correctly
- save the initializations to a storage medium; if the DAS does not have this capability, print out the initialization and store it at the central computer location and at the monitoring location
- check to see if the flagging routines are performed correctly; data that is collected during calibrations and down time should be flagged correctly
- check the DAS for excessive noise. Noisy data that is outside of the normal background is a concern. Noisy data can be caused by improperly connected leads to the multiplexer, noisy AC power, or a bad multiplexer. Refer to the owner's manual for help on noisy data
- check to see that the average times are correct. Some DAS consider 45 minutes to be a valid hour, while others consider 48 minutes. Agency guidelines should be referred to before setting up averaging times

14.3 The Information Management System

Eventually, all required data will reside in the AIRS data base. The AIRS database is divided into 4 subsystems, two of which are important to the ambient air monitoring: 1) the air quality subsystem (AQS) including air quality data and monitoring site descriptions, and 2) the geographic/common subsystem, which contains geographic and other codes common to the other 3 subsystems and database control information. Information on the AQS is described in 5 users manual:

1. AIRS Volume AQ1. - Air Quality Data Dictionary
2. AIRS Volume AQ2 - Air Quality Data Coding Manual
3. AIRS Volume AQ3 - Air Quality Data Storage Manual
4. AIRS Volume AQ4 - Air Quality Data Retrieval Manual
5. AIRS Volume AQ5 - Ad-hoc Retrieval Manual

Recommended procedures for coding, key punching, and data editing are described in various sections of these users manuals These documents should be available to data management personnel. The AQS system contains a number of files in which data are entered and stored.

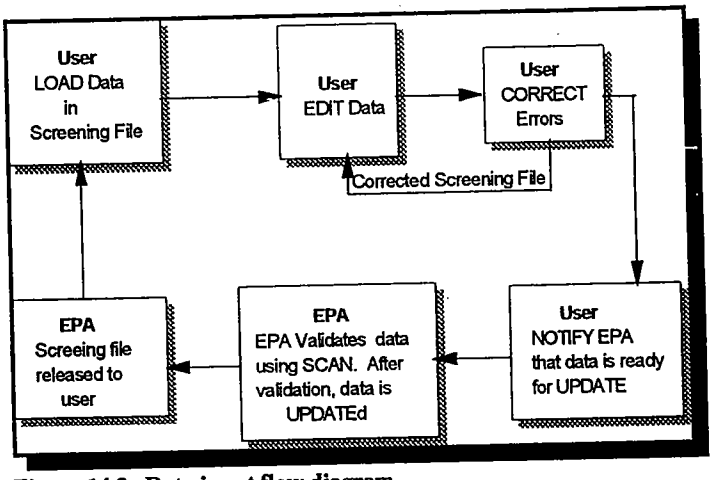


Figure 14.2 Data input flow diagram

14.3.1 Data Input

One of the functions of the AIRS is to read transactions coded by State, local and regional users of AIRS, validate these transactions, and use them to update the AIRS database as illustrated in Figure 14.2. To accomplish this, there are two primary players, AIRS users and the AIRS data base administrator (ADBA).

The AIRS users are responsible for the following steps in the update process:

LOAD	transfers transactions (either from tape or a database) into a screening file.
EDIT	checks the validity of the transactions in the screening file and produces a report to identify errors.
CORRECT	alters, removes, or creates transactions in the screening file in order to fix errors identified in the EDIT.
NOTIFY	informs the ADBA that transactions in the screening file are ready to be updated. This function can also be used to cancel a request to update a particular screening file for updating.

MESSAGE allows the user and the ADBA to track the above mentioned functions performed to a screening file when they were performed, and who performed them.

DELETE removes any transactions that exist in a screening file.

The ADBA primarily performs the following functions in the updating process:

SCAN produces a report used by the ADBA to coordinate the update processing across several screening files. This function also "locks" the screening file to prevent the user access to the screening file during the updating activity.

UPDATE changes values and files on the AIRS database identified during the SCAN process. This process also removes any transactions from the screening file that have been updated and releases the screening file back to the user.

14.3.2 Processing of Quality Assurance Information

It is of the utmost importance that all precision and accuracy assessment readings from an analyzer be processed exactly as ambient readings recorded at that time would be processed. Many automated data acquisition and processing systems do not include provision for handling such extra readings, and this capability may be difficult to incorporate into such systems unless it is done in the early planning stage. External or hand processing of such readings should be discouraged unless it is done with extreme care and assurance that processing is identical to the way ambient readings are processed by the automated system. Perhaps the best way to handle such readings is to enter them into the automatic processing system in such a way that the system thinks they are actual ambient readings and processes them accordingly. After processing, the readings can be removed from the final ambient data listing and used in the data quality assessment calculations.

14.3.3 Non-Programmed Adjustments to Ambient Data

Adjustments to ambient data, made routinely according to a documented, pre-established procedure (programmed adjustments), would be a normal part of an overall scheme to maintain high levels of data quality. In contrast, after-the-fact adjustments or "corrections" are occasionally proposed to ambient data based on unanticipated events or discoveries. This latter type of adjustment should be scrutinized completely before any changes are made to ambient data. These changes should be discussed with the appropriate EPA Regional Office prior to enacting these changes. In general, such adjustments are discouraged as there is a substantial risk that they may cause more harm than good. There is also a risk that such proposed adjustments might be used or might appear to be used for ulterior purposes.

If, after scrutiny, a special, unprogrammed adjustment is determined to be appropriate and is made to a block of ambient data, it is very important to ensure that the exact same adjustment is also made to any QA data (precision and accuracy measurements) obtained during the affected time period. Any data quality calculations affected by the change should also be recomputed. All such adjustments should be completely documented, including the rationale and justification for the adjustment.

15. Assessment and Corrective Action

An assessment is an evaluation process used to measure the performance or effectiveness of a system and its elements. It is an all-inclusive term used to denote any of the following: audit, performance evaluation, management systems review, peer review, inspection and surveillance[9]. For the Ambient Air Quality Monitoring Program, the following assessments will be discussed: network reviews, performance evaluations, technical systems audits and data quality assessments.

15.1 Network Reviews

Conformance with network requirements of the Ambient Air Monitoring Network set forth in 40 CFR Appendices D[17] and E[18] are determined through annual network reviews of the ambient air quality monitoring system. The annual review of the network is used to determine how well the network is achieving its required monitoring objectives and how it should be modified to continue to meet its objectives. Most network reviews are accomplished by the EPA Regional Office, however, the following information can be useful to State and local organizations to prepare for reviews or assess their networks.

In order to maintain consistency in implementing and collecting information from a network review, EPA has developed *SLAMS/NAMS/PAMS Network Review Guidance*. The information presented in this section provides some excerpts from this guidance document.

15.1.1 Network Selection

Due to the resource-intensive nature of network reviews, it may be necessary to prioritize agencies and/or pollutants to be reviewed. The following criteria may be used to select networks:

- date of last review
- areas where attainment/nonattainment redesignations are taking place or are likely to take place
- results of special studies, saturation sampling, point source oriented ambient monitoring, etc.
- agencies which have proposed network modifications since the last network review

In addition, pollutant-specific priorities may be considered (e.g., newly designated ozone nonattainment areas, PM_{10} "problem areas", etc.).

Once the agencies have been selected for review, significant data and information pertaining to the review should be compiled and evaluated. Such information might include the following:

- network files for the selected agency (including updated site information and site photographs)
- AIRS reports (AMP220, 225, 380, 390, 450)
- air quality summaries for the past five years for the monitors in the network
- emissions trends reports for major metropolitan areas

- emission information, such as emission density maps for the region in which the monitor is located and emission maps showing the major sources of emissions
- National Weather Service summaries for monitoring network area

Upon receiving the information, it should be checked to ensure it was the latest revision and for consistency. Discrepancies should be noted on the checklist (Appendix 15) and resolved with the agency during the review. Files and/or photographs that need to be updated should also be identified.

15.1.2 Conformance to 40 CFR Part 58 Appendix D- Network Design Requirements

With regard to 40 CFR Part 58 Appendix D[17] requirements, the network reviewer must determine the adequacy of the network in terms of number and location of monitors: specifically, (1) is the agency meeting the number of monitors required by the design criteria requirements?; and (2) are the monitors properly located, based on the monitoring objectives and spatial scales of representativeness?

15.1.2.1 Number of Monitors

For SLAMS, the number of monitors required is not specified in the regulations, with the exception of $PM_{2.5}$ stations, but rather is determined by the Regional Office and State agencies on a case-by-case basis to meet the monitoring objectives specified in Appendix D[17]. Adequacy of the network may be determined by using a variety of tools, including the following:

- maps of historical monitoring data
- maps of emission densities
- dispersion modeling
- special studies/saturation sampling
- best professional judgement
- SIP requirements
- revised monitoring strategies (e.g., lead strategy, reengineering air monitoring network)

For NAMS, areas to be monitored must be selected based on urbanized population and pollutant concentration levels. To determine whether the number of NAMS are adequate, the number of NAMS operating is compared to the number of NAMS specified in Appendix D[17] and summarized in Table 6-6 in this Handbook. The number of NAMS operating can be determined from the AMP220 report in AIRS. The number of monitors required based on concentration levels and population can be determined from the AMP450 report and the latest census population data.

For PAMS, the required number and type of monitoring sites and sampling requirements are based on the population of the affected MSA/CMSA or ozone nonattainment area (whichever is larger). PAMS minimum monitoring network requirements are summarized in Table 6-9.

15.1.2.2 Location of Monitors

For SLAMS, the location of monitors is not specified in the regulations, but is determined by the Regional Office and State agencies on a case-by-case basis to meet the monitoring objectives specified in Appendix D[17]. Adequacy of the location of monitors can only be determined on the basis of stated objectives. Maps, graphical overlays, and GIS-based information is extremely helpful in visualizing or assessing the adequacy of monitor locations. Plots of potential emissions and/or historical monitoring data versus monitor locations are especially useful.

For NAMS, locations are based on the objectives specified in Appendix D[17]. Most often, these locations are those that have high concentrations and large population exposure. Population information may be obtained from the latest census data and ambient monitoring data from the AIRS AMP450 Quick Look Report.

For PAMS, there is considerable flexibility when locating each PAMS within a nonattainment area or transport region. The three fundamental criteria which need to be considered when locating a final PAMS site are: (1) sector analysis - the site needs to be located in the appropriate downwind (or upwind) sector (approximately 45°) using appropriate wind directions; (2) distance - the sites should be located at distances appropriate to obtain a representative sample of the areas precursor emissions and represent the appropriate monitoring scale; and (3) proximate sources.

15.1.3 Conformance to 40 CFR Part 58 Appendix E[18] - Probe Siting Requirements

Applicable siting criteria for SLAMS, NAMS and PAMS are specified in Appendix E[18]. The on-site visit itself consists of the physical measurements and observations needed to determine compliance with the Appendix E[18] requirements, such as height above ground level, distance from trees, paved or vegetative ground cover, etc.

Prior to the site visit, the reviewer should obtain and review the following:

- most recent hard copy of site description (including any photographs)
- data on the seasons with the greatest potential for high concentrations for specified pollutants
- predominant wind direction by season

The checklist provided in Appendix 15 is also intended to assist the reviewer in determining conformance with Appendix E[18]. In addition to the items on the checklist, the reviewer should also do the following:

- ensure that the manifold and inlet probes are clean
- estimate probe and manifold inside diameters and lengths
- inspect the shelter for weather leaks, safety, and security
- check equipment for missing parts, frayed cords, etc.
- check that monitor exhausts are not likely to be introduced back to the inlet
- record findings in field notebook and/or checklist

- take photographs/videotape in the 8 directions
- document site conditions, with additional photographs/videotape

15.1.4 Checklists and Other Discussion Topics

Checklists are provided in Appendix 15 to assist network reviewers (SLAMS, NAMS, and PAMS) in conducting the review. In addition to the items included in the checklists, other subjects for possible discussion as part of the network review and overall adequacy of the monitoring program include:

- installation of new monitors
- relocation of existing monitors
- siting criteria problems and suggested solutions
- problems with data submittals and data completeness
- maintenance and replacement of existing monitors and related equipment
- quality assurance problems
- air quality studies and special monitoring programs
- other issues
  - -proposed regulations
  - -funding

15.1.5 Summary of Findings

Upon completion of the network review, a written network evaluation should be prepared. The evaluation should include any deficiencies identified in the review, corrective actions needed to address the deficiencies, and a schedule for implementing the corrective actions. The kinds of discrepancies/deficiencies to be identified in the evaluation include discrepancies between the agency network description and the AIRS network description; and deficiencies in the number, location, and/or type of monitors. Regions are encouraged to send copies of the SLAMS, NAMS and PAMS network reviews to OAQPS's Monitoring and Quality Assurance Group. Also, the AIRS has an area for the entry of these reviews.

15.2 Performance Evaluations

Performance evaluations (PEs) are a means of independently verifying and evaluating the quality of data from a measurement phase, or the overall measurement system. This is accomplished through the use of samples of known composition and concentration or devices that produce a known effect. These samples can be introduced into the measurement system as single blind (identity is known but concentration is not) or double blind (concentration and identity unknown). These samples can be used to control and evaluate bias, accuracy and precision and to determine whether DQOs or MQOs have been satisfied. PEs can also be used to determine inter- and intra-laboratory variability and temporal variability over long projects.

15.2.1 National Performance Audit Program

The NPAP is a cooperative effort among OAQPS, the 10 EPA Regional Offices, and the 170 state and local agencies that operate the SLAMS/NAMS/PAMS/PSD air pollution monitors. Also included in the NPAP are approximately 135 organizations (governmental and private) that operate air monitors at PSD sites. Participation in the NPAP is required for agencies operating SLAMS/NAMS/PAMS/PSD monitors as per Section 2.4 of 40 CFR Part 58, Appendix A and Section 2.4 of 40 CFR Part 58, Appendix B. Participation in the NPAP program is also mandatory for the 22 agencies which monitor for photochemical oxidants under EPA's Photochemical Assessment Monitoring (PAMS) program. These agencies monitor for carbonyl compounds, volatile organic compounds, NO_x and ozone.

The NPAP's goal is to provide audit materials and devices that will enable EPA to assess the proficiency of agencies that are operating monitors in the SLAMS/NAMS/PAMS/PSD networks. To accomplish this, the NPAP has established acceptable limits or performance criteria, based on the data quality needs of the SLAMS/NAMS/PAMS/PSD requirements, for each of the audit materials and devices used in the NPAP.

All audit devices and materials used in the NPAP are certified as to their true value, and that certification is traceable to a National Institute of Standards and Technology (NIST) standard material or device wherever possible. The audit materials used in the NPAP are as representative and comparable as possible to the calibration materials and actual air samples used and/or collected in the SLAMS/NAMS/PAMS/PSD networks. The audit material/gas cylinder ranges used in the NPAP are specified in the Federal Register.

The NPAP is managed by the Monitoring and Quality Assurance Group of OAQPS. The mailing address for the NPAP is:

NPAP Project Officer
US EPA
Office of Air Quality Planning and Standards
MD-14
Research Triangle Park, NC 27711

The NPAP audits are accomplished using a variety of mailable audit systems. The participants use these audit systems to generate pollutant concentrations and flowing air streams which are introduced into their sampling system. The pollutant concentrations and air stream flow rate are unknown to the audit participants. The outputs from the sampler that result from the use of the audit system are recorded on a data form, returned to EPA, and compared to the concentration or flow rate that should have been generated by the audit system under the environmental conditions at the site. The differences between the EPA expected (certified) values and the NPAP participants' reported values are calculated and returned to the participant. Table 15-1 lists the acceptance criteria for the audit material.

Table 15-1 NPAP Acceptance Criteria

Audit	EPA determined limits
High volume/PM-10 (SSI)	% difference > ± 15% for 1 or more flows
Dichot (PM-10)	% difference > ±15% for 1 or more flows
Pb (analytical)	% difference > ± 15% for 1 or more levels
SO_2, NO_2, O_3 and CO	Mean absolute % difference > 15%
PAMS	
Volatile Organic Compounds	Compound Specific
Carbonyls	Compound and level specific

Description of NPAP Audit Materials/Devices

The following materials and devices are currently being used in NPAP:

High-Volume/PM-10 (SSI) Flow Audits

The reference flow (ReF) device used for the high volume flow audit consists of a modified orifice, a wind deflector, a manometer, and five resistance plates. The ReF for the PM-10 size selective inlet (SSI) flow audit is similar except a filter is used as the only resistance.

Sulfur Dioxide/Carbon Monoxide (GDS) Audits

The gas dilution system (GDS) consists of a dilution device, a zero air generator and a cylinder of gas containing approximately 30 ppm sulfur dioxide and 3000 ppm carbon monoxide.

Ozone (TECO 165) Audit

The audit device is self-contained with its own zero air and ozone generation system.

Lead Audit

The samples are 1.9 cm wide and 20 cm long glass fiber filter strips that have been spiked with an aqueous solution of lead nitrate and oven-dried. Two filter strips comprise a sample.

Dichotomous (PM-10) Flow Audit

The audit device consists of a laminar flow element (LFE), an inclined manometer, an altimeter, and a small dial thermometer. It measures fine flow (15.00 lpm) and total flow (16.7 lpm).

Ozone/Nitrogen Dioxide/Sulfur Dioxide/Carbon Monoxide (TECO 175) Audit

The audit device is a combination of the TECO 165 and the GDS audit systems. It uses the same zero air generation system as the GDS, the ozone generation system of the TECO 165, and a gas cylinder containing approximately 3000 ppm carbon monoxide, 30 ppm sulfur dioxide and 30 ppm nitric oxide. The ozone generation system is used with the pollutant gas to convert nitric oxide to nitrogen dioxide via a gas phase titration.

PAMS Volatile Organic Compound (VOC) Audit

This audit uses a gas transfer system (GTS), stock (concentrated) compressed gas mixtures containing PAMS compounds and 1.5L compressed gas (audit) cylinders. The stock mixtures are mixed and diluted using the GTS and the resulting mixture is placed in the 1.5L audit cylinders. These audit cylinders are pressurized to 800-1000 psi to yield recoverable gas volumes of 60 to 80 L. Three audits are scheduled for each year. Each of the 22 PAMS agencies receives one cylinder for each audit. The cylinders contain between 15 and 35 PAMS analytes at concentrations from 10 to 60 ppbv as carbon. The PAMS VOC audit was added to the NPAP in 1995. There are plans to phase out the treated aluminum cylinders for replacement with humidified SUMMA ® or Silcosteel ® stainless steel canisters.

PAMS Carbonyl Compound Audit

This audit uses three glass tubes containing dinitrophenylhydrazene (DNPH) coated silica gel which have been spiked with solutions containing acetone, formaldehyde and acetaldehyde. Each tube contains from 0.2 to 10 micrograms of each dirivatized carbonyl compound. A blank cartridge is typically included with each audit sample set. The audit is conducted on the same schedule as the PAMS VOC audit. Each PAMS agency recovers the carbonyl compounds from the three DNPH-tubes and reports the results to EPA. The PAMS carbonyl audit was added to the NPAP in 1995.

15.2.2 $PM_{2.5}$ FRM Performance Evaluation

The Federal Reference Method (FRM) Performance Evaluation is a quality assurance activity which will be used to evaluate measurement system bias of the $PM_{2.5}$ monitoring network. The pertinent regulations for this performance audit are found in 40 CFR Part 58, Appendix A, section 3.5.3. The strategy is to collocate a portable FRM $PM_{2.5}$ air sampling instrument with an established routine air monitoring site, operate both monitors in exactly the same manner and then compare the results of this instrument against the routine sampler at the site. For allocation of FRM evaluations, every method designation ***must:***

- allocate 25% of sites, including collocated sites (even those collocated with FRM instruments), to FRM performance evaluations (values of .5 and greater round up) each year. All sites would be audited within 4 years
- have at least 1 monitor evaluated
- be evaluated at a frequency of 4 per year

Since performance evaluations are independent assessments, Figure 15.1 was developed to define independence for the FRM performance evaluation to allow State and local organizations to implement this activity. Since the regulations define the performance evaluations as an NPAP like activity, EPA has made arrangements to implement this audit. State/locals can determine, on a yearly basis, to utilize federal implementation by directing their appropriate percentage of grant resources back to the OAQPS or implement the audit themselves.

Independent assessment - an assessment performed by a qualified individual, group, or organization that is not part of the organization directly performing and accountable for the work being assessed. This auditing organization must not be involved with the generation of the routine ambient air monitoring data. An organization can conduct the FRM Performance Audit if it can meet the above definition and has a management structure that, at a minimum, will allow for the separation of its routine sampling personnel from its auditing personnel by two levels of management, as illustrated in Figure 1. In addition, the pre and post weighing of audit filters must be performed by separate laboratory facility using separate laboratory equipment. Field and laboratory personnel would be required to meet the FRM Performance Audit field and laboratory training and certification requirements. The State and local organizations are also asked to consider participating in the centralized field and laboratory standards certification process.

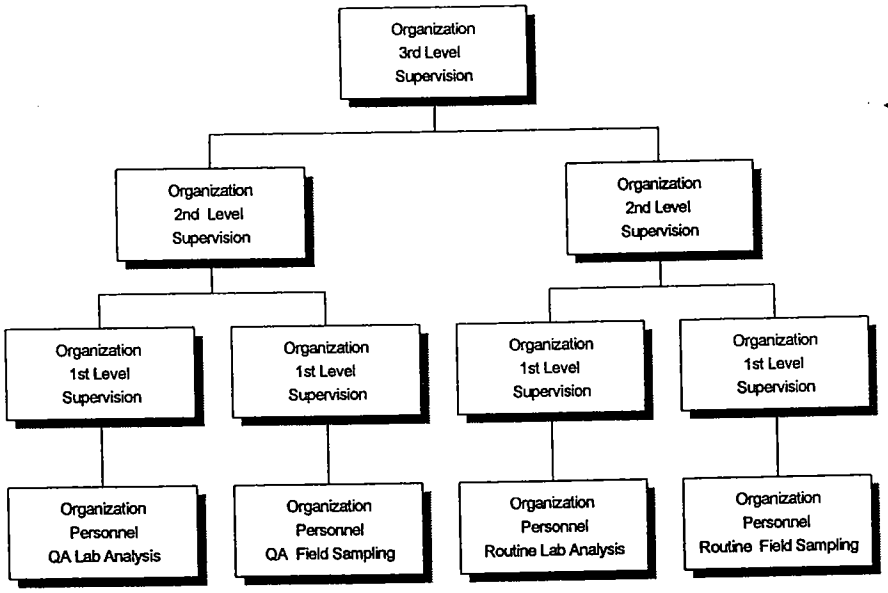


Figure 1

Organizations planning to implement the FRM Performance Audit must submit a plan demonstrating independence to the EPA Regional Office responsible for overseeing quality assurance related activities for the ambient air monitoring network.

Figure 15.1 Definition of independent assessment

The following activities will be established for federal implementation:

- field personnel assigned to each EPA Region, the hours based upon the number of required audits in the Region
- 2 National laboratories, one in Region 4 and one in Region 10 to serve as weighing labs

Information on the FRM performance evaluation can be found in the *FRM Performance Evaluation Implementation Plan* found on the AMTIC Bulletin Board.

15.2.3 State and Local Organization Performance Audits

In addition to NPAP, State and local organizations also conduct performance audits. Detailed information on the procedures for this audit can be found in Appendix 15.

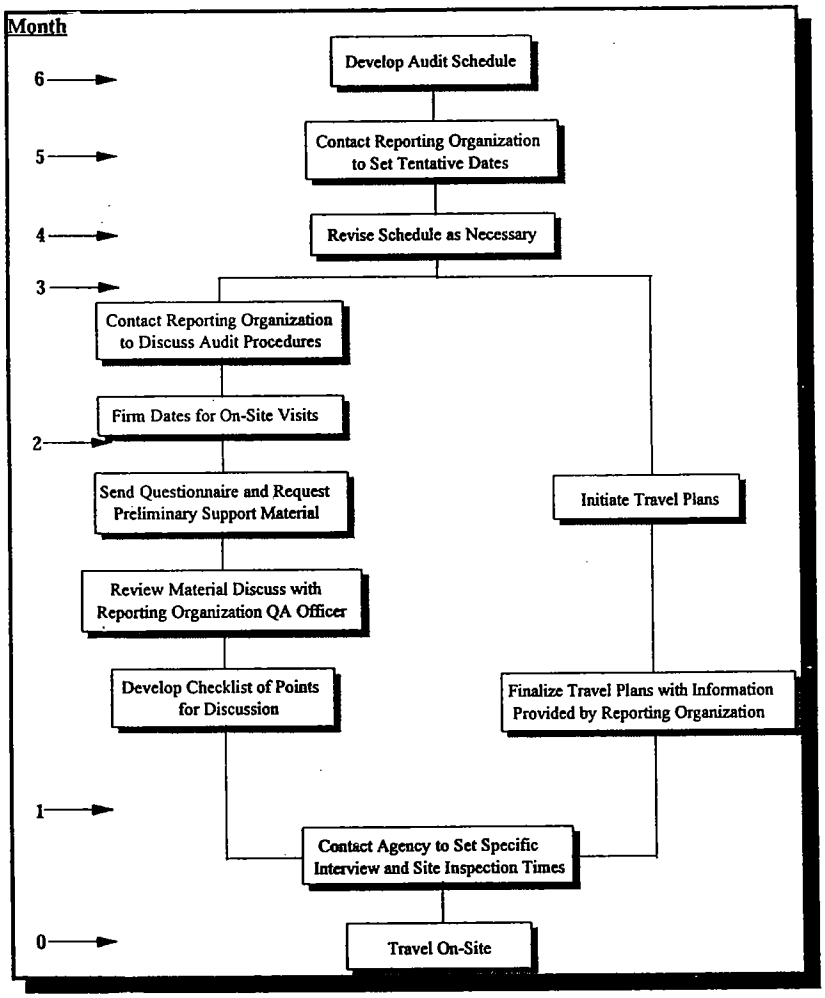


Figure 15.2 Pre-audit activities

15.3 Technical Systems Audits

A systems audit is an on-site review and inspection of a State or local agency's ambient air monitoring program to assess its compliance with established regulations governing the collection, analysis, validation, and reporting of ambient air quality data. A systems audit of each state or autonomous agency within an EPA Region is performed every three years by a member of the Regional Quality Assurance (QA) staff. Detailed discussions of the audits performed by the EPA and the State and local organizations are found in Appendix 15; the information presented in this section provides general guidance for conducting technical systems audits. A systems audit should consist of three separate phases:

- pre-audit activities
- on-site audit activities
- post-audit activities

Summary activity flow diagrams have been included as Figures 15.2, 15.3 and 15.5, respectively. The reader may find it useful to refer to these diagrams while reading this guidance.

15.3.1 Pre-Audit Activities-

At the beginning of each fiscal year, the audit lead or a designated member of the audit team, should establish a tentative schedule for on-site systems audits of the agencies within their Region. It is suggested that the audit lead develop an audit plan. This plan should address the elements listed in Table 15-2. The audit plan is not a major undertaking and in most cases will be a one page table or report. However, the document

represents thoughtful and conscious planning for an efficient and successful audit. The audit plan should be made available to the organization audited, with adequate lead time to ensure that appropriate personnel and documents are available for the audit. Three months prior to the audit, the audit lead should contact the quality assurance officer (QAO) of the organization to be audited to coordinate specific dates and schedules for the on-site audit visit. During this initial contact, the audit lead should arrange a tentative schedule for meetings with key personnel as well as for inspection of selected ambient air quality monitoring and measurement operations. At the same time, a schedule should be set for the exit interview used to debrief the agency director or his/her designee, on the systems audit outcome. As part of this scheduling, the audit lead should indicate any special requirements such as access to specific areas or activities. The audit lead should inform the agency QAO that the QAO will receive a questionnaire, which is to be reviewed and completed.

Table 15-2 Suggested Elements of an Audit Plan

Audit Title -	Official title of audit that will be used on checksheets and reports
Audit Number-	Year and number of audit can be combined; 91-1, 91-2Date of audit
Scope -	Establishes the boundary of the audit and identifies the groups and activities to be evaluated. The scope can vary from general overview, total system, to part of system, which will effect the length of the audit.
Purpose -	What the audit should achieve
Standards -	Standards are criteria against which performance is evaluated. These standards must be clear and concise and should be used consistently when auditing similar facilities or procedures. The use of audit checklists is suggested to assure that the full scope of an audit is covered. An example checklist for the Regional RSA is found in Appendix 15-A.
Audit team -	Team lead and members.
Auditees -	People that should be available for the audit from the audited organization. This should include the Program Manager, Principal Investigator, organizations QA Representative, and other management, and technicians as necessary.
Documents -	Documents that should be available in order for the audit to proceed efficiently. Too often documents are asked for during an audit, when auditors do not have the time to wait for these documents to be found. Documents could include QMPs, QAPjPs, SOPs, GLPs, control charts, raw data, QA/QC data, previous audit reports etc.
Timeline -	A timeline of when organizations (auditors/auditees) will be notified of the audit in order for efficient scheduling and full participation of all parties.

The audit lead should emphasize that the completed questionnaire is to be returned within one (1) month of receipt. The information within the questionnaire is considered a minimum, and both the Region and the agency under audit should feel free to include additional information. Once the completed questionnaire has been received, it should be reviewed and compared with the pertinent criteria and regulations. The PARS and completeness data as well as any other information on data quality can augment the documentation received from the reporting organization under audit. This preliminary evaluation will be instrumental in selecting the sites to be evaluated and in the decision on the extent of the monitoring site data audit. The audit lteam should then prepare a checklist detailing specific points for discussion with agency personnel.

The audit team should be made of several members to offer a wide variety of backgrounds and expertise. This team may then divide into groups once on-site, so that both audit coverage and time utilization can be

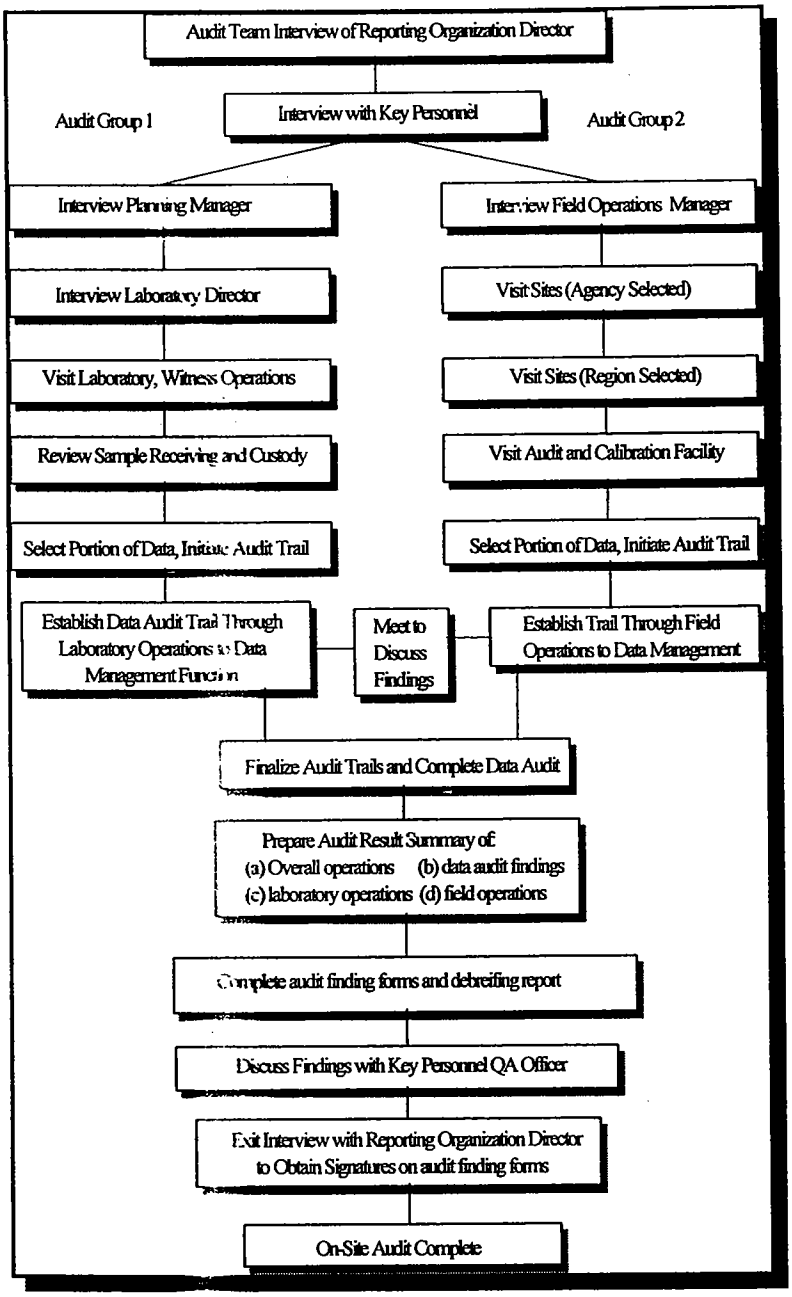


Figure 15.3 On-site activities

optimized. A possible division may be that one group assesses the support laboratory and headquarters operations while another evaluates sites, and subsequently assesses audit and calibration information. The audit lead should confirm the proposed audit schedule with the audited organization immediately prior to traveling to the site.

15.3.2. On-Site Activities

The audit team should meet initially with the audited agency's director or his/her designee to discuss the scope, duration, and activities involved with the audit. This should be followed by a meeting with key personnel identified from the completed questionnaire, or indicated by the agency QAO. Key personnel to be interviewed during the audit are those individuals with responsibilities for: planning, field operations, laboratory operations, QA/QC, data management and reporting. At the conclusion of these introductory meetings, the audit team may begin work as two or more independent groups, as illustrated in Figure 15.3. To increase uniformity of site inspections, it is suggested that a site checklist be developed and used. The format for Regional TSAs are found in Appendix 15.

The importance of the audit of data quality (ADQ) cannot be overstated. Thus, sufficient time and effort should be devoted to this activity so that the audit team has a clear understanding and complete documentation of data flow. Its importance stems from the need to have documentation on the quality of ambient air monitoring data for all the criteria pollutants for which the agency has monitoring requirements. The ADQ will serve as an effective framework for organizing the extensive amount of information gathered during the audit of laboratory, field monitoring and support functions within the agency.

The entire audit team should prepare a brief written summary of findings, organized into the following areas: planning, field operations, laboratory operations, quality assurance/quality control, data management, and reporting. Problems with specific areas should be discussed and an attempt made to rank them in order of their potential impact on data quality. For the more serious problems, audit findings should be drafted (Fig. 15.4) .

The audit finding form has been designed such that one is filled out for each major deficiency that requires formal corrective action. They inform the agency being audited about a serious finding that may compromise the quality of the data and therefore require specific corrective actions. They are initiated by the audit team, and discussed at the debriefing. During the debriefing discussion, evidence may be presented that reduces the significance of the finding; in which case the finding may be removed. If the audited agency is in agreement with the finding, the form is signed by the agency's director or his/her designee during the exit interview. If a disagreement occurs, the QA Team should record the opinions of the agency audited and set a time at some later date to address the finding at issue.

Audit Finding

Audit Title: _____ **Audit #:** ____ **Finding #:**____

_____

Finding:

_____

Discussion:

QA Lead Signature: **Date:**

Audited Agencies
Signature: **Date:**

Figure 15.4. Audit finding form

The audit is now completed by having the audit team members meet once again with key personnel, the QAO and finally with the agency's director to present their findings. This is also the opportunity for the agency to present their disagreements. The audit team should simply state the audit results, including an indication of the potential data quality impact. During these meetings, the audit team should also discuss the systems

audit reporting schedule and notify agency personnel that they will be given a chance to comment in writing, within a certain time period, on the prepared audit report in advance of any formal distribution.

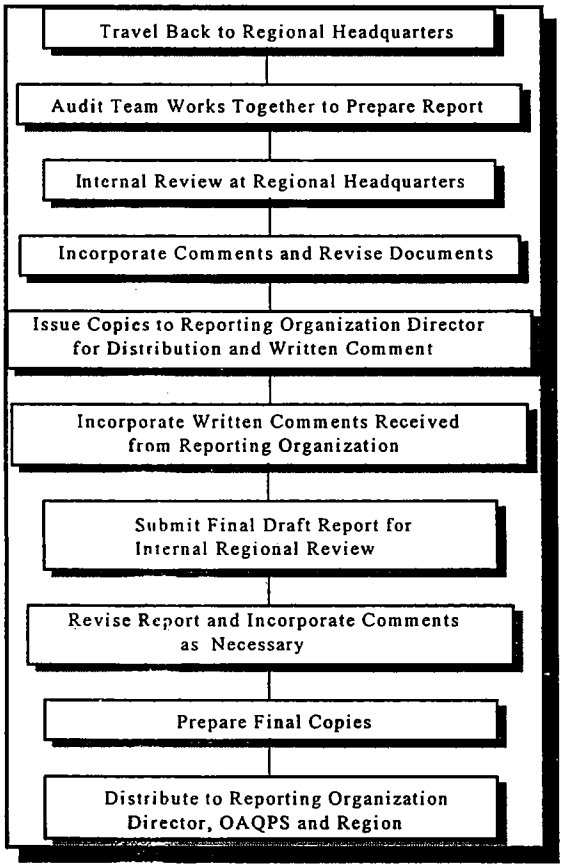


Figure 15.5. Post-audit activities

15.3.3 Post-Audit Activities

The major post-audit activity is the preparation of the systems audit report. The report will include:

- audit title and number and any other identifying information
- audit team leaders, audit team participants and audited participants
- background information about the project, purpose of the audit, dates of the audit, particular measurement phase or parameters that were audited, and a brief description of the audit process
- summary and conclusions of the audit and corrective action requirements
- attachments or appendices that include all audit evaluations and audit finding forms

To prepare the report, the audit team should meet and compare observations with collected documents and results of interviews and discussions with key personnel. Expected QA project plan implementation is compared with observed accomplishments and deficiencies and the audit findings are reviewed in detail. Within thirty (30) calendar days of the completion of the audit, the audit report should be prepared and submitted.

The technical systems audit report is submitted to the audited agency. It is suggested that a cover letter be used to reiterate the fact that the audit report is being provided for review and written comment. The letter should also indicate that, should no written comments be received by the audit lead within thirty (30) calendar days from the report date, it will be assumed acceptable to the agency in its current form, and will be formally distributed without further changes.

If the agency has written comments or questions concerning the audit report, the audit team should review and incorporate them as appropriate, and subsequently prepare and resubmit a report in final form within thirty (30) days of receipt of the written comments. Copies of this report should be sent to the agency director or his/her designee for internal distribution. The transmittal letter for the amended report should indicate official distribution and again draw attention to the agreed-upon schedule for corrective action implementation.

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15.4 Data Quality Assessments

A data quality assessment (DQA) is the statistical analysis of environmental data, to determine whether the quality of data is adequate to support the decision which are based on the DQOs. Data are appropriate if the level of uncertainty in a decision, based on the data, is acceptable. The DQA process is described in detail in *Guidance for the Data Quality Assessment Process*, EPA QA/G-9 [41], in Section 18 and is summarized below.

1. *Review the data quality objectives (DQOs) and sampling design of the program*: review the DQO and develop one, if it has not already been done. Define statistical hypothesis, tolerance limits, and/or confidence intervals.

2. *Conduct preliminary data review.* Review QA data and other available QA reports, calculate summary statistics, plots and graphs. Look for patterns, relationships, or anomalies.

3. *Select the statistical test*: select the best test for analysis based on the preliminary review, and identify underlying assumptions about the data for that test.

4. *Verify test assumptions*: decide whether the underlying assumptions made by the selected test hold true for the data and the consequences.

5. *Perform the statistical test:* perform test and document inferences. Evaluate the performance for future use.

The G-9[41] document provides many appropriate statistical tests. QAD is also developing statistical software to complement the document. Both can be found on the QAD Homepage *(http://es.epa.gov/ncerqa)*.

OAQPS plans on performing data quality assessments for the pollutants of the Ambient Air Quality Monitoring Network at a yearly frequency for data reports and at a 3-year frequency for more interpretative reports. Reporting organizations and State and local agencies are encouraged to implement data quality assessments at their levels. Attaining the DQOs at a local level will ensure that the DQOs will be met when data is aggregated at higher levels.

16. Reports to Management

This section provides guidance and suggestions to air monitoring organizations on how to report the quality of the aerometric data and how to convey personnel information and requests for assistance concerning quality control and quality assurance problems. The guidance offered here is primarily intended for reporting organizations that provide data to one or more of these national networks:

- SLAMS (State and Local Air Monitoring Stations)
- NAMS (National Air Monitoring Stations, a subset of SLAMS)
- PAMS (Photochemical Air Monitoring Stations)
- PSD (Prevention of Significant Deterioration stations)
- Air Toxics

This guidance may also be useful in preparing reports that summarize data quality of other pollutant measurements such as those made at Special Purpose Monitoring Stations and state-specific programs.

Several kinds of reports can be prepared; the size and frequency of the reports will depend on the information requested or to be conveyed. A brief, corrective action form or letter-style report might ask for attention to an urgent problem. On the other hand, an annual quality assurance report to management would be a much larger report containing sections such as:

- executive summary
- network background and present status
- quality objectives for measurement data
- quality assurance procedures
- results of quality assurance activities
- recommendations for further quality assurance work, with suggestions for improving performance and fixing problems with equipment, personnel training, infrastructure needs, etc.

A report to management should not solely consist of tabulations of analyzer-by-analyzer precision and accuracy check results for criteria pollutants. This information is required to be submitted with the data each quarter and is thus already available to management through AIRS. Instead, the annual quality assurance report to management should summarize and discuss the results of such checks. These summaries from individual reporting organizations can be incorporated into additional reports issued by the State and/or the EPA Regional Office.

This section provides general information for the preparation of reports to management and includes:

- the types of reports that might be prepared, the general content of each type of report, and a suggested frequency for their preparation
- sources of information that can be tapped to retrieve information for the reports
- techniques and methods for concise and effective presentation of information

Appendix 16 presents examples of two types of reports to management; the annual quality assurance report to management and a corrective action request.

16.1 Guidelines for Preparation of Reports to Management

16.1.1 Types of QA Reports to Management

Listed in Table 16-1 are examples of typical QA reports to management. An individual reporting organization may have others to add to the list or may create reports that are combinations of those listed below.

Table 16-1 Types of QA Reports to Management

Type of QA Report to Management	Contents	Suggested Reporting Frequency				
		As required	Week	Month	Quarter	Year
Corrective action request	Description of problem; recommended action required; feedback on resolution of problem	x				
Control chart with summary	Repetitive field or lab activity; control limits versus time. Prepare monthly or whenever new check or calibration samples are used.	x		x		
National Performance Audit Program results	Summary of SLAMS, NAMS, and NPAP audit results	x			x	x
State and local organization performance audits	Summary of audit results; recommendations for action, as needed.	x				x
System audits	Summary of system audit results; recommendations for action, as needed.	x				x
Quality assurance report to management	Executive summary. Precision, bias, and system and performance audit results.					x
Network reviews (by EPA Regional Office)	Review results and suggestions for actions, as needed.	x				x

16.1.2 Sources of Information

Information for inclusion in the various reports to management may come from a variety of sources, including: records of precision and accuracy checks, results of systems and performance audits, laboratory and field instrument maintenance logbooks, NPAP audits, etc. Table 16-2 lists useful sources and the type of information expected to be found.

Table 16-2 Sources of Information for Preparing Reports to Management

Information Source	Expected Information and Usefulness
State implementation plan	Types of monitors, locations, and sampling schedule
Quality assurance program and project plans	Data quality indicators and goals for precision, accuracy, completeness, timeliness
Quality objectives for measurement data document	Quality objectives for measurement data. Audit procedures and frequency.
Laboratory and field instrument maintenance logbooks	Record of maintenance activity, synopsis of failures, recommendations for equipment overhaul or replacement
Laboratory weighing room records of temperature, humidity	A record of whether or not environmental control in the weighing room is adequate to meet goals
Audit results (NPAP, local, etc.)	Results of audit tests on ambient air pollutant measurement devices

16.1.3 Methods of Presenting Information

Reports to Management are most effective when the information is given in a succinct, well-summarized fashion. Methods useful for distilling and presenting information in ways that are easy to comprehend are listed in Table 16-3. Several of these methods will be available on-line in the revised AIRS database; others are available in commercially available statistical and spreadsheet computer programs.

Table 16-3. Presentation Methods for Use in Reports to Management

Presentation Method	Typical Use	Examples
Written text	Description of results and responses to problems	Appendix 16
Control chart	Shows whether a repetitive process stays within QC limits.	Figure 12.3 of this Handbook
Black box report	Shows if project goals were met.	Executive Summary of Appendix 16
Bar charts	Shows relationships between numerical values.	Included in most graphic and spreadsheet programs
X Y (scatter) charts	Shows relationships between two variables.	Included in most graphic and spreadsheet programs
Probability limit charts	Show a numerical value with its associated precision range.	Figure 1 of Appendix 16

16.1.4 Annual Quality Assurance Report

The annual quality assurance report (an example is provided in Appendix 16) should consist of a number of sections that describe the quality objectives for measurement data and how those objectives have been met. A suggested organization might include:

Executive Summary of Report to Management - The executive summary should be a short (no more than two page) section that summarizes the annual quality assurance report to management. It should contain a checklist graphic that lets the reader know how the reporting organization has met its goals for the report period. In addition, a short discussion of future needs and plans should be included.

Introduction - This section describes the quality objectives for measurement data and serves as an overview of the reporting organization's structure and functions. It also briefly describes the procedures used by the reporting organization to assess the quality of field and laboratory measurements.

Quality information for each ambient air pollutant monitoring program - These sections are organized by ambient air pollutant category (e.g., gaseous criteria pollutants, air toxics). Each section includes the following topics:

- program overview and update
- quality objectives for measurement data
- data quality assessment

16.1.5 Corrective Active Request

A corrective action request should be made whenever anyone in the reporting organization notes a problem that demands either immediate or long-term action to correct a safety defect, a operational problem, or a failure to comply with procedures. A typical corrective action request form, with example information entered, is shown in Appendix 16. A separate form should be used for each problem identified.

The corrective action report form is designed as a closed-loop system. First it identifies the originator, that person who reports and identifies the problem, states the problem, and may suggest a solution. The form then directs the request to a specific person (or persons), i.e., the recipient, who would be best qualified to "fix" the problem. Finally, the form closes the loop by requiring that the recipient state how the problem was resolved and the effectiveness of the solution. The form is signed and a copy is returned to the originator and other copies are sent to the supervisor and the applicable files for the record.

17. Data Review, Verification and Validation

Data review, verification and validation are techniques used to accept, reject or qualify data in an objective and consistent manner. Verification can be defined as confirmation by examination and provision of objective evidence that *specified requirements* have been fulfilled. Validation can be defined as confirmation by examination and provision of objective evidence that the particular requirements for a specific *intended use* are fulfilled. It is important to describe the criteria for deciding the degree to which each data item has met its quality specifications as described in an organization's QAPP. This section will describe the techniques used to make these assessments.

In general, these assessment activities are performed by persons implementing the environmental data operations as well as by personnel "independent" of the operation, such as the organization's QA personnel and at some specified frequency. The procedures, personnel and frequency of the assessments should be included in an organization's QAPP. These activities should occur prior to submitting data to AIRS and prior to final data quality assessments that will be discussed in Section 18.

Each of the following areas of discussion should be considered during the data review/verification/validation processes. Some of the discussion applies to situations in which a sample is separated from its native environment and transported to a laboratory for analysis and data generation; others are applicable to automated instruments. The following information is an excerpt from *EPA G-5*[32]:

Sampling Design - How closely a measurement represents the actual environment at a given time and location is a complex issue that is considered during development of the sampling design. Each sample should be checked for conformity to the specifications, including type and location (spatial and temporal). By noting the deviations in sufficient detail, subsequent data users will be able to determine the data's usability under scenarios different from those included in project planning.

Sample Collection Procedures- Details of how a sample is separated from its native time/space location are important for properly interpreting the measurement results. Sampling methods and field SOPs provide these details, which include sampling and ancillary equipment and procedures (including equipment decontamination). Acceptable departures (for example, alternate equipment) from the QAPP, and the action to be taken if the requirements cannot be satisfied, should be specified for each critical aspect. Validation activities should note potentially unacceptable departures from the QAPP. Comments from field surveillance on deviations from written sampling plans also should be noted.

Sample Handling- Details of how a sample is physically treated and handled during relocation from its original site to the actual measurement site are extremely important. Correct interpretation of the subsequent measurement results requires that deviations from the sample handling section of the QAPP and the actions taken to minimize or control the changes, be detailed. Data collection activities should indicate events that occur during sample handling that may affect the integrity of the samples. At a minimum, investigators should evaluate the sample containers and the preservation methods used and ensure that they are appropriate to the nature of the sample and the type of data generated from the sample. Checks on the identity of the sample (e.g., proper labeling and chain of custody records) as well as proper physical/chemical storage

conditions (e.g., chain of custody and storage records) should be made to ensure that the sample continues to be representative of its native environment as it moves through the analytical process.

Analytical Procedures- Each sample should be verified to ensure that the procedures used to generate the data were implemented as specified. Acceptance criteria should be developed for important components of the procedures, along with suitable codes for characterizing each sample's deviation from the procedure. Data validation activities should determine how seriously a sample deviated beyond the acceptable limit so that the potential effects of the deviation can be evaluated during DQA.

Quality Control- The quality control section of the QAPP specifies the QC checks that are to be performed during sample collection, handling and analysis. These include analyses of check standards, blanks and replicates, which provide indications of the quality of data being produced by specified components of the measurement process. For each specified QC check, the procedure, acceptance criteria, and corrective action (and changes) should be specified. Data validation should document the corrective actions that were taken, which samples were affected, and the potential effect of the actions on the validity of the data.

Calibration- Calibration of instruments and equipment and the information that should be presented to ensure that the calibrations:

- were performed within an acceptable time prior to generation of measurement data
- were performed in the proper sequence
- included the proper number of calibration points
- were performed using standards that "bracketed" the range of reported measurement results otherwise, results falling outside the calibration range should be flagged as such
- had acceptable linearity checks and other checks to ensure that the measurement system was stable when the calibration was performed

When calibration problems are identified, any data produced between the suspect calibration event and any subsequent recalibration should be flagged to alert data users.

Data Reduction and Processing- Checks on data integrity evaluate the accuracy of "raw" data and include the comparison of important events and the duplicate keying of data to identify data entry errors.

Data reduction is an irreversible process that involves a loss of detail in the data and may involve averaging across time (for example, hourly or daily averages) or space (for example, compositing results from samples thought to be physically equivalent) such as the $PM_{2.5}$ spatial averaging techniques. Since this summarizing process produces few values to represent a group of many data points, its validity should be well-documented in the QAPP. Potential data anomalies can be investigated by simple statistical analyses[41].

The information generation step involves the synthesis of the results of previous operations and the construction of tables and charts suitable for use in reports. How information generation is checked, the requirements for the outcome, and how deviations from the requirements will be treated, should be addressed.

17.1 Data Review Methods

The flow of data from the field environmental data operations to the storage in the database requires several distinct and separate steps:

- initial selection of hardware and software for the acquisition, storage, retrieval and transmittal of data
- organization and the control of the data flow from the field sites and the analytical laboratory
- input and validation of the data
- manipulation, analysis and archival of the data
- submittal of the data into the EPA's AIRS database.

Both manual and computer-oriented systems require individual reviews of all data tabulations. As an individual scans tabulations, there is no way to determine that all values are valid. The purpose of manual inspection is to spot unusually high (or low) values (outliers) that might indicate a gross error in the data collection system. In order to recognize that the reported concentration of a given pollutant is extreme, the individual must have basic knowledge of the major pollutants and of air quality conditions prevalent at the reporting station. Data values considered questionable should be flagged for verification. This scanning for high/low values is sensitive to spurious extreme values but not to intermediate values that could also be grossly in error.

Manual review of data tabulations also allows detection of uncorrected drift in the zero baseline of a continuous sensor. Zero drift may be indicated when the daily minimum concentration tends to increase or decrease from the norm over a period of several days. For example, at most sampling stations, the early morning (3:00 a.m. to 4:00 a.m.) concentrations of carbon monoxide tend to reach a minimum (e.g., 2 to 4 ppm). If the minimum concentration differs significantly from this, a zero drift may be suspected. Zero drift could be confirmed by review of the original strip chart.

In an automated data processing system, procedures for data validation can easily be incorporated into the basic software. The computer can be programmed to scan data values for extreme values, outliers or ranges. These checks can be further refined to account for time of day, time of week, and other cyclic conditions. Questionable data values are then flagged on the data tabulation to indicate a possible error. Other types of data review can consist of preliminary evaluations of a set of data, calculating some basic statistical quantiles and examining the data using graphical representations.

17.2 Data Verification Methods

Data verification is defined as the confirmation by examination and provision of objective evidence that *specified requirements* have been fulfilled[32]. These requirements for each data operation is included in the organizations QAPP and in SOPs. The data verification process involves the inspection, analysis, and acceptance of the field data or samples. These inspections can take the form of technical systems audits (internal or external) or frequent inspections by field operators and lab technicians. Questions that might be asked during the verification process include:

- Were the environmental data operations performed according to the SOP's governing those operations?
- Were the environmental data operations performed on the correct time and date originally specified? Many environmental operations must be performed within a specific time frame; for example, the NAAQS samples for particulates are collected once every six days from midnight to midnight. The monitor timing mechanisms must have operated correctly for the sample to be collected within the time frame specified.
- Did the sampler or monitor perform correctly? Individual checks such as leak checks, flow checks, meteorological influences, and all other assessments, audits, and performance checks must have been acceptably performed and documented.
- Did the environmental sample pass an initial visual inspection? Many environmental samples can be flagged (qualified) during the initial visual inspection.
- Were the environmental data operations performed to meet data quality objectives designed for those specific data operations and were the operations performed as specified? The objectives for environmental data operations must be clear and understood by all those involved with the data collection.

17.3 Data Validation Methods

Data validation is a routine process designed to ensure that reported values meet the quality goals of the environmental data operations. Data validation is further defined as examination and provision of objective evidence that the particular requirements for a specific *intended use* are fulfilled. A progressive, systematic approach to data validation must be used to ensure and assess the quality of data.

The purpose of data validation is to detect and then verify any data values that may not represent actual air quality conditions at the sampling station. Effective data validation procedures usually are handled completely independently from the procedures of initial data collection.

Because the computer can perform computations and make comparisons extremely rapidly; it can also make some determination concerning the validity of data values that are not necessarily high or low. Data validation procedures should be recommended as standard operating procedures. One way to do this is to test the difference between successive data values, since one would not normally expect very rapid changes in concentrations of a pollutant during a 5-min or 1-h reporting period. When the difference between two successive values exceeds a predetermined value, the tabulation can be flagged, with an appropriate symbol.

Quality control data can support data validation procedures. If data assessment results clearly indicate a serious response problem with the analyzer, the agency should review all pertinent quality control information to determine whether any ambient data, as well as any associated assessment data, should be invalidated. When precision, bias or accuracy assessment readings are obtained during any period for which the ambient readings immediately before or immediately after these readings are determined, by suitable reason, to be invalid, then the precision, bias and accuracy readings should also be invalidated. Any data quality calculations using the invalidated readings should be redone. Also, the precision, bias or accuracy checks should be rescheduled, preferably in the same calendar quarter. The basis or justification for all data invalidations should be permanently documented.

Certain criteria, based upon CFR and field operator and laboratory technician judgement, may be used to invalidate a sample or measurement. These criteria should be explicitly identified in the organizations QAPP. Many organizations use flags or result qualifiers to identify potential problems with data or a sample. A flag is an indicator of the fact and the reason that a data value (a) did not produce a numeric result, (b) produced a numeric result but it is qualified in some respect relating to the type or validity of the result, or (c) produced a numeric result but for administrative reasons is not to be reported outside the organization. Flags can be used both in the field and in the laboratory to signify data that may be suspect due to contamination, special events or failure of QC limits. Flags can be used to determine if individuals samples (data), or samples from a particular instrument, will be invalidated. In all cases, the sample (data) should be thoroughly reviewed by the organization prior to any invalidation.

Flags may be used alone or in combination to invalidate samples. Since the possible flag combinations can be overwhelming and can not always be anticipated, an organization needs to review these flag combinations and determine if single values or values from a site for a particular time period will be invalidated. The organization should keep a record of the combination of flags that resulted in invalidating a sample or set of samples. These combinations should be reported to the EPA Region and can be used to ensure that the organization evaluates and invalidates data in a consistent manner.

Procedures for screening data for possible errors or anomalies should also be implemented. References 41 and 90 recommend several statistical screening procedures for ambient air quality data that should be applied to identify gross data anomalies. Additional information on validation of air monitoring data is contained in references 89 and 110.

17.3.1 Automated Methods

When zero or span drift validation limits (see Section 12) are exceeded, ambient measurements should be invalidated back to the most recent point in time where such measurements are known to be valid. Usually this point is the previous calibration (or accuracy audit), unless some other point in time can be identified and related to the probable cause of the excessive drift (such as a power failure or malfunction). Also, data following an analyzer malfunction or period of non-operation should be regarded as invalid until the next subsequent (level 1) calibration unless unadjusted zero and span readings at that calibration can support its validity.

17.3.2 Manual Methods

For manual methods, the first level of data validation should be to accept or reject monitoring data based upon results from operational checks selected to monitor the critical parameters in all three major and distinct phases of manual methods--sampling, analysis, and data reduction. In addition to using operational checks for data validation, the user must observe all limitations, acceptance limits, and warnings described in the reference and equivalent methods per se that may invalidate data. It is further recommended that results from performance audits/evaluations required in 40 CFR 58 Appendices A and B not be used as a sole criteria for data invalidation because these checks (performance audits) are intended to assess the quality of the data.

18.0 Reconciliation with Data Quality Objectives

Section 3 described the data quality objective (DQO) process, which is an important planning tool to determine the objectives of an environmental data operation, to understand and agree upon the allowable uncertainty in the data, and with that, optimize the sampling design. This information, along with sampling and analytical methods and appropriate QA/QC should be documented in an organization's QAPP. The QAPP is then implemented by the State or local organization under the premise that if it is followed, the DQOs should be met. Reconciliation with the DQO involves reviewing both routine and QA/QC data to determine whether the DQOs have been attained and that the data is adequate for its intended use. This process of evaluating the data against the DQOs has been termed data quality assessment (DQA).

The DQA process has been developed for cases where formal DQOs have been established. However, these procedures can also be used for data that do not formally have DQOs. Guidance on the DQA process can be found in the document titled *Guidance for Data Quality Assessment (EPA QA/G-9)*[41]. This document focuses on evaluating data for fitness in decision- making and also provides many graphical and statistical tools.

DQA is built on a fundamental premise: " *Data quality, as a concept, is meaningful only when it relates to the intended use of the data*[41]". By using the DQA Process, one can answer two fundamental questions:

1. Can the decision (or estimate) be made with the desired confidence, given the quality of the data set?
2. How well can the sampling design be expected to perform over a wide range of possible outcomes?

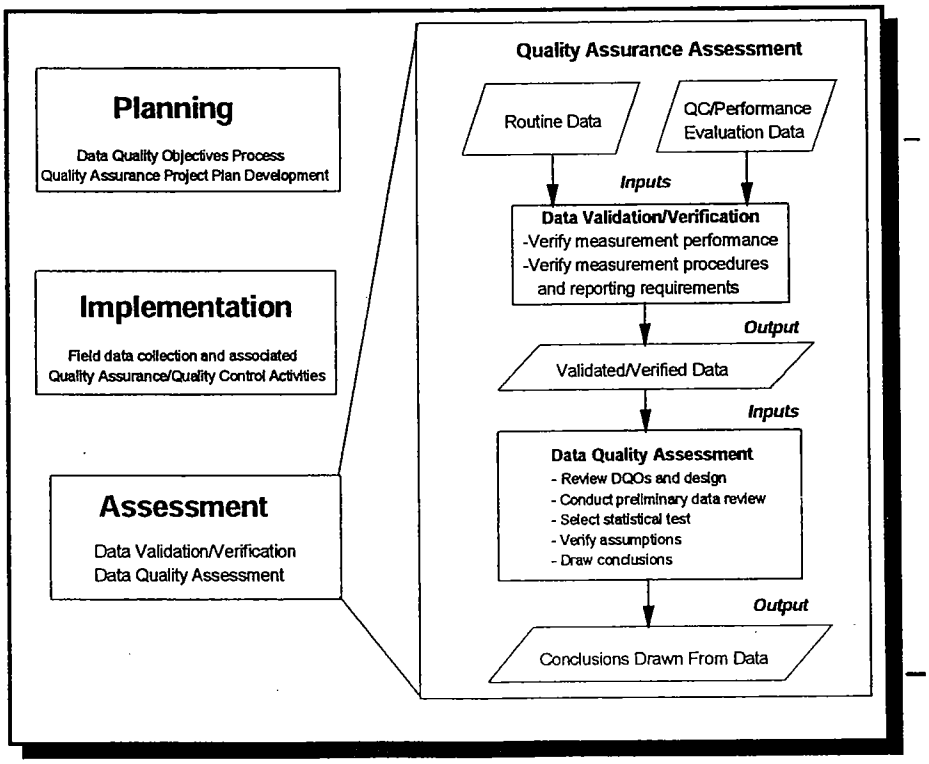

Figure 18.1 DQA in the context of the data life cycle.

DQA is a key part of the assessment phase of the data life cycle (Fig. 18.1), which is very similar to the ambient air QA life cycle described in Section 2 (Fig. 2.2). As the part of the assessment phase that follows data validation and verification, DQA determines how well the validated data can support their intended use.

18.1 Five Steps of the DQA Process

As described in *EPA QA/G-9*[41], the DQA process is comprised of five steps. The steps are detailed below. Since DQOs are available for the $PM_{2.5}$ program, they will be used as an example for the type of information that might be considered in each step. The $PM_{2.5}$ information is italicized and comes from a Model $PM_{2.5}$ QAPP for a fictitious reporting organization called Palookaville. The Model QAPP was developed to help States and local organizations develop QAPPs based upon the new R-5[34] QAPP requirements.

Step 1. Review DQOs and Sampling Design. Review the DQO outputs to assure that they are still applicable. If DQOs have not been developed, specify DQOs before evaluating the data (e.g., for environmental decisions, define the statistical hypothesis and specify tolerable limits on decision errors; for estimation problems, define an acceptable confidence probability interval width). Review the sampling design and data collection documentation for consistency with the DQOs.

The $PM_{2.5}$ DQOs define the primary objective of the $PM_{2.5}$ ambient air monitoring network ($PM_{2.5}$ NAAQS comparison), translate the objective into a statistical hypothesis (3-year average of annual mean $PM_{2.5}$ concentrations less than or equal to 15 $\mu g/m^3$ and 3-year average of annual 98th percentiles of the $PM_{2.5}$ concentrations less than or equal to 65 $\mu g/m^3$), and identify limits on the decision errors (incorrectly conclude area in non-attainment when it truly is in attainment no more than 5% of the time, and incorrectly conclude area in attainment when it truly is in non-attainment no more than 5% of the time).

The CFR contains the details for the sampling design, including the rationale for the design, the design assumptions, and the sampling locations and frequency. If any deviations from the sampling design have occurred, these will be indicated and their potential effect carefully considered throughout the entire DQA.

Step 2. Conduct Preliminary Data Review. Review QA reports, calculate basic statistics, and generate graphs of data. Use this information to learn about the structure of the data and identify patterns, relationships, or potential anomalies.

A preliminary data review will be performed to uncover potential limitations to using the data, to reveal outliers, and generally to explore the basic structure of the data. The first step is to review the quality assurance reports. The second step is to calculate basic summary statistics, generate graphical presentations of the data, and review these summary statistics and graphs.

***Review Quality Assurance Reports**. Palookaville will review all relevant quality assurance reports that describe the data collection and reporting process. Particular attention will be directed to looking for anomalies in recorded data, missing values, and any deviations from standard operating procedures. This is a qualitative review. However, any concerns will be further investigated in the next two steps.*

Calculation of Summary Statistics and Generation of Graphical Presentations. *Palookaville will generate some summary statistics for each of its primary and QA samplers. The summary statistics will be calculated at the quarterly, annual, and three-year levels and will include only valid samples. The summary statistics are:*

> *Number of samples, mean concentration, median concentration, standard deviation, coefficient of variation, maximum concentration, minimum concentration, interquartile range, skewness and kurtosis.*

These statistics will also be calculated for the percent differences at the collocated sites. The results will be summarized in a table. Particular attention will be given to the impact on the statistics caused by the observations noted in the quality assurance review. In fact, Palookaville may evaluate the influence of a potential outlier by evaluating the change in the summary statistics resulting from exclusion of the outlier.

Palookaville will generate some graphics to present the results from the summary statistics and to show the spatial continuity over Palookaville. Maps will be created for the annual and three-year means, maxima, and interquartile ranges for a total of 6 maps. The maps will help uncover potential outliers and will help in the network design review. Additionally, basic histograms will be generated for each of the primary and QA samplers and for the percent difference at the collocated sites. The histograms will be useful in identifying anomalies and evaluating the normality assumption in the measurement errors.

Step 3. Select the Statistical Test. Select the most appropriate procedure for summarizing and analyzing the data, based upon the reviews of the DQOs, the sampling design, and the preliminary data review. Identify the key underlying assumptions that must hold for the statistical procedures to be valid.

The primary objective for the $PM_{2.5}$ mass monitoring is determining compliance with the $PM_{2.5}$ NAAQS. As a result, the null and alternative hypotheses are:

$$H_0: X \quad 15 \ \mu g/m^3 \text{ and } Y \quad 65 \ \mu g/m^3$$
$$H_A: X > 15 \ \mu g/m^3 \text{ or } Y > 65 \ \mu g/m^3$$

where X is the three-year average $PM_{2.5}$ concentration and Y is the three-year average of the annual 98th percentiles of the $PM_{2.5}$ concentrations recorded for an individual monitor. The exact calculations for X and Y are specified in 40 CFR Part 50 Appendix N. The null hypothesis is rejected, that is, it is concluded that the area is not in compliance with the $PM_{2.5}$ NAAQS when the observed three-year average of the annual arithmetic mean concentration exceeds 15.05 $\mu g/m^3$ or when the observed three-year average of the annual 98th percentiles exceeds 65.5 $\mu g/m^3$. If the bias of the sampler is greater than -10% and less than +10% and the precision is within 10%, then the error rates (Type I and Type II) associated with this statistical test are less than or equal to 5%. The definitions of bias and precision will be outlined in the following step.

Step 4. Verify Assumptions of Statistical Test. Evaluate whether the underlying assumptions hold, or whether departures are acceptable, given the actual data and other information about the study.

The assumptions behind the statistical test include those associated with the development of the DQOs in addition to the bias and precision assumptions. Their method of verification will be addressed in this step. Note that when less than three years of data are available, this verification will be based on as much data as are available.

The DQO is based on the annual arithmetic mean NAAQS. *For each primary sampler, Palookaville will determine which, if either, of the $PM_{2.5}$ NAAQS is violated. In the DQO development, it was assumed that the annual standard is more restrictive than the 24-hour standard. If there are any samplers that violate ONLY the 24-hour NAAQS, then this assumption is not correct. The seriousness of violating this assumption is not clear. Conceptually, the DQOs can be developed based on the 24-hour NAAQS and the more restrictive bias and precision limits selected. However, Palookaville will assume the annual standard is more restrictive, until proven otherwise.*

Normal distribution for measurement error. Assuming that measurement errors are normally distributed is common in environmental monitoring. Palookaville has not investigated the sensitivity of the statistical test to violate this assumption; although, small departures from normality generally do not create serious problems. Palookaville will evaluate the reasonableness of the normality assumption by reviewing a normal probability plot, calculating the Shapiro-Wilk W test statistic (if sample size less than 50), and calculating the Kolmogorov-Smirnoff test statistic (if sampler size greater than 50). All three techniques are provided by standard statistical packages and by the statistical tools provided in EPA QA/G-9D: Data Quality Evaluation Statistical Tools (DataQUEST). If the plot or statistics indicate possible violations of normality, Palookaville may need to determine the sensitivity of the DQOs to departures in normality.

Decision error can occur when the estimated 3-year average differs from the actual, or true, 3-year average. This is not really an assumption as much as a statement that the data collected by an ambient air monitor is stochastic, meaning that there are errors in the measurement process, as mentioned in the previous assumption.

The limits on precision and bias are based on the smallest number of required sample values in a 3-year period. In the development of the DQOs, the smallest number of required samples was used. The reason for this was to ensure that the confidence was sufficient in the minimal case; if more samples are collected, then the confidence in the resulting decision will be even higher. For each of the samplers, Palookaville will determine how many samples were collected in each quarter. If this number meets or exceeds 12, then the data completeness requirements for the DQO are met.

The decision error limits were set at 5%. Again, this is more of a statement. If the other assumptions are met, then the decision error limits are less than or equal to 5%.

Measurement imprecision was established at 10% coefficient of variation (CV). For each sampler, Palookaville will review the coefficient of variation calculated in Step 2. If any exceed 10%, Palookaville may need to determine the sensitivity of the DQOs to larger levels of measurement imprecision.

Table 18-1 will be completed during each DQA. The table summarizes which, if any, assumptions have been violated. A check will be placed in each of the row/column combinations that apply. Ideally, there will be no checks. However, if there are checks in the table, the implication is that the decision error rates are unknown even if the bias and precision limits are achieved. As mentioned above, if any of the DQO assumptions are violated, then Palookaville will need to reevaluate its DQOs.

Achievement of bias and precision limits. Lastly, Palookaville will check the assumption that at the three-year level of aggregation the sampler bias is within ± 10% and precision is less than 10%. The data from the collocated samplers will be used to estimate quarterly, annual, and three-year bias and precision estimates even though it is only the three-year estimates that are critical for the statistical test.

Since all the initial samplers being deployed by Palookaville will be FRMs, the samplers at each of the collocated sites will be identical method designations. As such, it is difficult to determine which of the collocated samplers is closer to the true $PM_{2.5}$ concentration. Palookaville will calculate an estimate of precision. A bias measure will also be calculated but it can only describe the relative difference of one sampler to the other, not definitively indicate which sampler is more "true." Following are the algorithms for calculating precision and bias. This are similar, but differ slightly, from the equations in 40 CFR Part 58 Appendix A[14].

Table 18-1. Summary of Violations of DQO Assumptions

Site	Violate 24-Hour Standard ONLY?	Measurement Errors Non-Normal?	Data Complete? (12 samples per quarter)	Measurement CV > 10%?
Primary Samplers				
A1				
A2				
A3				
A4				
B1				
QA Samplers				
A1				
B1				

Before describing the algorithm, first some ground work. When less than three years of collocated data are available, then the three-year bias and precision estimates must be predicted. Palookaville's strategy for accomplishing this will be to use all available quarters of data as the basis for projecting where the bias and precision estimates will be at the end of the three-year monitoring period. Three-year point estimates will be computed by weighting the quarterly components, using the most applicable of the following assumptions:

1. *Most recent quarters precision and bias are most representative of what the future quarters will be.*
2. *All previous quarters precision and bias are equally representative of what the future quarters will be.*
3. *Something unusual happened in the most recent quarter, so the most representative quarters are all the previous ones, minus the most recent.*

Each of these scenarios results in weights that will be used in the following algorithms. The weights are shown in Table 18-2 where the variable Q represents the number of quarters for which observed bias and precision estimates are available. Note that when Q=12, that is, when there are bias and precision values for all of the quarters in the three-year period, then all of the following scenarios result in the same weighting scheme.

Table 18-2. Weights for Estimating Three-Year Bias and Precision

Scenario	Assumption	Weights
1	Latest quarter most representative	$w_q = 12-(Q-1)$ for latest quarter, $w_q = 1$ otherwise
2	All quarters equally representative	$w_q = 12/Q$ for each quarter
3	Latest quarter unrepresentative	$w_q = 1$ for latest quarter, $w_q = 11/(Q-1)$ otherwise

In addition to point estimates, Palookaville will develop confidence intervals for the bias and precision estimates. This will be accomplished using a re-sampling technique. The protocol for creating the confidence intervals are outlined in Box 18-1.

Box 18-1. Method for Estimating Confidence in Achieving Bias and Precision DQOs

Let Z be the statistic of interest (bias or precision). For a given weighting scenario, the re-sampling will be implemented as follows:

1. *Determine M, the number of collocated pairs per quarter for the remaining 12-Q quarters (default is M=15 or can use M=average number observed for the previous Q quarters.*
2. *Randomly select with replacement M collocated pairs per quarter for each of the future 12-Q quarters in a manner consistent with the given weighting scenario.*
   Scenario 1: Select pairs from latest quarter only.
   Scenario 2: Select pairs from any quarter.
   Scenario 3: Select pairs from any quarter except the latest one.
   Result from this step is "complete" collocated data for a three-year period, from which bias and precision estimates can be determined.
3. *Based on the "filled-out" three-year period from step 2, calculate three-year bias and precision estimate, using Equation 1 where $w_q = 1$ for each quarter.*
4. *Repeat steps 2 and 3 numerous times, such as 1000 times.*
5. *Determine P, the fraction of the 1000 simulations for which the three-year bias and precision criteria are met. P is interpreted as the probability that the sampler is generating observations consistent with the three-year bias and precision DQOs.*

The algorithms for determining whether the bias and precision DQOs have been achieved for each sampler follow

Bias Algorithm

1. *For each measurement pair, estimate the percent relative bias, d_i.*

$$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} x100$$

where X_i represents the concentration recorded by the primary sampler, and Y_i represents the concentration recorded by the collocated sampler.

2. *Summarize the percent relative bias to the quarterly level, $D_{j,q}$, according to*

$$D_{j,q} = \frac{1}{n_{j,q}} \sum_{i=1}^{n_{j,q}} d_i$$

where $n_{j,q}$ is the number of collocated pairs in quarter q for site j.

3. *Summarize the quarterly bias estimates to the three-year level using*

$$\hat{D}_j = \frac{\sum_{q=1}^{n_q} w_q D_{j,q}}{\sum_{q=1}^{n_q} w_q} \qquad \textit{Equation 1}$$

where n_q is the number of quarters with actual collocated data and w_q is the weight for quarter q as specified by the scenario in Table 18-2.

4. *Examine $D_{j,q}$ to determine whether one sampler is consistently measuring above or below the other. To formally test this, an non-parametric test will be used. The test is called the Wilcoxon Signed Rank Test and is described in EPA QA/G-9[41]. If the null hypothesis is rejected, then one of the samplers is consistently measuring above or below the other. This information may be helpful in directing the investigation into the cause of the bias.*

Precision Algorithm

1. *For each measurement pair, calculate the coefficient of variation according to Equation 20 from Section 14 and repeated below:*

$$CV_i = \frac{d_i}{\sqrt{2}}$$

2. *Summarize the coefficient of variation to the quarterly level, $CV_{j,q}$, according to*

$$CV_{j,q} = \sqrt{\frac{\sum_{i=1}^{n_j} CV_i^2}{n_{j,q}}}$$

where $n_{j,q}$ is the number of collocated pairs in quarter q for site j.

3. *Summarize the quarterly precision estimates to the three-year level using*

$$\hat{CV}_j = \sqrt{\frac{\sum_{q=1}^{n_q} (w_q CV_{j,q}{}^2)}{\sum_{q=1}^{n_q} w_q}} \qquad \text{Equation 2}$$

where n_q is the number of quarters with actual collocated data and w_q is the weight for quarter q as specified by the scenario is Table 24-2.

4. *If the null hypothesis in the Wilcoxon signed rank test was not rejected, then the coefficient of variation can be interpreted as a measure of precision. If the null hypothesis in the Wilcoxon signed rank test was rejected, the coefficient of variation has both a component representing precision and a component representing the (squared) bias.*

Confidence in Bias and Precision Estimates

1. *Follow the method described in Box 18-1 to estimate the probability that the sampler is generating observations consistent with the three-year bias and precision DQOs. The re-sampling must be done for each collocated site.*

Summary of Bias and Precision Estimation

The results from the calculations and re-sampling will be summarized in Table 18-3. There will be one line for each site operating a collocated sampler.

Table 18-3. Summary of Bias and Precision

Collocated	Three-year Bias Estimate (Equation. 1)	Three-year Precision Estimate (Equation. 2)	Null Hypothesis of Wilcoxon Test Rejected?	*P* (Box 18-1)
A1				
B1				

Step 5. Draw Conclusions from the Data.- Perform the calculations required for the statistical test and document the inferences drawn as a result of these calculations. If the design is to be used again, evaluate the performance of the sampling design.

Before determining whether the monitored data indicate compliance with the $PM_{2.5}$ NAAQS, Palookaville must first determine if any of the assumptions upon which the statistical test is based are violated. This can be easily checked in Step 5 because of all the work done in Step 4. In particular, as long as

- *in Table 18-1, there are no checks, and*
- *in Table 18-3,*
  - *the three year bias estimate is in the interval [-10%,10%], and*
  - *the three year precision estimate is less than or equal to 10%*

then the assumptions underlying the test appear to be valid. As a result, if the observed three-year average $PM_{2.5}$ concentration is less than 15 $\mu g/m^3$ and the observed three-year average 98th percentile is less than 65 $\mu g/m^3$, the conclusion is that the area seems to be in compliance with the $PM_{2.5}$ NAAQS, with an error rate of 5%.

If any of the assumptions have been violated, then the level of confidence associated with the test is suspect and will have to be further investigate.

DQA without DQOs

Even though DQOs, based upon the EPA G-4 guidance has not been developed for all criteria pollutants, a process very similar to this approach was originally used[27]. In addition, State and local organizations collect enough types of QA/QC data to estimate the quality of there data and should be able to express the confidence in that information.

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Appendix 2

QA-Related Guidance Documents for Ambient Air Monitoring Activities

The following documents provide guidance on various aspects of the Ambient Air Quality Monitoring Program. It is anticipated that many of these documents will be available on the Internet and the AMTIC Bulletin Board.

QA-RELATED AMBIENT MONITORING DOCUMENTS

DOCUMENT TITLE	STATUS
General	
Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I: A Field Guide to Environmental Quality Assurance, U.S. Environmental Protection Agency, EPA-600/R-94-038a, April 1994.	Current
Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Specific Methods, U.S. Environmental Protection Agency, EPA-600/R-94-038b, April 1994.	Interim edition [replaces EPA-600/4-77-027a (revised 1990)]; final updated edition expected early 1998.
Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III: Stationary Source Specific Methods, U.S. Environmental Protection Agency, EPA-600/R-94-038c, September 1994.	Interim edition [replaces EPA-600/4-77-027b (revised 1992); final updated edition expected late 1995.
Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements, U.S. Environmental Protection Agency, EPA-600/R-94/038d, Revised April 1994.	
Quality Assurance Handbook for Air Pollution Measurement Systems, Volume V: Precipitation Measurement Systems (Interim Edition), EPA-600/R-94-038e, April 1994.	Interim edition (replaces EPA-600/4-82-042a-b); final updated edition expected early 1996.
Air Monitoring Strategy for State Implementation Plans, EPA-450/2-77-010, June 1977.	Historical interest only
Guideline on the Implementation of the Ambient Air Monitoring Regulations 40 CFR Part 58, EPA-450/4-79-038, November 1979.	Historical interest only
Model Quality Assurance Project Plan for the $PM_{2.5}$ Ambient Air Monitoring Program, March 1998	Presently on AMTIC *www.epa.gov/ttn/amtic/pmqa.html*
Quality Management	
EPA Quality Systems Requirements for Environmental Programs, EPA QA/R-1	Available in Summer, 1998
Guidance for Developing Quality Systems for Environmental Data Operations EPA QA/G-1	Fall, 1998.
EPA Requirements for Quality Management Plans," EPA QA/R-2 U.S. Environmental Protection Agency, QAD, August 1994.	Final version of this document is expected to be available in Summer, 1998.
Guidance for Preparing Quality Management Plans EPA QA/G-2:	Unsure when available.

DOCUMENT TITLE	STATUS
Guidance for the Management Systems Review Process EPA QA/G-3: Draft January, 1994	Available in Summer, 1998.
EPA Requirements for Quality Assurance Project Plans, QA/R-5, Current Version: Draft - August 1994	Final version of this document will be available in Spring, 1997.
"Guidance on Quality Assurance Project Plans" EPA/G-5, EPA/600/R-98/018.	Final - February 1998
Policy and Program Requirements to Implement the Mandatory Quality Assurance Program, Order 5360.1, April 1984.	Current, basis for EPA QA program (updated in 1995 draft Order)
Data Quality Objectives	
Data Quality Objectives for the Toxic Air Monitoring System (Stages I and II), December 1987.	Historical interest only.
Data Quality Objectives for the Urban Air Toxic Monitoring Program (Stages I and II), June 6, 1988.	Historical interest only.
Guidance on Applying the Data Quality Objectives Process for Ambient Air Monitoring Around Superfund Sites (Stages I and II), EPA-450/4-89-015, August 1989.	Basically current guidance
Guidance on Applying the Data Quality Objectives Process for Ambient Air Monitoring Around Superfund Sites (Stage III), EPA-450/4-90-005, March 1990.	Basically current guidance
Decision Error Feasibility Trials (DEFT) Software for the Data Quality Objectives Process, QA/G-4D: EPA/600/R-96/056,	Final: September, 1994
The Data Quality Objectives Process: Case Studies, EPA QA/G-4CS:	Expected to be available in Fall, 1998.
Guidance for the Data Quality Objectives Process, U.S. *QA/G-4*, EPA/600/R-96/055,	Final: September, 1994
Ambient Air Monitoring Data Quality Objectives (DQOs) for the Photochemical Assessment Monitoring Stations Program preliminary draft report, July 9, 1992.	Incorporated DQOs in PAMS Implementation Manual
NPAP	
Hunike, Elizabeth T. and Joseph B. Elkins, "The National Performance Audit Program (NPAP)," EPA-600/A-93-143, 1993.	Historical interest only; not a policy or guidance document
Hunike, Elizabeth T., "Standard Operating Procedure for Performing the Routine Activities of the AREAL Coordinator of the National Performance Audit Program," U.S. Environmental Protection Agency, AREAL, Office of Research and Development, AREAL/RTP-SOP-QAD-553, September 1993.	Current

DOCUMENT TITLE	STATUS
Quality Assurance Project Plan for the National Performance Audit Program (NPAP), U.S. Environmental Protection Agency, September 15, 1993. Includes the following Standard Operating Procedures: - SOP-QAD-004: Audit Systems Verification Center Operational Procedures - SOP-QAD-508: Calibration of ReF Devices for Surveying Performance of Hi-Vol Sampler Flow Rates - SOP-QAD-510: Conducting the Lead NPAP Audit - SOP-QAD-512: Calibration of a Pulsed Fluorescent SO2 Analyzer - SOP-QAD-520: SO2 Audit Device Calibration - SOP-QAD-521: Conducting the Sulfate-Nitrate NPAP Audit - SOP-QAD-523: Analysis of NO/NO2/NOx in Gas Cylinders - SOP-QAD-542: NO2 Audit Device Quality Assurance Operation Checks - SOP-QAD-543: Quality Assurance Checks of Dichot (PM-10) Audit Devices - SOP-QAD-544: Conducting an Ozone National Performance Audit - SOP-QAD-546: Computer Data Entry, Report Printing and Maintenance for the NPAP - SOP-QAD-547: Conducting Performance Audits for Carbon Monoxide - SOP-QAD-548: Data Validation for Data Bases of the NPAP - SOP-QAD-549: Analysis of CO in Gas Cylinders with GFC Analysis - SOP-QAD-551: Editing NPAP Data Bases - SOP-QAD-553: Performing the Routine Activities of the AREAL Coordinator of the NPAP	Revision of the NPAP QAPP
P&A	
Analysis of Protocol Gases: An Ongoing Quality Assurance Audit, U.S. Environmental Protection Agency, EPA-600/A-93-168, May 1993.	Historical interest only
Guideline on the Meaning and Use of Precision and Accuracy Data Required by 40 CFR Part 58, Appendices A and B, U.S. Environmental Protection Agency, EPA-600/4-83-023, June 1983.	Some items out of date (e.g., SAROAD versus AIRS, no PM-10, etc.)
Issues Concerning the Use of Precision and Accuracy Data, Special Report, U.S. Environmental Protection Agency, EPA-450/4-84-006, February 1984.	Historical interest only

DOCUMENT TITLE	STATUS
Guidance for the Data Quality Assessment: Practical Methods for Data Analysis EPA QA/G-9 EPA/600/R-96/084,	Final: January, 1998
System Audits	
National Air Audit System Guidance Manual for FY 1988-FY 1989, U.S. Environmental Protection Agency, EPA-450/2-88-002, February 1988.	National audit report discontinued in FY89
Network Design and Siting	
Enhanced Ozone Monitoring Network Design and Siting Criteria Guidance Document, EPA-450/4-91-033, November 1991.	
PAMS Implementation Manual, EPA-454/B-93-051, March 1994	
Guidance for Conducting Ambient Air Monitoring for Lead Around Lead Point Sources, January 1992.	Designed to supersede EPA-450/4-81-006, assuming change in lead NAAQS and revised EPA lead policy; policy has been changed but not NAAQS
Guidance for Network Design and Optimum Site Exposure for PM2.5 and PM10, December, 1997	Draft published 12/15/97. Presently on AMTIC *www.epa.gov/ttn/amtic*
Guideline for PM-10 Monitoring and Data Reporting, May 1985.	Partially out of date
Guideline for Short-Term Lead Monitoring in the Vicinity of Point Sources, OAQPS Number 1.2-122, March 26, 1979.	Superseded by *Guidance for Conducting Ambient Air Monitoring for Lead Around Point Sources*, January 1992
Network Design and Optimum Site Exposure Criteria for Particulate Matter, EPA-450/4-87-009, May 1987.	Basically current; could be revised when new PM standard is proposed
Guidance for Network Design and Optimum Exposure for $PM_{2.5}$ and PM_{10}. Draft December 1997	Currently draft on AMTIC
Network Design and Site Exposure Criteria for Selected Noncriteria Air Pollutants, EPA-450/4-84-022, September 1984.	Partially out of date
Appendix E and F to Network Design and Site Exposure Criteria for Selected Noncriteria Air Pollutants, EPA-450/4-84-022a, October 1987.	Partially out of date
Optimum Sampling Site Exposure Criteria for Lead, EPA-450/4-84-012, February 1984.	Historical interest only
Optimum Site Exposure Criteria for SO2 Monitoring, EPA-450/3-77-013, April 1977.	Should be revised when EPA promulgates final SO_2 regulation

DOCUMENT TITLE	STATUS
Selecting Sites for Carbon Monoxide Monitoring, EPA-450/3-75-077, September 1975.	Current guidance but out of date
Selecting Sites for Monitoring Total Suspended Particulates, EPA-450/3-77-018, December 1977.	Historical interest only
Site Selection for the Monitoring of Photochemical Air Pollutants, EPA-450/3-78-013, April 1978.	Need for revision partially met through *PAMS Implementation Manual* (EPA-454/8-98-051)
Ambient Air Monitoring Methods	
Photochemical Assessment Monitoring Stations Implementation Manual, EPA-454/B-93-051, October 1994	
Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air, EPA-600/8-90-005, March 1990.	Currently being revised; sections being included in *PAMS Implementation Manual*
EPA QA/G-6: Guidance for the Preparation of Standard Operating Procedures for Quality-Related Operations Final - EPA/600/R-96/027, November, 1995	
Ambient Air Monitoring Costs	
Guidance for Estimating Ambient Air Monitoring Costs for Criteria Pollutants and Selected Air Toxic Pollutants, EPA-454/R-93-042, October 1993.	Partially out of date; need longer amortization schedule
Other	
Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD), EPA-450/4-87-007, May 1987.	Partially out of date
EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards, EPA-600/R-93-224, Revised September 1993.	Current guidance
Guidebook: Preparation and Review of Emission Test Reports, January 10, 1992.	Current guidance
Guidebook: Preparation and Review of Site Specific Test Plans, OAQPS, December 1991.	Current guidance
Guideline on the Identification and Use of Air Quality Data Affected by Exceptional Events, EPA-450/4-86-007, July 1986.	Currently being updated by MQAG

DOCUMENT TITLE	STATUS
IntraAgency Task Force Report on Air Quality Indicators, EPA-450/4-81-015, February 1981.	Not a policy or guidance document; could be updated to include more modern analysis and presentation techniques
Screening Procedures for Ambient Air Quality Data, EPA-450/2-78-037, July 1978.	Could be updated to include more modern computer programs and newer screening procedures
Third Generation Air Quality Modeling System, Vol. 4: Project Verification and Validation, EPA-600/R-94-220d, June 1994 (draft, in review).	Being updated
Validation of Air Monitoring Data, U.S. Environmental Protection Agency, EPA-600/4-80-030, June 1980.	Partially out of date;

Appendix 3

Measurement Quality Objectives

Measurement Quality Objectives - Parameter NO_2 (Chemiluminescence)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.11	
Shelter Temperature Temperature range Temperature control	 Daily Daily	 20 to 30 C ± 2 C	 40 CFR, Pt. 53.20 Vol II, S 7.1 1/ Vol II, MS 2.3.2	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dewpoint. Shelter should have a 24- hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Equipment NO_2 analyzer Air flow controllers Flowmeters	Purchase specification	Reference or equivalent method Flow rate regulated to ± 2 % Accuracy ± 2 %	40 CFR, Pt 53.9 40 CFR, Pt 50, App F, S 2.2 EPA-600/4-75-003	
Detection Noise Lower detectable level	Purchase specification	0.005 ppm 0.01 ppm	40 CFR, Pt 53.20 & 23 "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria
Completeness Hourly Data	Quarterly	75 %	40 CFR, Pt 50.11	
Compressed Gases Dilution gas (zero air) Gaseous standards	 Purchase specification Purchase specification	 Free of contaminants NIST Traceable (e.g., EPA Protocol Gas)	 EPA-600/4-75-003 40 CFR, Pt 50, App F, S 1.3 EPA-600/R-97/121	 Return cylinder to supplier. Nitric oxide in nitrogen EPA Protocol Gases have a 24-month certification period and must be recertified to extend the certification.

Measurement Quality Objectives - Parameter NO_2 (Chemiluminescence)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Calibration				
Multipoint calibration (at least 5 points)	≥ 1/6 months., after failure of QC check or after maintenance	Residence time ≤ 2 min Dynam. parameter ≥ 2.75 ppm-min All points within ± 2 % of full scale of best-fit straight line	40 CFR, Pt 50, App F, S 1 Vol II, S 12.6 Vol II, MS 2.3.2	Zero gas and at least four upscale calibration points. Points outside acceptance criterion are repeated. If still outside consult manufacturers manual and invalidate data to last acceptable multipoint calibration or zero/span check .
Convertor efficiency	During multipoint calibrations	96 %	40 CFR, Pt. 50, App F	Replace or service converter.
Zero/span check- level 1	1/ 2 weeks	Zero drift ± 20 to 30 ppb Span drift ± 20 to 25 % Zero drift ± 10 to 15 ppb Span drift ± 15 %	Vol II, MS.2.3.2 Vol II, S 12.6 Vol II, MS 2.3.2 Vol II, S 12.6 Vol II, MS 2.3.2	**If calibration factors are updated after each zero/span,** invalidate data to last acceptable zero/span check, adjust analyzer, and perform multipoint calibration. **If fixed calibration factors are used to calculate data,** invalidate data to last acceptable zero/span check, adjust analyzer, and perform multipoint calibration.
Flowmeters	1/3 months	Accuracy ± 2 %	Vol II, App 12	Flowmeter calibration should be traceable to NIST standards.
Performance Evaluation				
(NPAP)	1/year at selected sites	Mean absolute difference 15 %	NPAP QAPP	Use information to inform reporting agency for corrective action and technical systems audits.
State audits	1/year	State requirements	Vol II, App 15, S 3	
Precision				
Single analyzer Reporting organization	1/ 2 weeks 1/3 months	None 95 % Confidence Interval ± 15 %	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 6	Concentration. = 0.08-0.10 ppm.
Accuracy				
Single analyzer Reporting organization	25 % of sites quarterly (all sites yearly)	None 95% Confidence Interval ± 20%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 3	Four concentration ranges. If failure, recalibrate analyzer and reanalyze samples. Repeated failure requires corrective action.

[1] - reference refers to the QA Handbook for Air Pollution Measurement Systems, Volume II . The use of "S" refers to sections within Part 1 of Volume II. The use of "MS" refers to method-specific sections in Volume II.

Measurement Quality Objectives - Parameter O_3 (Ultraviolet Photometric)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.9	
Shelter Temperature Temperature range Temperature control	 Daily Daily	 20 to 30 C. ± 2 C	 40 CFR, Pt. 53.20 Vol II, S 7.1 1/ *Determination of Ozone by Ultraviolet Analysis (draft)*	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dewpoint. Shelter should have a 24- hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Equipment O_3 analyzer	Purchase specification	Reference or equivalent method	40 CFR, Pt 53.9 EPA-600/4-79-057	Air flow controllers must be capable of regulating air flows as necessary to meet the output stability and photometer precision requirements. The photometric measurement of absorption is not directly related to flow rate, but may be indirectly related due to thermal or other effects.
Detection Noise Lower detectable level	Purchase specification	0.005 ppm 0.01 ppm	40 CFR, Pt. 53.20 & 23 "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria.
Completeness (seasonal) Maximum 1-hour concentration	Daily	75% values from 9:01 AM to 9:00 PM (LST)	40 CFR, Pt 50, App H, S 3	A missing daily maximum ozone value may be assumed to be less than the standard if valid daily maxima on the preceding and following days do not exceed 75 percent of the standard.
Transfer standard Qualification and certification Recertification to local primary standard	Upon receipt of transfer standard 1/3 months (if at a fixed site)	±4% or ±4 ppb (whichever greater) RSD of six slopes 3.7% Std. dev. of six intercepts 1.5% New slope = ±0.05 of previous	EPA-600/4-79-056 EPA-600/4-79-057 " "	6 comparison runs that include, at minimum, 6 concentrations per comparison run including 0 and 90 ± 5% of upper range. A single six-point comparison run.

Measurement Quality Objectives - Parameter O_3 (Ultraviolet Photometric)				
Requirement	**Frequency**	**Acceptance Criteria**	**Reference**	**Information/Action**
Local primary standard Certification/recertification to Standard Photometer (if recertified via a transfer standard)	1/year "	Difference ±5 % (preferably ± 3%) Regression slopes = 1.00 ± 0.03 and two intercepts are 0 ± 3 ppb	*Determination of Ozone by Ultraviolet Analysis (draft)* "	The local primary standard is a standard in its own right, but it must be repaired and recertified if the acceptance criterion is exceeded.
EPA Standard Reference Photometer recertification	1/year	Regression slope = 1.00 ± 0.01 and intercept < 3 ppb	Protocol for Recertification of Standard Reference Photometers... (TRC Environmental Document)	9 replicate analysis over 12 conc. ranges. Disagreement must be resolved. EPA Standard Reference Photometer rechecked with NIST. If OK Network STANDARD REFERENCE PHOTOMETER must be repaired.
Zero air	Purchase specification	Free of O_3 or any substance that might react with O_3 (e.g., NO, NO_2, hydrocarbons, and particulates)	EPA-600/4-79-057	Return cylinder to supplier
Ozone analyzer calibration Zero/span check -level 1 Multipoint calibration (at least 5 points)	1/ 2 weeks Upon receipt, adjustment, or 1/ 6 months	Zero drift ± 20 to 30 ppb Span drift ± 20 to 25 % Zero drift ± 10 to 15 ppb Span drift ± 15% Linearity error <5%	Vol II, S 12.6 " Vol II, S 12.6 " 40 CFR, Pt 50, App D, S 5.2.3 EPA-600/4-79-057 S.5 Vol II, S 12.2	**If calibration updated at each zero/span,** Invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration. **If fixed calibration used to calculate data,** Invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration. Zero gas and at least four upscale calibration points. Check verify accuracy of flow dilution. Redo analysis. If failure persists corrective action required.
Performance Evaluation (NPAP) State audits	1/year at selected sites 1/year	Mean absolute difference 15% State requirements	Vol II, S 16.3 Vol II, App 15, S 3	Use information to inform reporting agency for corrective action and technical systems audits.

Measurement Quality Objectives - Parameter O_3 (Ultraviolet Photometric)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Precision Single analyzer Reporting organization	1/ 2 weeks 1/3 months	None 95% CI < ± 15%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 6	Concentration = 0.08-0.10 ppm.
Accuracy Single analyzer Annual accuracy	25 % of sites quarterly (all sites yearly)	None 95% CI ± 20%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 6	Four concentration ranges. If failure, recalibrate and reanalyze. Repeated failure requires corrective action.

[1] - reference refers to the QA Handbook for Air Pollution Measurement Systems, Volume II . The use of "S" refers to sections within Part 1 of Volume II. The use of "MS" refers to method-specific sections in Volume II.

Measurement Quality Objectives - Parameter Lead (Atomic Absorption Spectroscopy)				
Requirement	**Frequency**	**Acceptance Criteria**	**Reference**	**Information/Action**
Reporting Units	All data	$\mu g/m^3$	40 CFR, Pt 50.12	
Filter Checks				
Visual defect check	All filters	See reference	Vol II, MS 2.2.4	Discard any defective filters
Filter Integrity				
Collection efficiency	Purchase specification	99%	40 CFR, Pt 50, App B, S 7.1	Measure using DOP test (ASTM-2988). Reject shipment
Integrity		2.4 mg max weight loss	"	
pH		6 to 10	"	
Equipment				
Sampler	Purchase specification	Reference or equivalent method	40 CFR, Pt 53.9	
			40 CFR, Pt 50, App B, S 7	
Flow rate transfer standard	Purchase specification	0.02 std. m^3/min	"	
Detection Limit				
LDL	Not applicable	0.07 g/m^3	40 CFR, Pt 50, App G, S 2	This value is based on a collaborative test of the method. Assumed air volume of 2,400 m^3.
Completeness	Quarterly	75%		
Sampler calibration				
Orifice calibration unit (flow rate transfer standard)	On receipt and yearly	Indicated flow rate within ± 2 % of actual flow rate	Vol II, MS 2.8.1 Vol II, MS 2.2.2	Adopt a new calibration curve. A rotary-type, gas displacement meter is the recommended NIST-traceable reference standard. Adjust or replace meter
Elapsed time meter	On receipt and 1/6 months	± 2 min/24,hours	"	
On/Off Timer	On receipt and 1/3 months	± 30 min/24 hour	Vol II, MS 2.2.2	Checked against elapsed time meter. Adjust or repair.
Sampler flow rate	On receipt, if audit deviation > 7 %, after maintenance	All points within ± 5 % of full scale of best-fit straight line	"	Rerun points outside limits until acceptable.

Measurement Quality Objectives - Parameter Lead (Atomic Absorption Spectroscopy)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Analytical calibration				
Reproducibility test	On receipt	5%	Vol II, MS 2.8.1	Reproducibility = 100 ([high response-low response]/average response). Responses should be corrected for the blank level. If acceptance criterion is exceeded, instrument should be checked by a service rep or qualified operator.
Calibration stability	Before first sample, after every tenth sample, after last sample	± 5 % deviation from calibration curve.	Vol II, MS 2.8.5	Alternate between two control standards with concentrations 1 µg/mL or 1 to 10 µg/mL. Take corrective action and repeat the previous ten analyses.
Performance Evaluation				
(NPAP)	1/year at selected sites	Mean absolute difference 15%	Vol II, S 16.3 40 CFR, Pt 58, App A	Use information to inform reporting agency for corrective action and technical systems audits
Sampler performance Audit (flow rate)	1/3 months	Percentage difference ±7%	Vol II, MS 2.2.8	Recalibrate before any additional sampling
Precision				
Single analyzer	1/6 days	None	40 CFR, Pt 58, App A, S 5.3	Both lead values must be > 0.15 µg/m^3
Reporting organization	1/ 3 months	95% CI < ± 15%	40 CFR, Pt 58, App A, S 5.3	
Accuracy				
Single analyzer	25 % of sites quarterly	Percentage difference ± 16%	Vol II, MS 2.8.8	Analyze three audit samples in each of the two concentration ranges. The audit samples shall be distributed as much as possible over the entire calendar quarter.
Reporting organization		95% CI ± 20%	40 CFR, Pt 58, App A, S 3.4 EPA-600/4-83-023	

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Measurement Quality Objectives - Parameter PM10 (Dichotomous Sampler)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Reporting Units	All data	$\mu g/m^3$	40 CFR, Pt 50.7	
Filter Checks				
Visual defect check	All filters	See reference	Vol II, MS 2.10.4	Discard any defective filters
Filter Integrity				
Collection efficiency	Purchase specification	99 %	40 CFR, Pt 50, App M, S 7.2	As measure by DOP test (ASTM-2988). Reject shipment.
Integrity		± 5 $\mu g/m^3$	"	
Alkalinity		< 25.0 microequivalents/gram	"	Following 2 months storage at ambient temp and relative humidity. Reject filters
Filter Conditioning				
Equilibration time	All Filters	at least 24 hours	40 CFR, Pt 50, App M, S 9.3	Repeat equilibration
Temperature range	"	15 to 30 C	40 CFR, Pt 50, App M, S 7.4	Keep thermometer in balance room and record temperature daily.
Temperature control	"	± 3 C	"	
Humidity range	"	20 to 45 % relative humidity	"	Keep hygrometer in the balance room and record humidity daily.
Humidity control	"	± 5 % relative humidity	"	
Equipment				
Sampler	Purchase specification	Reference or equivalent method	40 CFR, Pt 53.9	
Flow rate transfer standard	Purchase specification	± 2 % accuracy (NIST traceable)	40 CFR, Pt 50, App M, S7.3	
Analytical balance	Purchase specification	Sensitivity = 0.1 mg	40 CFR, Pt 50, App M, S 7.5 Vol II, MS 2.10.4	This acceptance criterion is inconsistent with other acceptance criteria for balance that are in the quality assurance handbook.
Mass reference standards	Purchase specification	NIST traceable (e.g., ANSI/ASTM Class 2)	Vol II, MS 2.10.4	
Detection Limit				
LDL	Not applicable	Not applicable	40 CFR, Pt 50, App M, S 3.1	The lower limit of the mass concentration is determined by the repeatability of filter tare weights, assuming the nominal air sample volume for the sampler.
Completeness	quarterly	75%	40 CFR, Pt 50, App K, S 2.3	

Measurement Quality Objectives - Parameter PM10 (Dichotomous Sampler)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Sampler Calibration				
Flow control device	On installation, after repairs, after out-of-limits flow check	<4% difference from manufacturers spec and actual	40 CFR, Pt 50, App M, S 7.1 Vol II, MS 2.10.2	Adopt new calibration curve if no evidence of damage, otherwise replace.
Elapsed time meter	On receipt and 1/6 months	± 15 min	40 CFR, Pt 50, App M, S 7.1 Vol II, MS 2.10.1	Adjust or replace.
Flow-rate transfer Standard	Periodically	±2% over the expected range of ambient conditions	40 CFR, Pt 50, App M, S 8.2 Vol II, MS 2.10.1	Checked against NIST-traceable primary standard.
Balance Calibration	1/year		Vol II, MS 2.10.4	Calibrate and maintain according to the manufacturer's recommendations.
Performance Evaluation (NPAP)	1/year at selected sites	Mean absolute difference 15%	Vol II, S 16.3	Use information to inform reporting agency for corrective action and technical systems audits
Precision				
Single analyzer	1/6 days	5 g/m^3 for conc. 80 $\mu g/m^3$	40 CFR, Pt 50, App M, S 4.1	Both PM10 values must be > 20 $\mu g/m^3$.
Reporting organization	1/ 3 months	7% for conc. >80 $\mu g/m^3$ 95% CI < ± 15%	40 CFR, Pt 58, App A, S 5.3 EPA-600/4-83-023	
Accuracy				
Single analyzer Annual accuracy	25 % of sites quarterly (all sites yearly)	None 95% CI ± 20%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 6	Transfer standards different then those used in calibration. Recalibrate before any additional sampling. Invalidate data to last acceptable flow check if difference $\geq$ 10%.

Measurement Quality Objectives - Parameter PM10 (Dichotomous Sampler)				
Requirement	**Frequency**	**Acceptance Criteria**	**Reference**	**Information/Action**
QC Checks Field calibration flow check	1/month	Percentage difference ±7 % from sampler's indicated flow rate or ± 10 % from design condition flow rate	40 CFR, Pt 50, App M, S 8.2 Vol II, MS 2.10.3	Trouble shoot and recalibrate sampler.
"Standard" filter weighing	at beginning of weighing day	± 20 g of original weight	Vol II, S 2.10.4	Trouble shoot and reweigh.
Reweighing filters	5 exposed and 5 unexposed/day	± 20 g of original weight	Vol II, S 2.10.4	Trouble shoot and reweigh.
Balance zero and calibration check	every fifth filter	± 4 g at zero ± 2 g at 10 mg	Vol II, S 2.10.4	Trouble shoot and reweigh.

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Measurement Quality Objectives - Parameter SO_2 (Ultraviolet Fluorescence)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.4	
Shelter Temperature Temperature range Temperature control	 Daily Daily	 20 to 30 C ± 2 C	 40 CFR Pt. 53.20 Vol II, S 7.1 1/ Vol II, MS 2.9	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain temperature above sample dewpoint. Shelter should have a 24- hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Equipment SO_2 analyzer Air flow controllers Flowmeters	Purchase specification	Reference or equivalent method Flow rate regulated to ± 2 % Accuracy ± 2 %	Vol II, MS 2.9 " "	
Detection Noise Lower detectable level	Purchase specification	.005 ppm .01 ppm	40 CFR, Pt 53.20 & 23 "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria.
Completeness Annual standard 24-hour standard 3-hour standard	Quarterly 24 hours 3 hours	75% 75% 75%	40 CFR, Pt 50.43 " "	
Compressed Gases Dilution gas (zero air) Gaseous standards	Purchase specification Purchase specification	SO_2 free, 21 % O_2/78 % N_2, 300 to 400 ppm CO_2, 0.1 ppm aromatics NIST Traceable (e.g., permeation tube or EPA Protocol Gas	Vol II, MS 2.9.2 EPA-600/R97/121	Return cylinder to supplier. It is recommended that a clean air system be used instead of compressed air cylinders. Sulfur dioxide in nitrogen EPA Protocol Gases have a 24-month certification period for concentrations between 40 and 499 ppm and a 36-month certification period for higher concentrations.

Measurement Quality Objectives - Parameter SO_2 (Ultraviolet Fluorescence)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Calibration				
Multipoint calibration (at least 4 points)	Upon receipt, adjustment, or 1/ 6 months	All points within + 2% of full scale of best-fit straight line	Vol II, S 12.6 Vol II, MS 2.9.2	Zero gas and at least three upscale points. Note: two pages from Section 2.4 (Calibration Procedures) of Vol II, MS 2.9.2 are missing from the 1994 reprinting of the QA Handbook.
Zero/span check -level 1	1/ 2 weeks	Zero drift ± 20 to 30 ppb Span drift ± 20 to 25 %	Vol II, S 12.6 "	**If calibration updated at each zero/span-** Invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration **If fixed calibration used to calculate data.** Invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration
		Zero drift ± 10 to 15 ppb Span drift ± 15%	Vol II, S 12.6 "	Flowmeter calibration should be traceable to NIST standards
Flowmeters	1/3 months	Accuracy ± 2 %	Vol II, App 12	
Performance Evaluation				
(NPAP)	1/year at selected sites	Mean absolute difference 15%	Vol II, S 16.3	Use information to inform reporting agency for corrective action and technical systems audits.
State audits	1/year	State requirements	Vol II, App 15, S 3	
Precision				
Single analyzer Reporting organization	1/2 weeks 1/3 months	None 95% CI < ± 15%	40 CFR, Pt 58, App EPA-600/4-83-023 Vol II, S 16, S2	Concentration = 0.08-0.10 ppm.
Accuracy				
Annual accuracy check-Reporting organization	25 % of sites quarterly (all sites yearly)	None 95% CI · ± 20%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, S 16	Four concentration ranges. If failure, recalibrate and reanalyze. Repeated failure requires corrective action.

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Measurement Quality Objectives - Parameter CO (Nondispersive Infrared Photometry)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppm	40 CFR, Pt 50.8	
Shelter Temperature Temperature range Temperature control	 Daily Daily	 20 to 30 C. < ± 2 C	40 CFR, Pt. 53.20 Vol II, S 7.1 [1/]	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dewpoint. Shelter should have a 24-hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Equipment CO analyzer Flow controllers Flowmeters	Purchase specification	Reference or equivalent method Flow rate regulated to ± 1% Accuracy ± 2%	40 CFR, Pt 50, App C " "	
Detection Limit Noise Lower detectable level	Purchase specification	0.5 ppm 1.0 ppm	40 CFR, Pt 53.20 & 23 "	Instruments designated as reference or equivalent have been determined to meet these acceptance criteria.
Completeness 8-hour average	hourly	75 % of hourly averages for the 8-hour period	40 CFR, Pt 50.8	
Compressed Gases Dilution gas (zero air) Gaseous standards	 Purchase specification Purchase specification	 < 0.1 ppm CO NIST Traceable (e.g., EPA Protocol Gas)	 40 CFR, Pt 50, App C " EPA-600/R97/12	 Return cylinder to supplier. Carbon monoxide in nitrogen or air EPA Protocol Gases have a 36-month certification period and must be recertified to extend the certification.

Measurement Quality Objectives - Parameter CO (Nondispersive Infrared Photometry)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Calibration				
Multipoint calibration (at least 5 points)	Upon receipt, adjustment, or 1/ 6 months	All points within ± 2% of full scale of best-fit straight line	Vol II, S 12.6 Vol II, MS.2.6.1	Zero gas and at least four upscale calibration points. Points outside acceptance criterion are repeated. If still outside criterion, consult manufacturers manual and invalidate data to last acceptable calibration.
Zero/span check-level 1	1/ 2 weeks	Zero drift ± 2 to 3 ppm Span drift ± 20 to 25 %	Vol II, S 12.6 "	**If calibration updated at each zero/span**, invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration.
		Zero drift ± 1 to 1.5 ppm Span drift ± 15%	Vol II, S 12.6 "	**If fixed calibration used to calculate data**, invalidate data to last acceptable check, adjust analyzer, perform multipoint calibration.
Flowmeters	1/3 months	Accuracy ± 2 %	Vol II, App 12	Flowmeter calibration should be traceable to NIST standards.
Performance Evaluation (NPAP)	1/year at selected sites	Mean absolute difference 15%	Vol II, S 16.3	Use information to inform reporting agency for corrective action and technical systems audits
State audits	1 /year	State requirements	Vol II, pp 15, S 3	
Precision				
Single analyzer	1/2 weeks	None		
Reporting organization	1/3 months	95% CI ± 15%	40 CFR, Pt 58, App A EPA-600/4-83-023 Vol II, App 15, S 5	Concentration = 8 to 10 ppm. Aggregation of a quarters measured precision values.
Accuracy				
Single analyzer	25 % of sites quarterly (all sites yearly)	None	40 CFR, Pt 58, App A	Four concentration ranges. If failure, recalibrate and reanalyze. Repeated failure requires corrective action.
Reporting organization		95% CI ± 20%		

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Measurement Quality Objectives- Parameter $PM_{2.5}$

Requirement	Frequency	Acceptance Criteria	40 CFR Reference	QA Guidance Document 2.12 Reference
Filter Holding Times				
Pre-sampling	all filters	< 30 days before sampling	Part 50, App.L Sec 8.3	Sec. 7.9
Post-sampling Weighing	"	< 10 days at 25° C from sample end date < 30 days at 4°C from sample end date	" "	Sec. 7.11 "
Sampling Period	All data	1380-1500 minutes or value if < 1380 and exceedance of NAAQS	Part 50, App.L Sec 3.3	
Reporting Units	All data	g/m^3	Part 50.3	Sec. 11.1
Detection Limit				
Lower DL	All data	2 g/m^3	Part 50, App.L Sec 3.1	
Upper Conc. Limit	All data	200 g/m^3	Part 50, App.L Sec 3.2	
Sampling Instrument				
Flow Rate	every 24 hours of op " "	≤ 5% of 16.67 ≤ 2% CV measured ≤ 5% average for < 5 min.	Part 50, App.L Sec 7.4 " "	
Filter Temp Sensor	"	≤ 5° C of ambient for <30min		
Data Completeness	quarterly	75%	Part 50, App. N, Sec. 2.1	

Measurement Quality Objectives- Parameter $PM_{2.5}$				
Requirement	**Frequency**	**Acceptance Criteria**	**40 CFR Reference**	**QA Guidance Document 2.12 Reference**
Filter				
Visual Defect Check	All Filters	See reference	Part 50, App.L Sec 6.0	Sec 7.5
Filter Conditioning Environment				
Equilibration	All filters	24 hours minimum	Part 50, App.L Sec 8.2	Sec. 7.6
Temp. Range	"	20-23° C	"	"
Temp. Control	"	±2° C SD over 24 hr	"	"
Humidity Range	"	30% - 40% RH or	"	"
		± 5% sampling RH but >20%RH	"	"
Humidity Control	"	± 5% SD over 24 hr.		
Pre/post sampling RH	"	± 5% RH	Part 50, App.L Sec 8.3.3	
Balance	"	located in filter conditioning environment	"8.3.2	
Filter Checks				
Lot Blanks	3 filters per lot	less than 15 g change between weighings	not described	Sec. 7.7
Exposure Lot Blanks	3 filters per lot	less than 15 g change between weighings	not described	Sec. 7.7
Lab QC Checks				
Field Filter Blank	10% or 1 per weighing session	±30 g change between weighings	Part 50, App.L Sec 8.3	Sec. 7.7
Lab Filter Blank	10% or 1 per weighing session	±15 g change between weighings	Part 50, App.L Sec 8.3	"
Balance Check	beginning, every 10th sample, end	≤3 g	not described	Sec. 7.9
Duplicate Filter Weighing	1 per weighing session	±15 g change between weighings	not described	Sec 7.11

Measurement Quality Objectives- Parameter $PM_{2.5}$

Requirement	Frequency	Acceptance Criteria	40 CFR Reference	QA Guidance Document 2.12 Reference
Calibration/Verification				
Flow Rate (FR) Calibration	If multi-point failure	± 2% of transfer standard	Part 50, App.L, Sec 9.2	Sec 6.3
FR multi-point verification	1/yr	± 2% of transfer standard	Part 50, App.L, Sec 9.2.5	Sec 6.3 & 8.4
One point FR verification	1/4 weeks	± 4% of transfer standard	Part 50, App.L, Sec 9.2	Sec 8.4
External Leak Check	every 5 sampling events	80 mL/min	Part 50, App.L, Sec 7.4	Sec. 6.6 & 8.4
Internal Leak Check	every 5 sampling events	80 mL/min	"	Sec. 6.6 & 8.4
Temperature Calibration	If multi-point failure	± 2% of standard	Part 50, App.L, Sec 9.3	Sec. 6.4
Temp M-point Verification	on installation, then 1/yr	± 2 C of standard	Part 50, App.L, Sec 9.3	Sec. 6.4 and 8.4
One-point temp Verification	1/4 weeks	± 4 C of standard	"	Sec. 6.4 and 8.4
Pressure Calibration	on installation, then 1/yr	±10 mm Hg	"	Sec. 6.5
Pressure Verification	1/4 weeks	±10 mm Hg	"	Sec. 8.2
Clock/timer Verification	1/ 4 weeks	1 min/mo	Part 50, App.L, Sec 7.4	not described
Accuracy				
FRM Performance Evaluation	25% of sites 4/yr	± 10%	Part 58, App A, Sec 3.5	Sec 10.2
External Leak Check	4/yr	< 80 mL/min	not described	Sec. 10.2
Internal Leak Check	4/yr	< 80 mL/min	not described	"
Temperature Audit	4/yr	± 2 C	not described	"
Pressure Audit	4/yr (?)	±10 mm Hg	not described	"
Balance Audit	1/yr	Manufacturers specs	not described	"
Accuracy				
Flow Rate Audit	1/2wk (automated) 4/yr (manual)	± 4% of audit standard	Part 58, App A, Sec 3.5	Sec. 10.2

Measurement Quality Objectives- Parameter $PM_{2.5}$				
Requirement	**Frequency**	**Acceptance Criteria**	**40 CFR Reference**	**QA Guidance Document 2.12 Reference**
Precision				
Collocated samples	every 6 days for 25% of sites	CV $\leq$ 10%	Part 58, App.A, Sec 3.5 and 5.5	Sec. 10.2
			not described	
Single analyzer	1/3 mo.	CV $\leq$ 10%	not described	not described
Single Analyzer	1/ yr	CV $\leq$ 10%	not described	not described
Reporting Org.	1/ 3 mo.	CV $\leq$ 10%		not described
Calibration & Check Standards				
Flow Rate Transfer Std.	1/yr	$\pm$2% of NIST-traceable Std.	Part 50, App.L Sec 9.1 & 9.2	Sec. 6.3
Field Thermometer	1/yr	$\pm$ 0.1° C resolution	not described	Sec 4.2 & 6.4
		$\pm$ 0.5° C accuracy		"
Field Barometer	1/yr	$\pm$ 1 mm Hg resolution	not described	"
		$\pm$ 5 mm Hg accuracy		"
Working Mass Stds.	3-6 mo.	0.025 mg	not described	Sec 4.3 and 7.3
Primary Mass Stds.	1/yr	0.025 mg	not described	"

Measurement Quality Objectives - Parameter PAMS Volatile Organic Compounds (VOC)

Requirement	Frequency	Acceptance Criteria	Reference	Information/Action
Standard Reporting Units	All data	ppbC	TAD, July 1997	
Shelter Temperature Temperature range	Daily	20 to 30 C.	Vol II, S 7.1 [1/]	Instruments designated as reference or equivalent have been tested over this temperature range. Maintain shelter temperature above sample dewpoint. Shelter should have a 24-hour temperature recorder. Flag all data for which temperature range or fluctuations are outside acceptance criteria.
Detection Limit System detection limit		1 ppbC	TAD Sect 2.8 2.3	Calculation based on multiple manual or automated analysis and 40 CFR recommendations
Completeness (sesonal)	annually	85 %	TAD 2.8.1	
Calibration Multipoint retention time calibration standard	Start of analytical season	correlation coefficient $\geq$ 0.995	TAD 2.8.2.3	Triplicate analysis of multiple level propane standards over the expected sample concentration range (a minimum of three levels)
Performance Evaluation NPAP	prior to start of sampling season and twice during monitoring season	In absence of specified objectives within 25%	TAD 2.8.2.3	Useful for informing reporting agency for corrective actions and technical systems audits.
Precision Duplicate samples	once/2weeks automated 10% -manual	± 25% RSD or RPD	TAD 2.8.2.1.1	Comparison of duplicate field samples, or replicate sample analysis using manual or automated field devices.
QC Checks Retention time (RT) calibration check Canister cleaning	Weekly	Response factor within 10% RPD of calibration curve < 10 ppbC total	TAD 2.8.2.3	Retention time checked versus annual PAMS retention time cylinder provided to each site in the program. Canister cleaning per approved methodology
Background/carryover	weekly and after calibration & RT	< 20 ppbC for both columns or <10 ppbC per column	TAD 2.8.2.3	Background testing according to TAD

Appendix 6-A

Characteristics of Spatial Scales Related to Each Pollutant

The following tables provides information in order to match the spatial scale represented by the monitor with the monitoring objectives. This information can also be found in 40 CFR Part 58, Appendix D.

Pollutant	Spatial Scale	Characteristics
PM_{10}	Micro	Areas such as downtown street canyons and traffic corridors; generally not extending more than 15 meters from the roadway but could continue the length of the roadway. Sites should be located near inhabited buildings or locations where the general public can be expected to be exposed to the concentration measured.
	Middle	Measurements of this type would be appropriate for the evaluation of possible short-term public health effects of particulate matter pollution. This scale also includes the characteristic concentrations for other areas with dimensions of a few hundred meters such as the parking lot and feeder streets associated with shopping centers, stadia, and office buildings. In the case of PM10, unpaved or seldom swept parking lots associated with these sources could be an important source in addition to the vehicular emissions themselves.
	Neighborhood	Measurements in this category would represent conditions throughout some reasonably homogeneous urban subregion with dimensions of a few kilometers. This category also includes industrial and commercial neighborhoods, as well as residential.
	Urban	This class of measurement would be made to characterize the particulate matter concentration over an entire metropolitan or rural area. Such measurements would be useful for assessing trends in area-wide air quality, and hence, the effectiveness of large scale air pollution control strategies.
	Regional	These measurements would characterize conditions over areas with dimensions of as much as hundreds of kilometers. Using representative conditions for an area implies some degree of homogeneity in that area. For this reason, regional scale measurements would be most applicable to sparsely populated areas with reasonably uniform ground cover. Data characteristics of this scale would provide information about larger scale processes of particulate matter emissions, losses and transport.
$PM_{2.5}$	Micro	Areas such as downtown street canyons and traffic corridors where the general public can be expected to be exposed to maximum concentrations from mobile sources. In some circumstances, the microscale is appropriate for particulate stations; core SLAMS on the microscale should however, be limited to urban sites that are representative of long term human exposure and of many such microenvironments in the area.
	Middle	Measurements of this type would be appropriate for the evaluation of possible short-term exposure public health effects of particulate matter pollution. This scale also includes the characteristic concentrations for other areas with dimensions of a few hundred meters such as the parking lot and feeder streets associated with shopping centers, stadia, and office buildings.
	Neighborhood	Measurements in this category would represent conditions throughout some reasonably homogeneous urban subregion with dimensions of a few kilometers and of generally more regular shape than middle scale. Much of the PM2.5 exposures are expected to be associated with this scale of measurement. This category also include industrial and commercial neighborhoods, as well as residential.
	Urban	This class of measurement would be made to characterize the particulate matter concentration over an entire metropolitan or rural area. Such measurements would be useful for assessing trends in area-wide air quality, and hence, the effectiveness of large scale air pollution control strategies.
	Regional	These measurements would characterize conditions over areas with dimensions of as much as hundreds of kilometers. Using representative conditions for an area implies some degree of homogeneity in that area. For this reason, regional scale measurements would be most applicable to sparsely populated areas with reasonably uniform ground cover. Data characteristics of this scale would provide information about larger scale processes of particulate matter emissions, losses and transport.

Pollutant	Spatial Scale	Characteristics
SO_2	Middle	Assessing the effects of control strategies to reduce urban concentrations (especially for the 3-hour and 24-hour averaging times) and monitoring air pollution episodes.
	Neighborhood	This scale applies in areas where the SO_2 concentration gradient is relatively flat (mainly suburban areas surrounding the urban center) or in large sections of small cities and towns. May be associated with baseline concentrations in areas of projected growth.
	Urban	Data from this scale could be used for the assessment of air quality trends and the effect of control strategies on urban scale air quality.
	Regional	Provide information on background air quality and interregional pollutant transport.
CO	Micro	Measurements on this scale would represent distributions within street canyons, over sidewalks, and near major roadways.
	Middle	This category covers dimensions from 100 meters to 0.5 kilometer. In certain cases, it may apply to regions that have a total length of several kilometers. If an attempt is made to characterize street-side conditions throughout the downtown area or along an extended stretch of freeway, the dimensions may be tens of meters by kilometers. Also include the parking lots and feeder streets associated with indirect sources (shopping centers, stadia, and office buildings) which attract significant numbers of pollutant emitters.
	Neighborhood	Homogeneous urban subregions, with dimensions of a few kilometers
O_3	Middle	Represents conditions close to sources of NOx such as roads where it would be expected that suppression of O_3 concentrations would occur.
	Neighborhood	Represents conditions throughout some reasonably homogeneous urban subregion, with dimensions of a few kilometers. Useful for developing, testing, and revising concepts and models that describe urban/regional concentration patterns.
	Urban	Used to estimate concentrations over large portions of an urban area with dimensions of several kilometers to 50 or more kilometers. Such measurements will be used for determining trends, and designing area-wide control strategies. The urban scale stations would also be used to measure high concentrations downwind of the area having the highest precursor emissions.
	Regional	Used to typify concentrations over large portions of a metropolitan area and even larger areas with dimensions of as much as hundreds of kilometers. Such measurements will be useful for assessing the ozone that is transported into an urban area.
NO_2	Middle	Dimensions from about 100 meters to 0.5 kilometer. These measurements would characterize the public exposure to NO_2 in populated areas.
	Neighborhood	Same as for O_3
	Urban	Same as for O_3

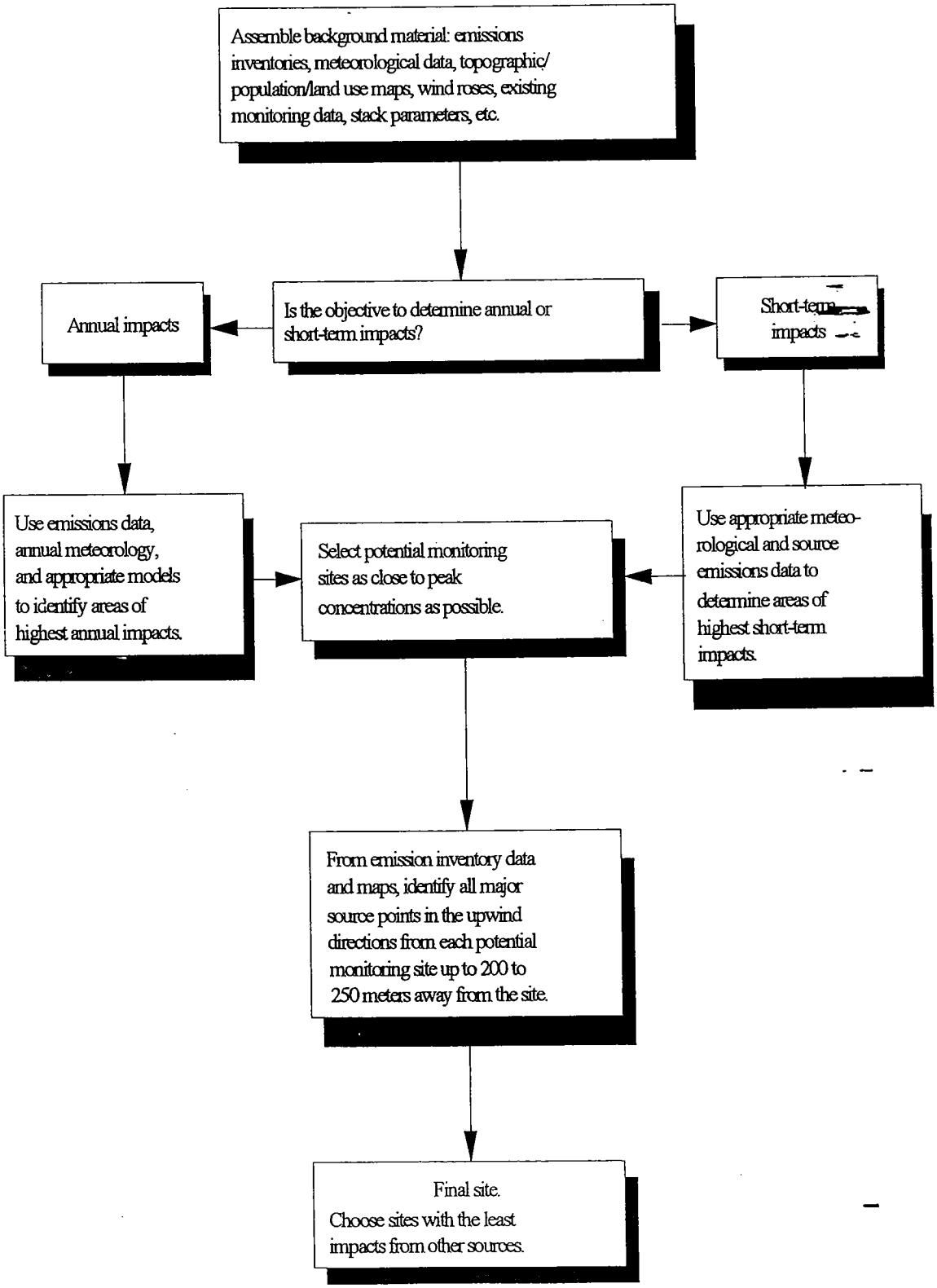
Pollutant	Spatial Scale	Characteristics
Pb	Micro	Would typify areas such as downtown street canyons and traffic corridors where the general public would be exposed to maximum concentrations from mobile sources. Because of the very steep ambient Pb gradients resulting from Pb emissions from mobile sources, the dimensions of the Micro scale for Pb generally would not extend beyond 15 meters from the roadway.
	Middle	Represents Pb air quality levels in areas up to several city blocks in size with dimensions on the order of approximately 100 meters to 500 meters. However, the dimensions for middle scale roadway type stations would probably be on the order of 50-150 meters because of the exponential decrease in lead concentration with increasing distances from roadways. The middle scale may for example, include schools and playgrounds in center city areas which are close to major roadways.
	Neighborhood	Would characterize air quality conditions throughout some relatively uniform land use areas with dimensions in the 0.5 to 4.0 kilometer range. Stations of this scale would provide monitoring data in areas representing conditions where children live and play.
	Urban	Would be used to present ambient Pb concentrations over an entire metropolitan area with dimensions in the 4 to 50 kilometer range.
PAMs	Neighborhood	Would define conditions within some extended areas of the city that have a relatively uniform land use and range from 0.5 to 4 km. Measurements on a neighborhood scale represent conditions throughout a homogeneous urban subregion. Precursor concentrations, on this scale of a few kilometers, will become well mixed and can be used to assess exposure impacts and track emissions. Neighborhood data will provide information on pollutants relative to residential and local business districts. VOC sampling at Site #2 is characteristic of a neighborhood scale. Measurements of these reactants are ideally located just downwind of the edge of the urban core emission areas. Further definition of neighborhood and urban scales is provided in Appendix D of 40 CFR 58 and Reference 9.
	Urban	Would represent concentration distributions over a metropolitan area. Monitoring on this scale relates to precursor emission distributions and control strategy plans for an MSA/CMSA. PAMS Sites #1, #3, and #4 are characteristic of the urban scale.

Appendix 6-B

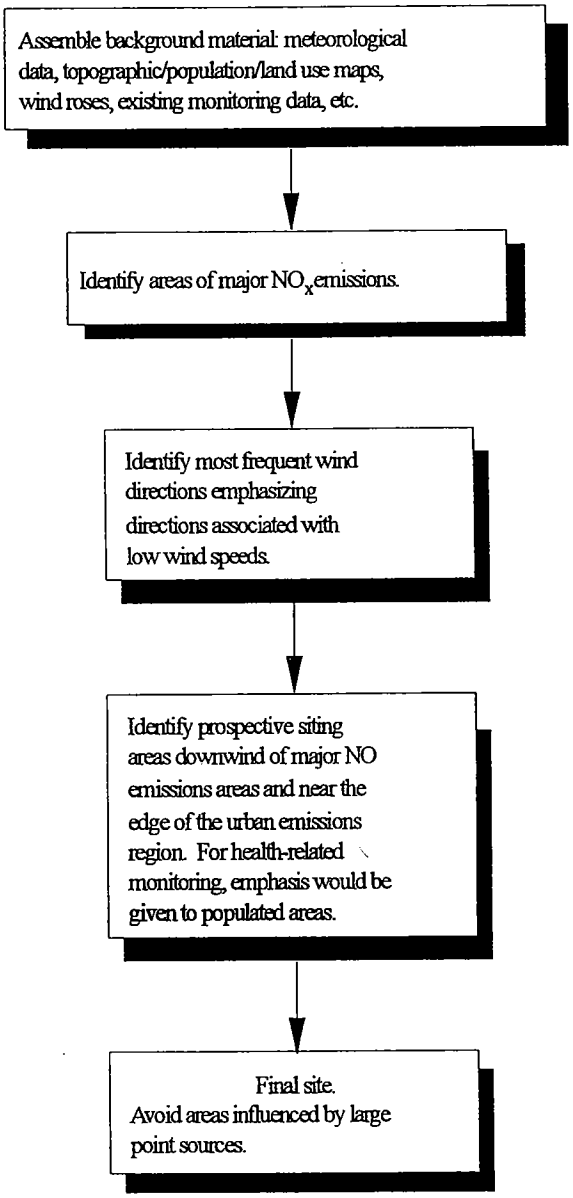
Procedures for locating Open Path Instruments

The following figures represent procedures for locating open path instruments for various pollutants based upon different sampling scales.

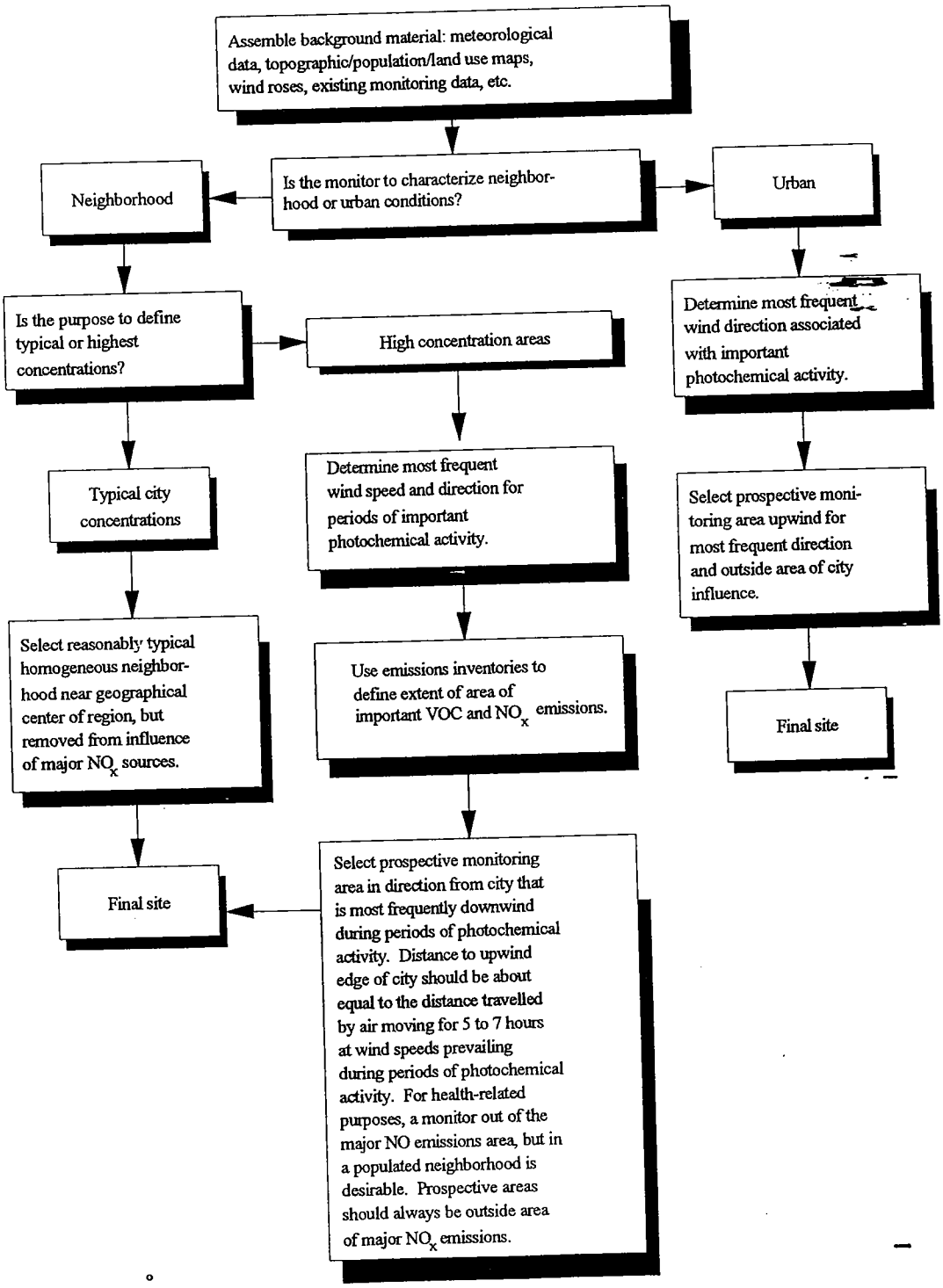
Procedures for Locating NO_2 Source-Impact Stations.



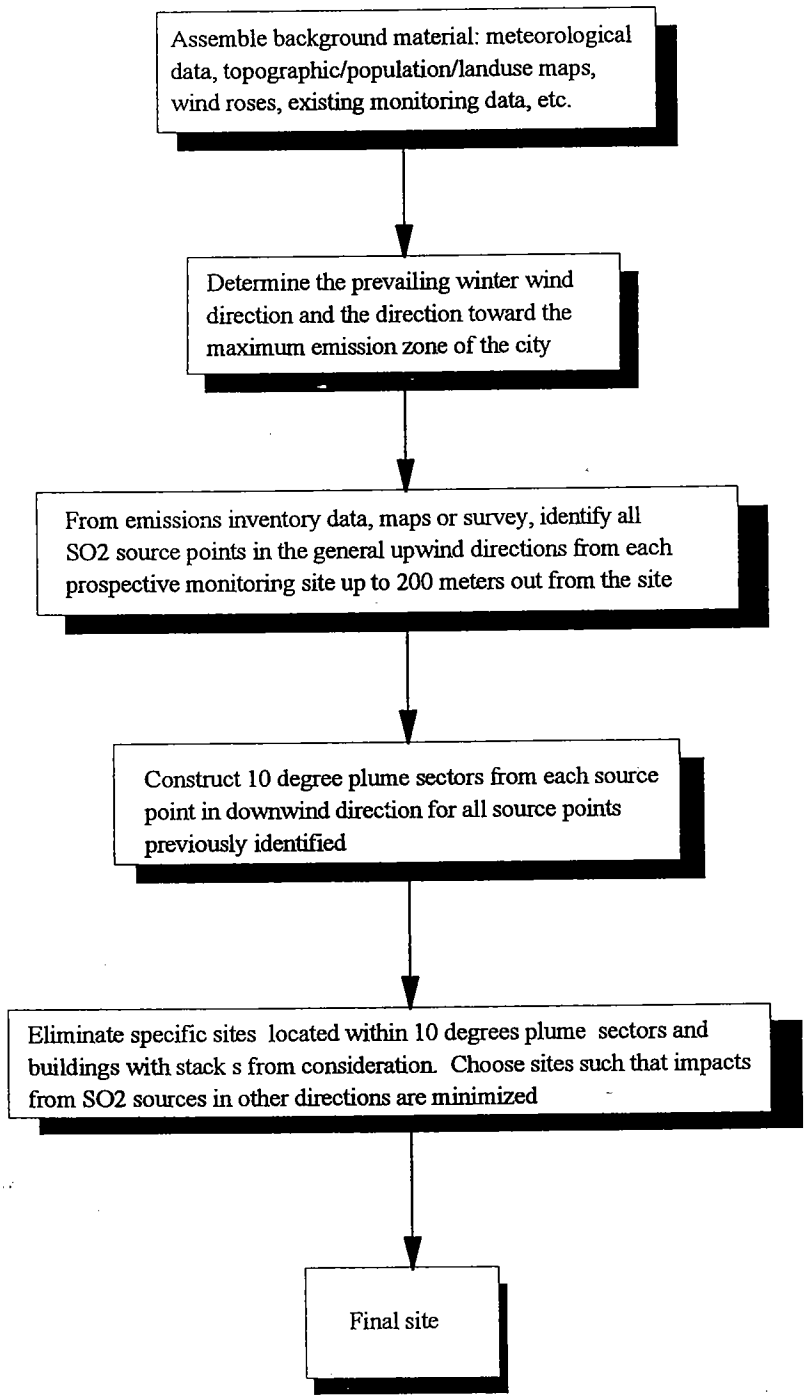
Procedures for Locating NO and NO_2 Neighborhood Scale Stations.



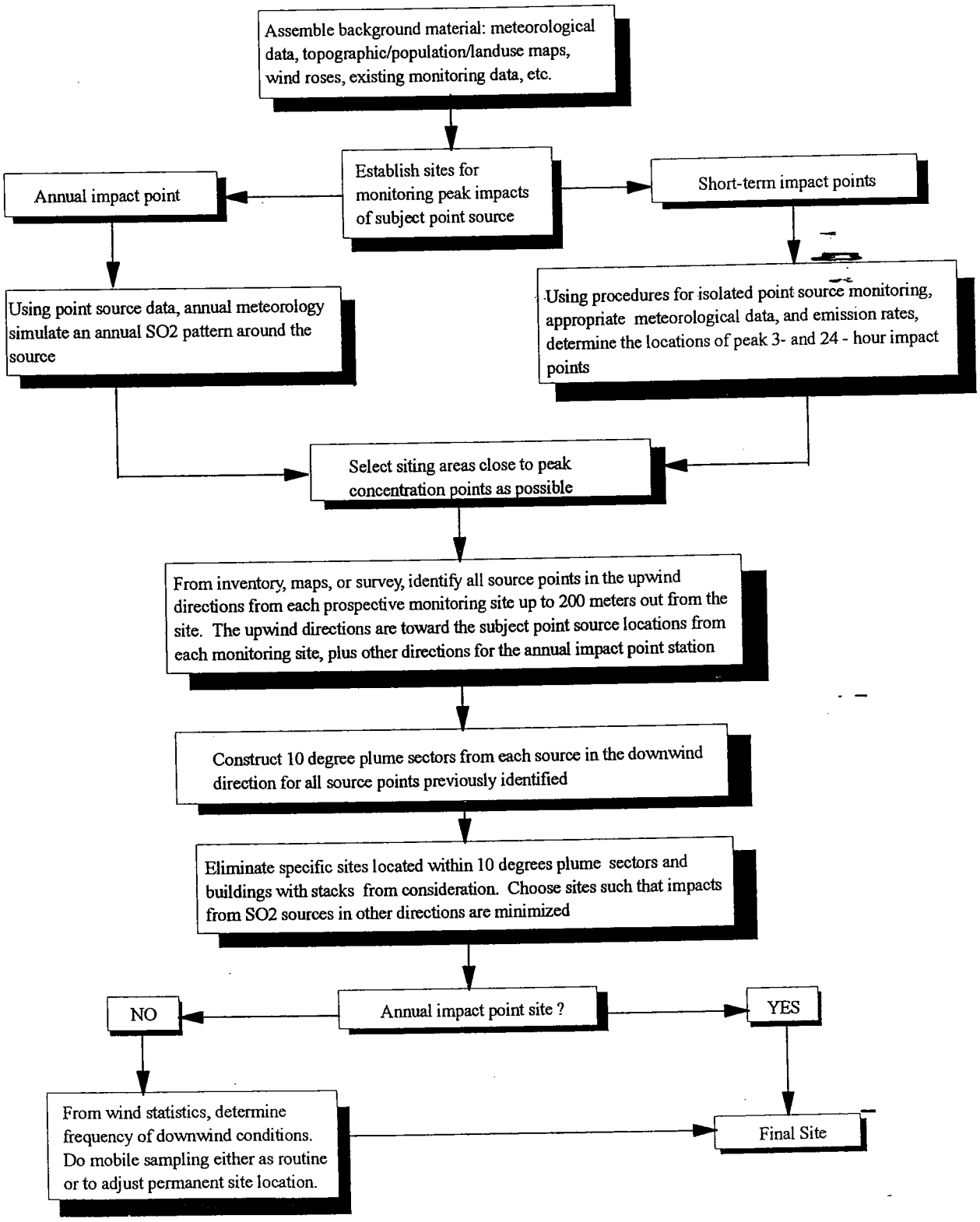
Procedures for Locating O_3 Neighborhood and Urban Scale Stations.



Procedures for Locating SO_2 Population Exposure Middle-Scale Stations



Procedures for Locating SO_2 Point Source-Impact Middle-Scale Stations



Appendix 12

Calibration of Primary and Secondary Standards for Flow Measurements

Calibration of Primary and Secondary Standards for Flow Measurements

1. Introduction

Air pollution monitoring quality control procedures call for flow calibrations to be performed on field calibration devices. These "field standard" calibration units require a mass flow or volumetric flow calibration to ascertain the final concentration of the gas. This appendix will examine the how to obtain a flow device that is traceable to the National Institute of Standards and Technology (NIST). This discussion will also discuss secondary and primary standards and the establishment of their traceability.

2. Definitions

Traceability: This term is defined in 40 CFR Parts 50 and 58 as meaning, "that a local standard has been compared and certified, either directly or via not more than one intermediate standard, to a primary standard such as a National Institute of Standards and Technology Standard Reference Material (NIST-SRM).[1]

Primary Standard: This is a flow device that is certified to be directly traceable to the NIST-SRM. These devices usually provide paperwork that proves that the device is traceable. Bubblemeters, volumetric burettes and some piston devices can be considered to be primary standards. Check with the vendor for certification of a primary standard. The primary standard should remain in the central laboratory and not be moved.

Transfer Standard: A transfer standard is a device that is certified against a primary standard. These standards usually travel to monitoring stations. Transfer standards can be volumetric, electronic flow meters, wet test meters, pressure gauges or pressure/flow transducers. These devices usually have a certain amount of error involved in their operation and can drift with time. Therefore they must be verified against a primary standard on a known set schedule.

Calibration Standards: Calibration standards are devices that are specifically designed to be placed in a monitoring location and can be used to calibrate air monitoring instruments. See Section 12 for definitions and cautions concerning calibrations of air quality instruments. These devices are commercially available from a number of vendors. These units usually are permeation devices or mass flow calibrators (MFC). The flow rates of these devices are verified by the transfer standard on a set schedule.

Permeation devices: Permeation devices are calibration units that pass a known volume of air over a permeation tube. The permeation tube is a small cylinder (usually steel) that has a permeable membrane at one end. Usually the tube is filled with a liquid that permeate out through the membrane at a given rate at a very narrow temperature range. By knowing the permeation rate and the air flow rate, a NIST traceable concentration in parts per million can be calculated[2].

Mass Flow Controller: MFC are a device that works on the principle of heat loss. The mass flow meter within the MFC has a small thermister that is sensitive to heat loss. A potential voltage is applied to the thermister. As the air flow increases across the thermister, the resistance of the thermister changes. This change in resistance can be measured very accurately by electronic circuitry. The mass flow circuitry can then be integrated with controlling loop circuit that can control/monitor the flow instantaneously. Usually, MFC have two channels, gas and diluant or air flow. The gas portion of the unit allows for gases from compressed cylinders to be allowed in and metered. The air flow side of the unit blends down the high concentration from the compressed cylinders to the desired working concentration. The flow rate of both portions of the unit must be measured accurately. It is important when purchasing a MFC calibrator that it meet the 40 CFR 50 requirements of have +/- 2% accuracy[3].

Verification: A verification is the process of checking one primary authority against another primary authority. This can be done by inter-comparing two primary standards against each other or an agency primary standard against another agencies primary standard or NIST standard.

Certification: A certification is the process of checking a transfer standard against a primary standard and establishing a mathematical relationship that is used to adjust the transfer standard values back to the primary standard.

Calibration: A calibration is the process of checking and adjusting the flow rate of a field calibration standard against a transfer standard.

3. Hierarchy of Standards

NIST Standards: The highest authority lies with the NIST. The NIST keeps a set of standards that is referenced by all manufacturers of glassware, standard equipment and electronic primary standards.

Primary Standards: The next level is a primary standard. Every state or local agency, contractor or laboratory should have, at a minimum, one primary standard. Normally, once you have received a primary standard from the manufacturer, it will not need to be re-verified by NIST. However, if a shift is observed, contact the manufacturer to reverify your primary standard against the manufacturer's standards. If two primary standards exist for flow devices, then one should be considered the alpha unit, etc. It is good laboratory practice that the alpha unit always remain in the laboratory and should not be used outside, unless you suspect the unit is not operating correctly, then it should be sent to the manufacturer for repair and re-certification to NIST standards. If the agency has two primary standards, the beta unit can be a traveling instrument but should be crossed referenced once per year to verify that neither unit has shifted its standards. Primary standards should agree with one another within 2%.

Transfer Standards: The next level of traceability is the transfer standard. Transfer standards can be many different devices. It is recommended that if one type of device be used as a transfer standard for an agency. This will eliminate any error that may occur from different types of standards. It is recommended that transfer standards be calibrated at least every six months. Electronic type of transfer standards sometimes have problems with baseline drift. If this appears to be a problem, then verification of the transfer standard should occur more often. If an agency is small, one transfer standard may be sufficient. However, most agencies will have many transfer standards and will probably need to reverify on a staggered schedule.

Calibration Standards: As discussed earlier, calibration standards can be MFC or permeation devices. These units are calibrated by the transfer standards. These should be calibrated quarterly, or if a shift in response occurs with the instruments. It is also recommended that the flow rates of calibration standards be calibrated when a cylinder is changed or a permeation tube is replaced.

4. Cautions

The following precautions should be taken before verifying or calibrating standards:

- When checking calibration standards, always ventilate the monitoring shelter properly. Gas concentrations may be generated that can be health hazards.
- Always transport the transfer standards in its protective carrying case. The internal hardware can be damaged by sudden jolts.
- Do not leave the transfer standards in the sun or a closed car. Extreme heat can damage the internal computer.
- Zero air systems and gas cylinders are operated under high pressure. Always bleed of pressure to the connecting lines before and after operation of the standard. This will assure that the unit will not be damaged.
- Use caution whenever using electronic equipment. Read the directions carefully to avoid electrical shock.

5. Primary Standard Verification

Generally, primary standards do not need to be re-verified to NIST standards. However, if the primary standard is a bubble, piston or electronic type of instrument, it is recommended that it be re-verified against another primary standard. If the agency suspects that the primary standard is not operating correctly, it is recommended that it be sent to the manufacturer for repair and re-calibration. The following procedure should be used when verifying a primary standard:

- Allow the primary standards to warm up sufficiently.
- Attach the alpha primary standard to an air flow generating device. Note: it is useful if MFC calibrator is available for this test. The MFC can meter air/gas flows and allow the user to change the flow rate in the ranges normally used by the primary standard. Attach tubing to the primary standard from the output of the air supply. With most primary standards, the gas flow range is 0 - 200 cc/min, while the air flow is 0 - 10 liters/min. Since this is a large difference, the primary standard usually are purchased with two or three sets of volumes. Attach the air flow measuring device to the primary standard. Making sure that the ports are open, allow air to pass through the primary standard. Record the barometric pressure and the shelter temperature.
- If using a MFC, set the flow rate Thumb Wheel Settings (TWS) to the desired setting. Allow the calibrator to stabilize, usually 2-3 minutes. Read the value of the alpha primary standard. Record 5-10 readings and average. Without changing the TWS, attach the beta primary standard. Record the response of this unit and average. Record these on to a sheet.
- Adjust the Thumb Wheel Settings to the next level that you wish to measure and repeat step 3. It is recommended that a minimum of 5 levels be measured.
- Repeat this procedure for the gas device using flows in the range of the primary standard flow device. Repeat steps 3-4.
- After the values have been averaged and tabulated, adjust the values to Standard Temperature and Pressure (STP). For air monitoring, standard temperature is 298° Kelvin, 29.92 inches of Mercury. Calculate the percent difference for each point (using the alpha primary standard as the known). Also, calculate the least squares regression of the air and gas flows, using the alpha as the abscissa.

Calculations

Since primary standards are volumetric measuring devices, the flows must be corrected to standard temperature and pressure, i.e., 298° Kelvin and 29.92 in Hg (inches of mercury). The following equation illustrates how to calculate the standard temperature and pressure correction factor:

$$Fc = Fr * (Pm/29.92 \text{ in Hg}) * (298° K/Tm) \quad \text{(equation 1)}$$

Where:

Fc = Corrected flow rate to standard conditions

Fr = Uncorrected flow rate readings

Pm = Atmospheric barometric pressure at the site; in Hg

Tm = Shelter temperature in degrees. Kelvin (i.e., 273° Kelvin + temperature in degrees C)

6. Transfer Standard Certification

After the Primary Standard has been certified to NIST standards or verified against another primary standard, the traceability of the primary standard can be "transferred" to the field transfer standard.

Generally, transfer standards should be re-verified on a regular basis or if the agency suspects that the transfer standard baseline has drifted or malfunctioned. The transfer standard must always be verified against a primary standard. The following procedure should be used when verifying a transfer standard:

- Allow the primary standard and transfer standard to warm up sufficiently.
- Attach the primary standard to an air flow generating device. Note: it is useful if MFC calibrator is available for this test. The MFC can meter air/gas flows and allow the user to change the flow rate in the ranges normally used by the primary and transfer standard. With most primary and transfer standards, the gas flow range is 0 - 200 cc/min, while the air flow is 0 - 10 liters/min. Since this is a large difference, the primary and transfer standard usually are purchased with two or three sets of volumes. Making sure that the ports are open, allow air to pass through the primary standard. Attach the output of the primary standard to the input of the transfer standard. Record the barometric pressure and the shelter temperature. Note: if the primary or transfer standard are piston type of instrument, this can cause the non-piston type of standard flow rates to fluctuate over a wide range. If this is the case, then the procedure as outlined in section .5 should be used, substituting the transfer standard for the beta primary standard.
- If using a MFC, set the flow rate Thumb Wheel Settings to the desired setting. Allow the calibrator to stabilize, usually 2-3 minutes. Read the value of the primary standard and the transfer standard. Record 5-10 readings and average the values from the primary standard and the transfer standard.
- Adjust the Thumb Wheel Settings to the next level that you wish to measure and repeat step 3. It is recommended that a minimum of 5 levels be measured.
- Repeat this procedure for the gas device using flows in the range of the primary and transfer standard flow devices. Repeat steps 3-4.
- After the values have been averaged and tabulated, adjust the values to STP. See equation 1. Calculate the percent difference for each point (using the primary standard as the known). Also, calculate the least squares regression of the air and gas flows, using the primary standard as the abscissa. Note: at this time, the relationship of the transfer standard and the primary standard must be examined. In some cases, the response of the transfer standard may not be 1:1 with the primary standard. If this is the case, then the correlation coefficient must the factor examined in accepting or rejecting the transfer standard as a useable standard. It is recommended that the correlation coefficient be no less than 0.9990. Also, if the agency deems it necessary, the slope, intercept and correlation coefficient may be averaged over a period of time to ascertain the relative drift of the transfer standard in relationship to the primary. It is recommended that a new transfer standard be tested at least twice to ascertain the drift of the instrument. If the slope and intercept or the transfer standard relative to a primary is not exactly 1:1, then a slope and intercept factor must be applied to the output of the transfer standard whenever it is used in a field situation. By using the equation $y = mx+b$, where y = raw reading from transfer standard, m = slope factor of the linear regression, x = adjusted reading of the transfer standard and b = the intercept of the linear regression, then the adjusted value for every reading on the transfer standard is; $x = (y-b)/m$. Every value read on the transfer standard should be adjusted using this equation. By performing this derivation, all transfer standard values are adjusted back to the primary standard.

7. Calibration of Field Standard

After the transfer standard has been certified to a primary standard, the traceability of the transfer standard can be "transferred" to the field calibration standard. Generally, calibration standards should be re-calibrated on a regular basis or if the agency suspects that the calibration standard baseline has drifted or malfunctioned. The calibration standard must always be verified against a transfer or primary standard. The following procedure should be used when verifying a transfer standard:

7.1 Mass Flow Calibration Standards

- Allow the calibration standard and transfer standard to warm up sufficiently.
- Note: if the calibration standard is a MFC calibrator, then the calibration standard response will be a TWS or a digital display. Attach tubing to the transfer standard from the output of the calibration standard. With most MFC calibrators, the gas flow range is 0 - 200 cc/min, while the air flow is 0 - 10 liters/min. Since this is a large difference, the transfer standard usually are purchased with two or three sets of volumes. Making sure that the ports are open, allow air to pass through the transfer standard. Record the barometric pressure and the shelter temperature.
- Set the flow rate TWS to the desired setting. Actuate the calibration standard (calibrator) manually or remotely using the data acquisition system if applicable. Allow the calibrator to stabilize, usually 2-3 minutes. Read the value of the transfer standard and record the digital display or TWS on the calibrator. Record 5-10 readings and average the values from the transfer standard.
- Adjust the Thumb Wheel Settings to the next level that you wish to measure and repeat steps 3. It is recommended that a minimum of 5 levels be measured.
- Repeat this procedure for the gas device using flows in the range of field calibration devices. Repeat steps 3-4. Note: with MFC calibrators, the gas and diluant air are brought together in an internal mixing chamber. The combined mixture is then shunted to the output of the calibrator. It is important to disconnect the air flow source from the unit and cap the air input port before measuring the gas flow.
- After the values have been averaged and tabulated, adjust the values to STP. See equation 1. Calculate the percent difference for each point (using the transfer standard as the known). Note: make sure to apply the correction factor for the transfer standard to the raw outputs if necessary before calculating the regression. Calculate the least squares regression of the air and gas flows, using the primary standard as the abscissa.
- Once the gas and air flows mass flow meters have been calibrated using the transfer standard, the next step is to calculate the concentration that will be blended down from the high concentration gas cylinder.

The equation for this calculation follows:

$$C = (G * Fg)/(Fg + Fa) \quad \text{(equation 2)}$$

where:

C = Final concentration of gas from the output of calibrator in ppm

G = Gas concentration from NIST traceable cylinder in ppm

Fg = Flow rate of the cylinder gas through the MFC, cc/min

Fa = Flow rate of air through the MFC, cc/min

7.2 Permeation Calibration Standards

Permeation devices work on a different principle from the MFC type of calibration standard. The permeation device allows a calibrated volume of air to pass over a permeation tube of a known permeation rate. It is the measurement of the flow rate to STP that is critical to the success of calibration of instruments.

- Allow the calibration standard permeation device and transfer standard to warm up sufficiently. Note: Most permeation devices must be operated at a specific temperature range for the operator to know the

permeation rate. Allow sufficient time for the permeation device to warm up to this temperature. See the manufacturer's manual for guidance.

- Attach the output of the permeation device to the input of the transfer standard. Set the flow rate TWS or rotometer to the desired setting. Actuate the calibration standard (calibrator) manually or remotely using the data acquisition system if applicable. Allow the calibrator to stabilize. Read the value of the transfer standard and record the TWS or rotometers on the calibrator. Record 5-10 readings and average the values from the transfer standard.
- Adjust the Thumb Wheel Settings or rotometer to the next level that you wish to measure and repeat steps 2. It is recommended that a minimum of 5 levels be measured.

Once the flow rates have been measured the calculation for permeation devices concentrations is as follows:

$$C = (Pr * Mv)/(Ft*Mw) \quad \text{(equation 3)}$$

where:

C = Concentration in ppm

Pr = permeation rate of permeation tube at a known temperature, usually as ug/min

Mv= Molar gas constant at standard pressure, 24.45 liters/mole

Mw = Molecular weight of the permeation gas, grams/mole

Ft = STP flow rate of diluant air across the permeation tube, liters/min

REFERENCES

1. Code of Federal Regulations, Title40, Part 50, "definitions"
2. Code of Federal Regulations, Title40, Part 50, Appendix A, section 10.
3. Code of Federal Regulations, Title40, Part 50, Appendix C, section 2.2

Appendix 14
Example Procedure for Calibrating a Data Aquisition System

The following is an example of a DAS calibration. The DAS owner's manual should be followed. The calibration of a DAS is performed by inputting known voltages into the DAS and measuring the output of the DAS.

1. The calibration begins by obtaining a voltage source and an ohm/voltmeter.

2. Place a wire lead across the input of the DAS multiplexer. With this "shorted" out, the DAS should read zero.

3. If the output does not read zero, adjust the output according to the owners manual.

4. After the background zero has been determined, it is time to adjust the full scale of the system. Most DAS system work on a 1, 5 or 10 volt range, i.e., the full scale equals an output of voltage. In the case of a 0 - 1000 ppb range instrument, 1.00 volts equals 1000 ppb. Accordingly, 500 ppb equals 0.5 volts (500 milivolts). To get the DAS to be linear throughout the range of the instrument being measured, the DAS must be tested for linearity.

5. Attach the voltage source to a voltmeter. Adjust the voltage source to 1.000 volts (this is critical that the output be **1.000 volts)**. Attach the output of the voltage source the DAS multiplexer. The DAS should read 1000 ppb. Adjust the DAS voltage A/D card accordingly. Adjust the output of the voltage source to 0.250 volts. The DAS output should read 250 ppb. Adjust the A/D card in the DAS accordingly. Once you have adjusted in the lower range of the DAS, check the full scale point. With the voltage source at 1.000 volts, the output should be 1000 ppb. If it isn't, then adjust the DAS to allow the high and low points to be as close to the source voltage as possible. In some cases, the linearity of the DAS may be in question. If this occurs, the data collected may need to be adjusted using a linear regression equation. See Section 2.0.9 for details on data adjustment. The critical range for many instruments is in the lower 10 % of the scale. It is critical that this be linear.

6. Every channel on a DAS should be calibrated. In some newer DAS systems, there is only one A/D card voltage adjustment which is carried throughout the multiplexer. This usually will adjust all channels. It is recommended that DAS be calibrated once per year.

Appendix 15

Audit Information

The following sections are included in the Appendix:

Section	Description
1	Network Audit Checklist
2	EPA Regional Technical System Audit Information and Questionnaire
3	State and Local Audit Procedures
4	California Air Resources Board Thru-The-Probe Criteria Audits

Section 1
Network Review Checklist

The following checklist is intended to assist reviewers in conducting a network review. The checklist will help the reviewer to determine if the network conforms with the network design and siting requirements specified in Appendices D and E. Section I of the checklist includes general information on the network. Section II addresses conformance with Appendix D requirements. Section III includes pollutant-specific evaluation forms to address conformance with Appendix E requirements. In addition to completing the checklist during the network review, the following list of action items is provided as a guide during an onsite visit of a monitoring station.

- ensure that the manifold and inlet probe are clean
- estimate probe and manifold inside diameter and length
- inspect the shelter for weather leads, safety, and security
- check equipment for missing parts, frayed cords, etc.
- check that monitor exhausts are not likely to be reentrained by the sampling inlet
- record findings in field notebook
- take photographs/videotape in eight directions

NETWORK REVIEW CHECKLIST

SECTION I - GENERAL INFORMATION

Reviewer: | Review Date:

1. State or Local Agency:

   Address

   Contact

   Telephone Number

2. Type of network review (check all that apply)
   ☐SLAMS ☐NAMS ☐PAMS ☐SPM/Other

3. Network Summary Description
   Number of sites currently operating or temporarily inoperative (30 days), not including collocated or index sites.

	SLAMS (excluding NAMS/PAMS)	NAMS	PAMS	SPM/Other
CO			---	
SO_2			---	
NO_2				
O_3				
PM10			---	
Pb			---	
$PM_{2.5}$				
VOC	---	---		
Carbonyls	---	---		
Met	---	---		

4. Network Description
   Date of most current official network description? _____

	Yes	No
Copy available for review?	☐	☐
For each site, are the following items included:		
AIRS Site ID	☐	☐
Sampling and Analysis Method	☐	☐
Operative Schedule	☐	☐
Monitoring Objective	☐	☐
Scale of Representativeness	☐	☐
Zip Code	☐	☐
Any Proposed Changes	☐	☐

5. Date of last network review? _____

Modifications made since last network review

	Number of Monitors		
	Added	Deleted	Relocated
Carbon Monoxide			
Lead			
Nitrogen Dioxide			
Ozone			
PM-10			
$PM_{2.5}$			
Sulfur Dioxide			
Total Suspended Particulate			
For PAMS:			
Carbonyls			
Meteorological Measurements			
VOCs			

7. Network Design and Siting
   Summarize any nonconformance with the requirements of 40 CFR 58, Appendices D and E found in Sections II and III

	AIRS Site ID	Site Type	Reason for Nonconformance
CO			
SO_2			
NO_2			
O_3			
PM10			
$PM_{2.5}$			
Pb			
VOC			
Carbonyls			
Met			

8. List problems found, actions to be taken, corrective measures, etc. called for in the last network review that still have not been addressed.

SECTION II - EVALUATION OF CONFORMANCE WITH APPENDIX D REQUIREMENTS

	Yes	No
1. Is the Agency meeting the number of monitors required based on 40 CFR Part 58 requirements?		
SLAMS	☐	☐
NAMS	☐	☐
PAMS	☐	☐

If no, explain:

	Yes	No
2. Is the Agency operating existing monitors according to 40 CFR Part 58 requirements?		
SLAMS	☐	☐
NAMS	☐	☐
PAMS	☐	☐

If no, explain:

	Yes	No
3. Are monitors properly located based on monitoring objectives and spatial scales of representativeness specified in Appendix D?		
SLAMS	☐	☐
NAMS	☐	☐
PAMS	☐	☐

If no, explain:

	Yes	No
4. For PAMS, when C or F sampling frequency is used, has an ozone event forecasting scheme been submitted and reviewed?	☐	☐

If no, explain:

Network Design/Review Determined by (check all that apply)

☐ Dispersion modeling ☐ Special studies (including saturation sampling)
☐ Best professional judgement ☐ Other (specify _____)

Comment (for example, SO_2 dispersion modeling for urbanized area A; PM-10 saturation study for urbanized area B, etc.)

Evaluation was based on the following information (check all that apply):

☐ emission inventory data ☐ traffic data ☐ AIRS site reports
☐ meteorological data ☐ topographic data ☐ site photographs, videotape, etc.
☐ climatological data ☐ historical data ☐ other (specify _____)

SECTION III - EVALUATION OF CONFORMANCE WITH APPENDIX E REQUIREMENTS

IIIA - CARBON MONOXIDE NAMS/SLAMS SITE EVALUATION

Agency Site Name : _____

Site Address : _____

City & State : _____

AIRS Site ID : _____

Date : _____

Observed by : _____

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET?	
			Yes	No
Horizontal and Vertical Probe Placement (Par. 4.1)	3 ±½ m for microscale			
	3-15 m for middle and neighborhood scale			
Spacing from Obstructions (Par. 4.2)	270 or 180 if on side of building			
Spacing from Roads (Par. 4.3)	2-10 m from edge of nearest traffic lane for microscale; 10 m from intersection, preferably at midblock			
	See Table 1 for middle and neighborhood scale			
Spacing from Trees (Par 4.4)	Should be 10 m from dripline of trees		N/A	

Comments

*Citations from 40 CFR 58, Appendix E.

IIIB - LEAD NAMS/SLAMS SITE EVALUATION

Agency Site Name : _____

Site Address : _____

City & State : _____

AIRS Site ID : _____

Date : _____

Observed by : _____

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET?	
			Yes	No
Vertical Probe Placement (Par. 7.1)	2-7 m above ground for microscale			
	2-15 m above ground for other scales			
Obstructions on Roof (Par. 7.2)	2 m from walls, parapets, penthouses, etc.			
Obstacle Distance (Par. 7.2)	2 x height differential			
Unrestricted Airflow (Par. 7.2)	At least 270 (except for street canyon sites)			
Furnace or Incinerator Flues (Par. 7.2)	**Recommended** that none are in the vicinity		N/A	
Spacing from Station to Road (Par. 7.3)	5-15 m for microscale			
	See Table 4 for other scales			
Spacing from Trees (Par. 7.4)	Should be 20 m from trees		N/A	
	10 m if trees are an obstruction			

Comments

*Citations from 40 CFR 58, Appendix E.

IIIC - NITROGEN DIOXIDE NAMS/SLAMS SITE EVALUATION

Agency Site Name : _____

Site Address : _____

City & State : _____

AIRS Site ID : _____

Date : _____

Observed by : _____

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET?	
			Yes	No
Vertical Probe Placement (Par. 6.1)	3-15 m above ground			
Spacing from Supporting Structure (Par. 6.1)	Greater than 1 m			
Obstacle Distance (Par. 6.2)	Twice the height the obstacle protrudes above probe			
Unrestricted Airflow (Par. 6.2)	Must be 270 or 180 if on side of building			
Spacing between Station and Roadway (Par. 6.3)	See Table 3			
Spacing from Trees (Par. 6.4)	Should be 20 m		N/A	
	10 m if trees are an obstruction			
Probe Material (Par. 9)	Teflon or pyrex glass			
Residence Time (Par. 9)	Less than 20 seconds			

Comments

*Citations from 40 CFR 58, Appendix E.

IIID - OZONE NAMS/SLAMS SITE EVALUATION

Agency Site Name : _____

Site Address : _____

City & State : _____

AIRS Site ID : _____

Date : _____

Observed by : _____

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET?	
			Yes	No
Vertical Probe Placement (Par. 5.1)	3-15 m above ground			
Spacing from Supporting Structure (Par. 5.1)	Greater than 1 m			
Obstacle Distance (Par. 5.2)	Twice the height the obstacle protrudes above probe			
Unrestricted Airflow (Par. 5.2)	Must include predominant wind. 180 if on side of building. Otherwise 270			
Spacing between Station and Roadway (Par. 5.3)	See Table 2			
Spacing from Trees (Par. 5.4)	Should be 20 m		N/A	
	10 m if blocking daytime wind			
Probe Material (Par. 9)	Teflon or pyrex glass			
Residence Time (Par. 9)	Less than 20 seconds			

Comments

*Citations from 40 CFR 58, Appendix E.

IIIE - $PM_{2.5}$ NAMS/SLAMS SITE EVALUATION

Agency Site Name : _____

Make and Model # of Instrument : _____

Site Address : _____

City & State : _____

AIRS Site ID : _____

Date : _____

Observed by : _____

CRITERIA*	REQUIREMENTS*	OBSERVED	CRITERIA MET?	
			Yes	No
Vertical Probe Placement (Par. 8.1)	2-7 m above ground for microscale			
	2-15 m above ground for other scales			
Obstructions on Roof	2 m from walls, parapets, penthouses, etc.			
Spacing from Trees (Par. 8.2)	Should be 20 m from dripline of trees		N/A	
	Must be 10 m from dripline if trees are an obstruction**			
Obstacle Distance (Par. 8.2)	2 x height differential (street canyon sites exempt)			
Unrestricted Airflow (Par. 8.2)	At least 270 including the predominant wind direction			
Furnace or Incinerator Flues (Par. 8.2)	**Recommended** that none are in the vicinity		N/A	
Distance between Co-located Monitors (Appendix A, Par. 3.5.2)	1 to 4 m			
Spacing from Station to Road (Par. 8.3)	See Par. 8.3 and/or Figure 2 of Appendix E			
Paving (Par. 8.4)	Area **should** be paved or have vegetative ground cover		N/A	

Comments

*Citations from 40 CFR 58, Appendix E.

**A tree is considered an obstruction if the distance between the tree(s) and the sampler is less than the height that the tree protrudes above the sampler.

IIIF - PM_{10} NAMS/SLAMS SITE EVALUATION

Agency Site Name : _____

Site Address : _____

City & State : _____

AIRS Site ID : _____

Date : _____

Observed by : _____

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET?	
			Yes	No
Vertical Probe Placement (Par. 8.1)	2-7 m above ground for microscale			
	2-15 m above ground for other scales			
Obstructions on Roof	2 m from walls, parapets, penthouses, etc.			
Spacing from Trees (Par. 8.2)	Should be 20 m from trees		N/A	
	10 m if trees are an obstruction			
Obstacle Distance (Par. 8.2)	2 x height differential (street canyon sites exempt)			
Unrestricted Airflow (Par. 8.2)	At least 270 including the predominant wind direction			
Furnace or Incinerator Flues (Par. 8.2)	**Recommended** that none are in the vicinity		N/A	
Distance between Co-located Monitors (Appendix A, Par. 3.3)	2 to 4 m			
Spacing from Station to Road (Par. 8.3)	See Par. 8.3 and/or Figure 2 of Appendix E			
Paving (Par. 8.4)	Area **should** be paved or have vegetative ground cover		N/A	

Comments

*Citations from 40 CFR 58, Appendix E.

IIIG - SULFUR DIOXIDE NAMS/SLAMS SITE EVALUATION

Agency Site Name : _____

Site Address : _____

City & State : _____

AIRS Site ID : _____

Date : _____

Observed by : _____

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET?	
			Yes	No
Horizontal and Vertical Probe Placement (Par. 3.1)	3-15 m above ground			
	> 1 m from supporting structure			
	Away from dirty, dusty areas			
	If on side of building, should be on side of prevailing winter wind		N/A	
Spacing from Obstructions (Par. 3.2)	1 m from walls, parapets, penthouses, etc.			
	If neighborhood scale, probe must be at a distance twice the height the obstacle protrudes above probe			
	270 arc of unrestricted airflow around vertical probes and wind during peak season must be included in arc			
	180 if on side of building			
	No furnace or incineration flues or other minor sources of SO_2 should be nearby		N/A	
Spacing from Trees (Par. 3.3)	Should be 20 m from dripline of trees		N/A	
	10 m when trees act as an obstruction			

Citations from 40 CFR 58, Appendix E.

Section 2
EPA Regional Technical Systems Audits Information and Questionnaire

1.0 Scope

The purpose of the guidance included here is to provide the background and appropriate technical criteria which form the basis for the air program evaluation by the Regional audit team. To promote national uniformity in the evaluation of state and local agency monitoring programs and agencies' performance, all EPA Regional Offices are required to use the questionnaire that follows, the audit finding and response forms (Figures 15.4 and 15.5 in Section 15), and the systems audit reporting format that follows in Section 6 of this appendix, upon implementing an audit.

The scope of a systems audit is of major concern to both EPA Regions and the agency to be evaluated. A systems audit, as defined in the context of this document, is seen to include an appraisal of the following program areas: network management, field operations, laboratory operations, data management, quality assurance and reporting. The guidance provided concerning topics for discussion during an on-site interview have been organized around these key program areas. Besides the on-site interviews, the evaluation should include the review of some representative ambient air monitoring sites and the monitoring data processing procedure from field acquisition through reporting into the AIRS computer system. The systems audit results should present a clear, complete and accurate picture of the agency's acquisition of ambient air monitoring data.

The following topics are covered in the subsections below:

- a discussion of:
  1. the requirements on the agency operating the SLAMS network;
  2. program facets to be evaluated by the audit; and
  3. additional criteria to assist in determining the required extent of the forthcoming audit;
- a recommended audit protocol for use by the Regional audit team, followed by a detailed discussion of audit results reporting,
- criteria for the evaluation of State and local agency performance including suggested topics for discussion during the on-site interviews,
- a questionnaire, organized around the six key program areas to be evaluated, and
- a bibliography of APA guideline documents, which provides additional technical background for the different program areas under audit.

Section 15 of this Handbook provides a general description of the audit process which includes planning, implementation, and reporting and complements the material in this appendix. It is suggested that Section 15 should be read and understood. The guidance provided in this section is addressed primarily to EPA Regional audit leads and members of the Regional audit teams to guide them in developing and implementing an effective and nationally uniform audit program. However, the criteria presented can also prove useful to agencies under audit to provide them with descriptions of the program areas to be evaluated. Clarification of certain sections, special agency circumstances, and regulation or guideline changes may require additional discussion or information. For these reasons, a list of contact names and telephone numbers are provided on the AMTIC Bulletin Board *(http://www.epa.gov/ttn/amtic)*.

The authority to perform systems audits is derived from the Code of Federal Regulation (Title 40); specifically: 40 CFR Part 35, which discusses agency grants and grant conditions, and 40 CFR Part 58, which addresses installation, operation and quality assurance of the SLAMS/NAMS networks. The regulations contained in 40 CFR Part 35 mandate the performance of audits of agency air monitoring programs by the Regional Administrators or their designees.

The specific regulatory requirements of an EPA-acceptable quality assurance program are to be found in to 40 CFR Part 58 Appendix A and in the document titled *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations*[32] The elements described in the document provide the framework for organizing the required operational procedures, integrating quality assurance activities and documenting overall program operations.

2.0 Guidelines for Preliminary Assessment and Audit Systems Planning

In performing a systems audit of a given agency, the Regional audit lead is seeking a complete and accurate picture of that agency's current ambient air monitoring operations. Past experience has shown that four (4) person-days should be allowed for an agency operating 10-20 sites within close geographical proximity. The exact number of people and the time allotted to conduct the audit are dependent on the magnitude and complexity of the agency and on the EPA Regional Office resources. During the allotted time frame, the Regional QA audit team should perform those inspections and interviews recommended in the questionnaire. This includes on-site interviews with key program personnel, evaluations of some ambient air monitoring sites operated by the agency, and scrutiny of data processing procedures.

3.0 Frequency of Audits

The EPA Regional Office retains the regulatory responsibility to evaluate agency performance every three years. Regional Offices are urged to use the questionnaire that follows, the audit finding and response forms (Figs. 15.4 and 15.5), and the audit reporting format in Section 6.0 of this appendix. Utilizing the forms mentioned above will establish a uniform basis for audit reporting throughout the country.

The primary screening tools to aid the EPA Regional QA audit team are:

A. National Performance Audit Program (NPAP) Data--which provide detailed information on the ability of participants to certify transfer standards and/or calibrate monitoring instrumentation. Audit data summaries provide a relative performance ranking for each participating agency when compared to the other participants for a particular pollutant. These data could be used as a preliminary assessment of laboratory operations at the different local agencies.

B. Precision and Accuracy Reporting System (PARS) Data--which provide detailed information on precision and accuracy checks for each local agency and each pollutant, on a quarterly basis. These data summaries could be used to identify out-of-control conditions at different local agencies, for certain pollutants.

C. AIRS AP430 Data Summaries-- which provide a numerical count of monitors meeting and those not meeting specifications on monitoring data completeness on a quarterly basis, together with an associated summary of precision and accuracy probability limits. In addition the program will provide data summaries indicating the percent of data by site and/or by state for each pollutant.

4.0 Selection of Monitoring Sites for Evaluation

It is suggested that approximately five percent (5%) of the sites of each local agency included in the reporting organization be inspected during a systems audit. Many reporting organizations contain a large number of monitoring agencies, while in other cases, a monitoring agency is its own reporting organization. For smaller local agencies, no fewer than two (2) sites should be inspected. To insure that the selected sites represent a fair cross-section of agency operations, one half of the sites to be evaluated should be selected by the agency itself, while the other half should be selected by the Regional QA audit team.

The audit team should use both the Precision and Accuracy Reporting System (PARS) and the AIRS computer databases in deciding on specific sites to be evaluated. High flexibility exists in the outputs obtainable from the AIRS AP430 computer program; data completeness can be assessed by pollutant, site, agency, time period and season. These data summaries will assist the audit team in spotting potentially persistent operational problems in need of more complete on-site evaluation. At least one site showing poor data completeness, as defined by AIRS must be included in those selected to be evaluated.

If the reporting organization under audit operates many sites and/or its structure is complicated and perhaps inhomogeneous, then an additional number of sites above the initial 5% level should be inspected so that a fair and accurate picture of the state and local agency's ability to conduct field monitoring activities can be obtained. At the completion of the site evaluations, the audit team is expected to have established the adequacy of the operating procedures, the flow of data from the sites, and be able to provide conclusions about the adequacy of the environmental data operations of the reporting organization.

5.0 Data and Information Management Audits

With the implementation of automated data acquisition systems, the data management function has become increasingly complex. Therefore, a complete systems audit must include a review of the data processing and reporting procedures starting at the acquisition stage and terminating at the point of data entry into the AIRS computer system. The process of auditing the data processing trail will be dependent on size and organizational characteristics of the reporting organization, the volume of data processed, and the data acquisition system's characteristics. The details of performing a data processing audit are left, therefore, to Regional and reporting organization personnel working together to establish a data processing audit trail appropriate for a given agency.

Besides establishing and documenting processing trails, the data processing audits procedure must involve a certain amount of manual recomputation of raw data. The preliminary guidance provided here, for the number of data to be manually recalculated, should be considered a minimum, enabling only the detection of gross data mishandling:

(a) For continuous monitoring of criteria pollutants, the Regional audit lead should choose two 24-hour periods from the high and low seasons for that particular pollutant per local agency per year. In most cases the seasons of choice will be winter and summer. The pollutant and time interval choices are left to the discretion of the Regional audit lead.

(b) For manual monitoring, four 24-hour periods per local agency per year should be recomputed. The Regional audit lead should choose the periods for the data processing audit while planning the systems audit and inspecting the completeness records provided by the AIRS AP430 data. The recommended acceptance limits for the differences between the data input into AIRS and that recalculated during the

on-site phase of the systems audit, are given in Table 1. Systems audits conducted on large reporting organizations (e.g. four local agencies) require recomputation of eight 24-hour periods for each of the criteria pollutants monitored continuously. This results from two 24-hour periods being recomputed for each local agency, for each pollutant monitored, during a given year. For manual methods, sixteen 24-hour periods are recomputed, consisting of four periods per local agency, per year.

Table 1. Acceptance Criteria for Data Audits

Data Acquisition Mode	Pollutants	Measurement Range (ppm)[a]	Tolerance Limits
Automatic Data Retrieval	SO_2, O_3, NO_2 CO	0-0.5, or 0-1.0 0-20, or 0-50	± 3ppb ± 0.3ppm
Strip chart Records	SO_2, O_3, NO_2 CO	0-0.5, or 0-1.0 0-20, or 0-50	± 20 ppb ± 1ppm
Manual Reduction	TSP Pb	_____ _____	± 2 ug/m^3 [b] ± 0.1 ug/m^3

(a) Appropriate scaling should be used for higher measurement ranges.
(b) Specified at 760 mm Hg and 25° C.

6.0 Audit Reporting

The Systems Audit Report format discussed in this section has been prepared to be consistent with guidance offered by the STAPPA/ALAPCO Ad Hoc Air Monitoring Audit Committee. The format is considered as acceptable for annual systems audit reports submitted to the OAQPS. audit team members shall use this framework as a starting point and include additional material, comments, and information provided by the agency during the audit to present an accurate and complete picture of its operations and performance evaluation.

At a minimum, the systems audit report should include the following six sections:

1) Executive Summary--summarizes the overall performance of the agency's monitoring program. It should highlight problem areas needing additional attention and should describe any significant conclusions and/or broad recommendations.

2) Introduction--describes the purpose and scope of the audit and identifies the audit team members, key agency personnel, and other section or area leaders who were interviewed. It should also indicate the agency's facilities and monitoring sites which were visited and inspected, together with the dates and times of the on-site audit visit. Acknowledgment of the cooperation and assistance of the Director and the QAO should also be considered for inclusion.

3) Audit Results--presents sufficient technical detail to allow a complete understanding of the agency operations. The information obtained during the audit should be organized using the recommended subjects and the specific instructions given below.

A. Network Design and Siting

1. **Network Size**--Provide an overview of the network size and the number of local agencies responsible to the state for network operation.

2. **Network Design and Siting**--Describe any deficiencies in network design or probe siting discovered during the audit. Indicate what corrective actions are planned to correct deficiencies.
3. **Network Audit**--briefly discuss the conclusions of the last network annual audit and outline any planned network revision resulting from that audit.
4. **Non-criteria Pollutants**--Briefly discuss the agency's monitoring and quality assurance activities related to non-criteria pollutants.

B. Resources and Facilities

1. **Instruments and Methods**--Describe any instrument nonconformance with the requirements of 40 CFR 50, 51, 53, and 58. Briefly summarize agency needs for instrument replacement over and above nonconforming instruments.
2. **Staff and Facilities**--Comment on staff training, adequacy of facilities and availability of NIST-traceable standard materials and equipment necessary for the agency to properly conduct the bi-weekly precision checks and quarterly accuracy audits required under 40 CFR Part 58, Appendix A.
3. **Laboratory Facilities**--Discuss any deficiencies of laboratory procedures, staffing and facilities to conduct the tests and analyses needed to implement the SLAMS/NAMS monitoring and the quality assurance plans.

C. Data and Data Management

1. **Data Processing and Submittal**-- Comment on the adequacy of the agency's staff and facilities to process and submit air quality data as specified in 40 CFR 58.35 and the reporting requirements of 40 CFR 58, Appendices A and F. Include an indication of the timeliness of data submission by indicating the fraction of data which are submitted more than forty-five (45) days late.
2. **Data Review**--A brief discussion of the agency's performance in meeting the 75% criteria for data completeness. Additionally, discuss any remedial actions necessary to improve data reporting.
3. **Data Correction**--Discuss the adequacy and documentation of corrections and/or deletions made to preliminary ambient air data, and their consistency with both the agency's QA Manual and Standard Operating Procedures, and any revised protocols.
4. **Annual Report**--Comment on the completeness, adequacy and timeliness of submission of the SLAMS Annual Report which is required under 40 CFR 58.26.

D. Quality Assurance/Quality Control

1. **Status of Quality Assurance Plan**--Discuss the status of the Agency's Quality Assurance Plan. Include an indication of its approval status, the approval status of recent changes and a general discussion of the consistency, determined during the systems audit, between the Agency Standard Operating Procedures and the Quality Assurance Plan.
2. **Audit Participation**--Indicate frequency of participation in an audit program. Include as necessary, the agency's participation in the National Performance Audit Program (NPAP) as required by 40 CFR Part 58. Comment on audit results and any corrective actions taken.
3. **Accuracy and Precision**--As a goal, the 95% probability limits for precision (all pollutants) and TSP accuracy should be less than ± 15%. At 95% probability limits, the accuracy for all other pollutants should be less than ±20%. Using a short narrative and a summary table, compare the reporting organization's performance against these goals over the last two years. Explain any deviations.

4) Discussion--includes a narrative of the way in which the audit results above are being interpreted. It should clearly identify the derivation of audit results which affect both data quality and overall agency operations, and should outline the basis in regulations and guideline documents for the specific, mutually agreed upon, corrective action recommendations.

5) Conclusions and Recommendations--should center around the overall performance of the agency's monitoring program. Major problem areas should be highlighted. The salient facts of mutually agreed upon corrective action agreements should be included in this section. An equally important aspect to be considered in the conclusion is a determination of the homogeneity of the agency's reporting organizations and the appropriateness of pooling the Precision and Accuracy data within the reporting organizations.

6) Appendix of Supporting Documentation--contains a clean and legible copy of the completed questionnaire and any audit finding forms. Additional documentation may be included if it contributes significantly to a clearer understanding of audit results

7.0 Criteria For The Evaluation of State and Local Agency Performance

Table 2 is designed to assist the audit team in interpretation of the completed questionnaire received back from the agency prior to the on-site interviews. It also provides the necessary guidance for topics to be further developed during the on-site interviews.

The table is organized such that the specific topics to be covered and the appropriate technical guidance are keyed to the major subject areas of the questionnaire. The left-hand side of the page itemizes the discussion topics and the right-hand side provides citations to specific regulations and guideline documents which establish the technical background necessary for the evaluation of agency performance.

Table 2 Criteria For The Evaluation of State and Local Agency Performance

Topic	Background Documents
Planning ▸ General information on reporting organization and status of Air Program, QA Plan and availability of SOPs ▸ Conformance of network design with regulation, and completeness of network documentation ▸ Organization staffing and adequacy of educational background and training of key personnel ▸ Adequacy of current facilities and proposed modifications	▸ State Implementation Plan ▸ U.S. EPA QAMS 005/80 ▸ Previous Systems Audit report ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II--Ambient Air Specific Methods, Section 2.0.1. ▸ 40 CFR 58 Appendices D and E ▸ OAQPS Siting Documents (available by pollutant) ▸ QA Handbook for Air Pollution Measurement Systems, Vol. I--Principles, Section 1.4 Vol. II--Ambient Air Specific Methods, Section 2.0.5

Topic	Background Documents
Field Operations	
▸ Routine operational practices for SLAMS network, and conformance with regulations	▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Section 2.0.9 ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II ▸ 40 CFR 50 plus Appendices A through G (potentially K for PM 1 O)
▸ Types of analyzers and samplers used for SLAMS network	▸ 40 CFR 58 Appendix C--Requirements for SLAMS analyzers
▸ Adequacy of field procedures, standards used and field documentation employed for SLAMS network	▸ QA Handbook for Air Pollution Measurement Systems, Vol. II ▸ Instruction Manuals for Designated Analyzers ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II--Ambient Air Specific Methods Section 2.0.9
▸ Frequency of zero/span checks, calibrations and credibility of calibration equipment used	▸ QA Handbook for Air Pollution Measurement Systems, Vol. II--Ambient Air Specific Methods Section 2.0.7
▸ Traceability of monitoring and calibration standards	▸ 40 CFR 58 Appendix A Section 2.3
▸ Preventive maintenance system including spare parts, tools and service contracts for major equipment	▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Section 2.0.6
▸ Record keeping to include inspection of some site log books and chain-of-custody procedures ▸ Data acquisition and handling system establishing a data audit trail from the site to the central data processing facility	▸ QA Handbook for Air Pollution Measurement Systems, Vol. II--Ambient Air Specific Methods Sections 2.0.3 and 2.0.9
Laboratory Operations	
▸ Routine operational practices for manual methods used in SLAMS network to include quality of chemical and storage times	▸ 40 CFR 50 Appendices A and B, and QA Handbook, Vol. II
▸ List of analytical methods used for criteria pollutants and adherence to reference method protocols	▸ 40 CFR 58 Appendix C; "List of Designated Reference and Equivalent Methods"
▸ Additional analyses performed to satisfy regional, state or local requirements	▸ Refer to locally available protocols for analysis of aldehydes, sulfate, nitrate, pollens, hydrocarbons, or other toxic air contaminants.
▸ Laboratory quality control including the regular usage of duplicates, blanks, spikes and multi-point calibrations	▸ U.S. EPA APTD-1132 "Quality Control Practices in Processing Air Pollution Samples" ▸ 40 CFR 58 Appendix C; "List of Designated Reference and Equivalent Methods"
▸ Participation in EPA NPAP and method for inclusion of audit materials in analytical run	▸ 40 CFR 58 Appendix A Section 2.4 ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Section 2.0.10
▸ Documentation and traceability of laboratory measurements such as weighing, humidity and temperature determinations	▸ 40 CFR 58 Appendix C; "List of Designated Reference and Equivalent Methods"
▸ Preventive maintenance in the laboratory to include service contracts on major pieces of instrumentation	▸ 40 CFR 58 Appendix C; "List of Designated Reference and Equivalent Methods"
▸ Laboratory record keeping and chain-of-custody procedures to include inspection of logbooks used	▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Section 2.0.6
▸ Adequacy of Laboratory facilities, Health and Safety practices and disposal of wastes	▸ Handbook for Analytical Quality Control in Water and Wastewater Laboratories
▸ Data acquisition, handling and manipulations system establishing data flow in the laboratory, data back-up system and data reduction steps	▸ QA Handbook for Air Pollution Measurement Systems. Vol. II. Sections 2.0.3 and 2.0.9
▸ Data validation procedures, establishing an audit trail for the laboratory to the central data processing facility	▸ Annual Book of ASTM Standards, Part 41, 1 978. Standard Recommended Practice for Dealing with Outlying Observations (E 178-75)

Topic	Background Documents
Data Management ▸ Data flow from field and laboratory activities to a central data processing facility ▸ Extent of computerization of data management system and verification of media changes, transcriptions and manual data entry ▸ Software used for processing and its documentation; to include functional description of software, test cases and configuration control for subsequent revisions ▸ System back-up and recovery capabilities ▸ Data screening, flagging and validation ▸ Data correction procedures and key personnel allowed to correct ambient air data ▸ Reports generated for in-house distribution and for submittal to EPA ▸ Responsibility for preparing data for entry into the SAROAD and PARS systems and for responsibility for its final validation prior to submission	▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Section 2.0.3 ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Section 2.0.9 ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Sections 2.0.3 and 2.0.9 ▸ Validation of Air Monitoring Data, EPA-600/4-80-030 ▸ Screening Procedures for Ambient Air Quality Data, EPA450/2-78-037 ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Section 2.0.9 ▸ AQS Manual Series, Vol. II, AIRS User's Manual, EPA
QA/QC Program ▸ Status of QA Program and its implementation ▸ Documentation of audit procedures, integrity of audit devices and acceptance criteria for audit results ▸ Participation in the National Performance Audit Program for what pollutants and ranking of results ▸ Additional internal audits such as document reviews or data processing audits ▸ Procedure and implementation of corrective action ▸ Frequency of performance and concentration levels for precision checks for each criteria pollutant	▸ 40 CFR 58 Appendix A and QAMS 005/80 ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Sections 2.0.16 and 2.0.12 ▸ 40 CFR 58 Appendix A ▸ QA Handbook for Air Pollution Measurement Systems, Vol. II, Section 2.0.10 ▸ 40 CFR 58 Appendix A
Reporting ▸ Preparation of precision and accuracy summaries for the PARS system ▸ Other internal reports used to track performance and corrective action implementation ▸ Summary air data reports required by regulations ▸ Completeness, legibility and validity of P & A data on Form 1	▸ PARS User's Manual (in preparation) ▸ 40 CFR 58 Appendix A ▸ 40 CFR 58 Appendices F and G ▸ 40 CFR 58 Appendix A

Systems Audit Long Form Questionnaire

A. Network Management
   1. General
   2. Network Design and Siting
   3. Organization, Staffing and Training
   4. Facilities

B. Field Operations
   1. Routine Operations
   2. Quality Control
   3. Preventative Maintenance
   4 Record Keeping
   5. Data Acquisition and Handling

C. Laboratory Operations
   1. Routine Operations
   2. Quality Control
   3. Preventative Maintenance
   4 Record Keeping
   5. Data Acquisition and Handling
   6. Specific Pollutants
      PM-10 and PM 2.5
      Lead

D. Data and Data Management
   1. Data handling
   2. Software Documentation
   3. Data Validation and Correction
   4. Data Processing
   5. Internal Reporting
   6. External reporting

E. Quality Assurance/Quality Control
   1. Status of Quality Assurance Program
   2. Audits and Audits System Traceability
   3. National Performance Audit Program (NPAP) and Additional Audits
   4. Documentation and data Processing Review
   5. Corrective Action System
   7. Audit Result Acceptance Criteria

A. NETWORK MANAGEMENT

1. General

Questions	Yes	No	Comments
a) Is there an organization chart showing the agency's structure and its reporting organization (attach charts)?			
b) Basis for the current structure of the agency's reporting organization?			
Field operations for all local agencies, conducted by a common team of field operators?			
Common calibration facilities are used for all local agencies?			
Precision checks performed by common staff for all local agencies?			
Accuracy checks performed by common staff for all local agencies?			
Data handling follows uniform procedure for all local agencies?			
Traceability of all standards by one central support laboratory?			
One central analytical laboratory handles all analyses for manual methods?			
c) Does the agency feel that the data for the reporting organizations it contains can be pooled?			

d) Describe any changes which will be made within the agency's monitoring program the next calendar year

e) Complete the table below for each of the pollutants monitored as part of your air monitoring network

	SO_2	NO_2	CO	O_3	PM-10	PM-2.5	Pb
NAMS							
SLAMS							
SPM PAMS							
Total							

Question	Yes	No	Comment
f) What is the most current official SLAMS Network Description?			
I. Is it available for public inspection			
II Does it include the following for each site			
Monitor ID Code (AIRS Site ID#)			
Sampling and Analysis Method			
Operative Schedule			
Monitoring Objective and Scale of Representativeness			
Any Proposed Changes			

g) Modification since last audit Date of last audit: _____

	Number of Monitors		
Pollutant	Added	Deleted	Relocated
SO_2			
NO_2			
CO			
O_3			
PM-10			
PM-2.5			
Pb			

H) What changes to the Air Monitoring Network are planned for the next period (discuss equipment needs in section B.3.g)

Question	Yes	No	Comment
I) Does an overall SLAM/NAMS Monitoring Plan exist?			
j) Has the agency prepared and implemented standard operating procedures (SOPs) for all facets of agency operation?			
k) Do the SOPs adequately address ANSI/ASQC E-4.quality system required by 40 CFR App A			

l) Clearly identify by section number and /or document title, major changes made to documents since the last on-site review	
Title/Section #	**Pollutant(s) Affected**

Question	Yes	No	Comment
m) Does the agency have an implemented plan for operations during emergency episodes? Indicate latest revision, approval date and current location of this plan			Document Title Revision Date: Approved:
n) During episodes, are communications sufficient so that regulatory actions are based on real time data?			
o) Identify the section of the emergency episode plan where quality control procedures can be found.			

2. Network Design and Siting

a) Indicate by Site ID # any non-conformance with the requirements of 40 CFR 58, Appendices D and E		
Monitor	**Site ID**	**Reason for Non-Conformance**
SO_2		
O_3		
CO		
NO_2		
PM-10		
PM-2.5		
Pb		

b) Please provide the following information on your previous Network Review required by 40 CFR 58.20d.
Review performed on: Date
Performed by:
Location and title of review document:

Briefly discuss all problems uncovered by this review

Question	Yes	No	Comment
c) Have NAMS hard copy information reports been prepared and submitted for all monitoring sites within the network?			
d) Does each site have the required information including:			
AIRS Site ID Number?			
Photographs/slides to the four cardinal compass points?			
Startup and shutdown dates?			
Documentation of instrumentation?			
Reasons for periods of missing data?			
e) Who has custody of the current network documents			Name: Title:
f) Does the current level of monitoring effort, site placement, instrumentation, etc., meet requirements imposed by current grant conditions?			
g) How often is the network design and siting reviewed?			Frequency: Date of last review:

h) Provide a summary of the monitoring activities conducted as the SLAMS/NAMS network by the agency			
I. Monitoring is *seasonal* for (indicate pollutant and month of high and low concentrations).			
Pollutant	**High Concentrations**	**Low Concentrations**	**Collocated (Y/N)**

II Monitoring is *year-round* for (indicate pollutant)	
Pollutant	**Collocated (Y/N)**

Question	Yes	No	Comment
I) Does the number of collocated monitoring sites meet the requirements of 40 CFR 58 Appendix A?			
j) Does the agency monitor and/or analyze for non-criteria air and /or toxic air pollutants?			

If j is yes complete forms below

Pollutant	Monitoring Method/Instrument	SOP Available (Y/N)

3. Organization, Staffing and Training

a) Key Individuals

Agency Director:
Slams Network Manager:
Quality Assurance Officer:
Field Operations Supervisor:
Laboratory Supervisor:
Data Management Supervisor:
SLAMS Reporting Supervisor:

b) Number of personnel available to each of the following program areas		
Program Area	Number	Comment on need for additional personnel
Network Design and Siting		
Resources and Facilities		
Data and Data Management		
QA/QC		

Question	Yes	No	Comment
c) Does the agency have an established training program?			
I Where is it documented			
II Does it make use seminars, courses, EPA sponsored college level courses?			

III Indicate below the 3 most recent training events and identify the personnel participating in them.

Event	Dates	Participant(s)

4. Facilities

a) Identify the principal facilities where the work is performed which is related to the SLAMS/NAMS network. Do not include monitoring sites but do include any work which is performed by contract or other arrangements

Facility	Location	Main SLAMS/NAMS Function

b) Indicate any areas of facilities that should be upgraded. Identify by location

c) Are there any significant changes which are likely to be implemented to agency facilities before the next systems audit? Comment on your agency's needs for additional physical space (laboratory, office, storage, etc.)

Facility	Function	Proposed Change - Date

B: FIELD OPERATIONS

1. Routine Operations

Complete the table

Pollutant Monitored	Date of Last SOP Revision
SO_2	
NO_2	
CO	
O3	
PM-10	
PM-2.5	
Pb	

Question	Yes	No	Comment
a) Is the documentation of monitoring SOPs complete			
b) Are such procedures available to all field operations personnel			
c) Are SOPs prepared and available to field personnel which detail operations during episode monitoring?			

d) For what does each reporting organization within the agency monitor		
Reporting Organization	**# of Sites**	**Pollutants**

Question	Yes	No	Comment
e) On average, how often are most of your sites visited by a field operator?			_____ per _____
f)Is this visit frequency consistent for all reporting organizations within your agency.			If no, why:
g) On average, how many sites does a single site operator have responsibility for?			
h) How many of the sites of your SLAMS/NAMS network are equipped with manifolds(s)			
I Briefly describe most common manifold type			
II Are Manifolds cleaned periodically			How often?
III If the manifold is cleaned, what is used			
IV Are manifold(s) equipped with a blower			
V Is there sufficient air flow through the manifold at all times?			Approximate air flow:
VI Is there a conditioning period for the manifold after cleaning?			Length of time:
I)What material is used for instrument lines? 2) How often are lines changed?			
j) Has the agency obtained necessary waiver provisions to operate equipment which does not meet the effective reference and equivalency requirements?			

k) Please complete the table below to indicate which analyzers do not conform with the requirements of 40 CFR 53 for NAMS, SLAMS, or SIP related SPM's

Pollutant	Number	Make/Model	Site ID	Comments on Variances
SO_2				
NO_2				
CO				
O_3				
PM-10				
PM-2.5				
Pb				

Please comment briefly and prioritize your currently identified instrument needs

2 Quality Control

a) Please indicate the frequency of multi point calibrations		
Reporting Organization	**Pollutant**	**Frequency**

Question	Yes	No	Comment
b) Are field calibration procedures included in the document SOPs			Location (site, lab etc.):
c) Are calibrations performed in keeping with the guidance in section Vol II of the QA Handbook for Air Pollution Measurement Systems?			If no, why?
d) Are calibration procedures consistent with the operational; requirements of Appendices to 40 CFR 50 or to analyzer operation/instruction manuals.			If no, why?
e) Have changes been made to calibration methods based on manufacturer's suggestions for a particular instrument			
f) Do standard materials used for calibrations meet the requirements of appendices to 40 CFR 50 (EPA reference methods) and Appendix A tp 40 CFR (traceability of materialsto NIST-SRMs or CRMs)?			Comment on deviations
g) Are all flow-measurement devices checked and certified ?			

h) Please list the authoritative standards used for each type of flow measurement, indicate the frequency of calibration standards to maintain field material/device credibility		
Flow Device	**Primary Standard**	**Frequency of Calibration**

Question	Yes	No	Comment
I) Where do filed operations personnel obtain gaseous standards?			
Are those standards certified by:			
The agency laboratory			
EPA/NERL standards laboratory			
A laboratory separate from this agency's but part of the same reporting organization?			
The vendor			
NIST			
j) Does the documentation include expiration data of certification?			
Reference to primary standard used			
What traceability is used?			
Please attach example of recent documentation of traceability			
k) Is calibration equipment maintained at each site?			For what pollutants
l) How is the functional integrity of this equipment documented			

m) Please complete table below for your agency's site standards (up to 7% of the sites, not to exceed 20 sites)

Parameter	Primary Standard	Secondary Standard	Recertification Date
CO			
NO_2			
SO_2			
O_3			

Please complete the table below for Continuous Analyzers		
Pollutant	Span Conc.	Frequency

PM 10 Analyzers	
Flow Rate	Frequency
$PM_{2.5}$ Analyzers	

Question	Yes	No	Comment
n) Are level 1 zero and span (z/s) calibrations (or calibration checks made for all continuous monitoring equipment and flow checks made for PM 10 and PM2.5 samplers			
o) Does the agency have acceptance criteria for zero/span checks			
I. Are these criteria known to the field operations personnel?			
II. Are they documented in standard operating procedures?			If not indicate document and section where they can be found?
III. Do the documents discussed in (II) above indicate when zero/span adjustments should and should not be made?			Indicate an example
IV. Are zero and span check control charts maintained?			

Question	Yes	No	Comment
p) In keeping with 40 CFR 58 regulations, are any necessary zero and span adjustments made after precision checks?			If no, why not?
(q) Are precision check control charts maintained?			
(r) Who has the responsibility for performing zero/span checks?			
(s) Are precision checks routinely performed within concentration ranges and with a frequency which meets or exceeds the requirements of 40 CFR 58, Appendix A?			Please comment on any discrepancies

(t) Please identify person(s) with the responsibility for performance of precision checks on continuous analyzers.

Person(s)_____

Title_____

3. Preventive Maintenance

a) Has the field operator been given any special training in performing preventive maintenance? Briefly comment on background and/or courses

b) Is this training routinely reinforced? Yes ___ No___
If no, why not?

c) If preventive maintenance is MINOR, it is performed at (check one or more): field site ___, Headquarters facilities___, equipment is sent to manufacturer_____

d) If preventive maintenance is MAJOR, it is performed at (check one or more): field site___, Headquarters facilities___,equipment is sent to manufacturer____

e) Does the agency have service contracts or agreements in place with instrument manufacturers? Indicate below or attach additional pages to show which instrumentation is covered.

f) Comment briefly on the adequacy and availability of the supply of spare parts, tools and manuals available to the field operator to perform any necessary maintenance activities. Do you feel that this is adequate to prevent any significant data loss?

g) Is the agency currently experiencing any recurring problem with equipment or manufacturer(s)? If so, please identify the equipment and/or manufacturer, and comment on steps taken to remedy the problem.

4. Record Keeping

Question	Yes	No	Comment
a) Is a log book(s) maintained at each site to document site visits, preventive maintenance and resolution of site operational problems and corrective actions taken?			Other uses?
b) Is the logbook maintained currently and reviewed periodically?			Frequency of Review
(c) Once entries are made and all pages filled, is the logbook sent to the laboratory for archiving?			If no, is it stored at other location(s) (specify)
(d) What other records are used?			
Zero/span record?			
Gas usage log?			
Maintenance log?			
Log of precision checks?			
Control charts?			
A record of audits?			
Please describe the use and storage of these documents.			
(e) Are calibration records or at least calibration constants available to field operators?			
Please attach an example field calibration record sheet to this questionnaire			

5. Data Acquisition and Handling

(a) With the exception of PM 10, are instrument outputs (that is data) recorded to (a) stripcharts, (b) magnetic tape acquisition system, (c) digitized and telemetered directly to agency headquarters? Please complete the table below for each of the reporting organizations, or agencies within the overall R.O.

Reporting Organization	Pollutants	Data Acquisition Media (a, b, c or combination)

Question	Yes	No	Comment
b) Is there stripchart backup for all continuous analyzers?			
(c) Where is the flow of high-volume samplers recorded at the site?			
For samplers with flow controllers?			Log sheet___, Dixon chart___, Other___ (specify)
On High-volume samplers without flow controllers?			Log sheet____, Dixon chart___, Other _____ (specify)

d) What kind of recovery capabilities for data acquisition equipment are available to the field operator after power outages, storms, etc? Briefly describe below.

(e) Using a summary flow diagram, indicate below all data handling steps performed at the air monitoring site. Identify the format, frequency and contents of data submittals to the data processing section. Clearly indicate points at which flow path differs for different criteria pollutants. Be sure to include all calibration, zero/span and precision check data flow paths. How is the integrity of the data handling system verified?

C. LABORATORY OPERATIONS

1. Routine Operations

(a) What analytical methods are employed in support of your air monitoring network?

Analysis	Methods
PM-10	
Pb	
PM 2.5	
SO_4	
NO_3	
Others (list by pollutant)	

Question	Yes	No	Comment
b) Are bubblers used for any criteria pollutants in any agencies?			If yes, attach a table which indicates the number of sites where bubblers are used, the agency and pollutant(s).
(c) Do any laboratory procedures deviate from the reference, equivalent, or approved methods?			If yes, are the deviations for lead analysis _____, PM-10 filter conditioning____ or other _____ (specify below)?
(d) Have the procedures and/or any changes been approved by EPA?			Date of Approval
(e) Is the documentation of Laboratory SOP complete?			

Complete the table below.

Analysis	Method
PM-10	
Pb	
SO_4	
NO_3	
PM 2.5	
Others (list by pollutant)	

(f) Is sufficient instrumentation available to conduct your laboratory analyses? Yes___ No___ If no, please indicate instrumentation needs

Instrument Needed	Analysis	New or Replacement	Year of Acquisition

2. Quality Control

a) Please complete the table for your agency's laboratory standards.

Parameter	Primary Standard	Secondary Standard	Recertification Date
CO			
NO2			
SO2			
O3			
Weights			
Temperature			
Moisture			
Barometric Pressure			
Flow			
Lead			
Sulfate			
Nitrate			

Question	Yes	No	Comment
b) Are all chemicals and solutions clearly marked with an indication of shelf life?			
c) Are chemicals removed and properly disposed of when shelf life expires?			
d) Are only ACS chemicals used by the laboratory?			

e) Comment on the traceability of chemicals used in the preparation of calibration standards.

Question	Yes	No	Comment
f) Does the laboratory Purchase standard solutions such as those for use with lead or other AA analysis?			
__ Make the solutions themselves?			
If the laboratory staff routinely make their own standard solutions, are procedures for such available?			Attach an example.
g) Are all calibration procedures documented?			Where?_____ (title) _____ (revision)
Unless fully documented, attach a brief description of a calibration procedure.			
(h) Are at least one duplicate, one blank, and one standard or spike included with a given analytical batch?			Identify analyses for which this is routine operation

Ii) Briefly describe the laboratory's use of data derived from blank analyses.

Question	Yes	No	Comment
Do criteria exist which determine acceptable/non-acceptable blank data?			

Please complete the table below.

Pollutant	Blank Acceptance Criteria
SO2	
NO2	
SO4	
NO3	
Pb	
$PM_{2.5}$	

j) How frequently and at what concentration ranges does the lab perform duplicate analysis? What constitutes acceptable agreement? Please complete the table below

Pollutant	Frequency	Acceptance Criteria
SO2		
NO2		
SO4		
NO3		
Pb		
PM-10		

(k) How does the lab use data from spiked samples? Please indicate what may be considered acceptable percentage recovery by analysis? Please complete the table below

Pollutant	% Recovery Acceptance Criteria

Question	Yes	No	Comment
(l) Does the laboratory routinely include samples of reference material obtained from EPA within an analytical batch			If yes, indicate frequency, level, and material used.
(m) Are mid-range standards included in analytical batches?			
If yes, are such standards included as a QC check (span check) on analytical stability?			

Please indicate the frequency, level and compound used in the space provided below

(n) Do criteria exist for "real time quality control based on the results obtained for the mid-range standards discussed above?			

Question	Yes	No	Comment
If yes, briefly discuss them below or indicate the document in which they can be found.			
(o) Are appropriate acceptance criteria documented for each type of analysis conducted?			
Are they known to at least the analysts working with respective instruments?			

3. Preventive Maintenance

Question	Yes	No	Comment
(a) For laboratory equipment, who has responsibility for major and/or minor preventive maintenance? Person_____ Title_____			
(b) Is most maintenance performed: in the lab?			
in the instrument repair facility?			
at the manufacturer's facility?			
(c) Is a maintenance log maintained for each major laboratory instrument?			Comment
(d) Are service contracts in place for the following analytical instruments			
Analytical Balance			
Atomic Absorption Spectrometer			
Ion Chromatograph			
Automated Colorimeter			

4. Record Keeping

Question	Yes	No	Comment
(a) Are all samples that are received by the laboratory logged in?			
assigned a unique laboratory sample number?			
routed to the appropriate analytical section?			
Discuss sample routing and special needs for analysis (or attach a copy of the latest SOP which covers this). Attach a flow chart if possible			
(b) Are logbooks kept for all analytical laboratory instruments?			

Question	Yes	No	Comment
(c) Do these logbooks indicate:			
analytical batches processed?			
quality control data?			
calibration data?			
results of blanks, spikes and duplicates?			
initials of analyst?			
(d) Is there a logbook which indicates the checks made on: weights			
humidity indicators?			
balances?			
thermometer(s)?			
(e) Are logbooks maintained to track the preparation of filters for the field?			
Are they current?			
Do they indicate proper use of conditioning?			
Weighings?			
Stamping and numbering?			
(f) Are logbooks kept which track filters returning from the field for analysis?			
(g) How are data records from the laboratory archived? Where? Who has the responsibility? Person Title How long are records kept? Years			
(h) Does a chain-of-custody procedure exist for laboratory samples?			If yes, indicate date, title and revision number where it can be found.

5. Data Acquisition and Handling

Question	Yes	No	Comment
(a) Identify those laboratory instruments which make use of computer interfaces directly to record data. Which ones use stripcharts? integrators?			
(b) Are QC data readily available to the analyst during a given analytical run?			
(c) For those instruments which are computer interfaced, indicate which are backed up by stripcharts?			
(d) What is the laboratory's capability with regard to data recovery? In case of problems, can they recapture data or are they dependent on computer operations? Discuss briefly.			
(e) Has a users manual been prepared for the automated data acquisition instrumentation?			Comment
Is it in the analyst's or user's possession?			
Is it current?			
(f) Please provide below a data flow diagram which establishes, by a short summary flow chart: transcriptions, validations, and reporting format changes the data goes through before being released to the data management group. Attach additional pages as necessary.			

6. Specific Pollutants: PM-10 and PM 2.5 and Lead

Question	Yes	No	Comment
PM10 and PM 2.5			
(a) Are filters supplied by EPA used at SLAMS sites?			
(b) Do filters meet the specifications in the Federal Register 40 CFR 50?			
(c) Are filters visually inspected via strong light from a view box for pinholes and other imperfections?			If no, comment on way imperfections are determined?
(d) Are filters permanently marked with a serial number?			Indicate when and how this is accomplished
(e) Are unexposed filters equilibrated in controlled conditioning environment which meets or exceeds the requirements of 40 CFR 50?			If no, why not?
(f) Is the conditioning environment monitored?			Indicate frequency
Are the monitors properly calibrated			Indicate frequency
(g) Is the balance checked with Class "S" weights each day it is used?			If no, indicate frequency of such checks
(h) Is the balance check information placed in QC logbook?			If no, where is it recorded?
(i) Is the filter weighed to the nearest milligram?			If not, what mass increment
(j) Are filter serial numbers and tare weights permanently recorded in a bound notebook?			If no, indicate where
(k) Are filters packaged for protection while transporting to and from the monitoring sites?			
(l) How often are filter samples collected? (Indicate average lapse time (hrs.) between end of sampling and laboratory receipt.)			
(m) Are field measurements recorded in logbook or on filter folder?			
(n) Are exposed filters reconditioned for at least 24 hrs in the same conditioning environment as for unexposed filters?			If no, why not?
(o) Are exposed filters removed from folders, etc., before conditioning?			
(p) Is the exposed filter weighed to the nearest milligram?			
(q) Are exposed filters archived			When? Where? Indicate retention period

Question	Yes	No	Comment
(r) Are blank filters reweighed?			If no, explain why not. If yes, how frequently?
(s) Are analyses performed on filters?			Indicate analyses other than Pb and mass which are routinely performed.
(t) Are sample weights and collection data recorded in a bound laboratory logbook?			
On data forms?			
(u) Are measured air volumes corrected to reference conditions as given in CFR regulations (Q_{std} of 760 mm Hg and 25 C) prior to calculating the Pb concentration?			If not, indicate conditions routinely employed for both internal and external reporting
LEAD			
(a) Is analysis for lead being conducted using atomic absorption spectrometry with air acetylene flame?			If not, has the agency received an equivalency designation of their procedure?
(b) Is either the hot acid or ultrasonic extraction procedure being followed precisely?			Which?
(c) Is Class A borosilicate glassware used throughout the analysis?			
(d) Is all glassware scrupulously cleaned with detergent, soaked and rinsed three times with distilled-deionized water?			If not, briefly describe or attach procedure.
(e) If extracted samples are stored, are linear polyethylene bottles used?			
(f) Are all batches of glass fiber filters tested for background lead content?			
At a rate of 20 to 30 random filters per batch of 500 or greater?			Indicate rate
(g) Are ACS reagent grade HNO_3 and HCI used in the analysis			If not, indicate grade used
(h) Is a calibration curve available having concentrations that cover the linear absorption range of the atomic absorption instrumentation?			
(I) Is the stability of the calibration curve checked by alternately remeasuring every 10th sample a concentration 1 g Pb/ml; 10 g Pb/ml?			If not, indicate frequency.
(j) Are measured air volumes corrected to reference conditions as given in CFR regulations (Q_{std} of 760 mm Hg and 25 C) prior to calculating the Pb concentration?			If not, indicate conditions routinely employed for both internal and external reporting.
(k) In either the hot or ultrasonic extraction procedure, is there always a 30-min H_2O soaking period to allow HNO_3 trapped in the filter to diffuse into the rinse water?			

Question	Yes	No	Comment
(l) Is a quality control program in effect that includes periodic quantification of (1) lead in 3/4" x 8" glass fiber filter strips containing 100-300 g Pb/strip, and/or (2) a similar strip with 600-1000 g strip, and (3) blank filter strips with zero Pb content to determine if the method, as being used, has any bias?			Comment on lead QC program or attach applicable SOP
(m) Are blank Pb values subtracted from Pb samples assayed?			If not, explain why

D: DATA AND DATA MANAGEMENT

1. Data Handling

Question	Yes	No	Comment
(a) Is there a procedure, description, or a chart which shows a complete data sequence from point of acquisition to point of submission of data to EPA?			

Please provide below a data flow diagram indicating both the data flow within the reporting organization and the data received from the various local agencies.

(b) Are data handling and data reduction procedures documented?			
For data from continuous analyzers?			
For data from non-continuous methods?			

(c) In what format and medium are data submitted to data processing section? Please provide separate entry for each reporting organization.

Reporting Organization	Data Medium	Format

Question	Yes	No	Comment
(d) How often are data received at the processing center from the field sites and laboratory? at least once a week?____ every 1- 2 weeks?____ once a month?____			
(e) Is there documentation accompanying the data regarding any media changes, transcriptions, and/or flags which have been placed into the data before data are released to agency internal data processing? Describe.			
(f) How are the data actually entered to the computer system? Digitization of stripcharts? Manual or computerized transcriptions? Other?			
(g) Is a double-key entry system used for data at the processing center?			
duplicate card decks prepared			If no, why not?
(h) Have special data handling procedures been adopted for air pollution episodes?			If yes, provide brief description

2. Software Documentation

Question	Yes	No	Comment
(a) Does the agency have available a copy of the AIRS Manual?			
(b) Does the agency have the PARS user's guide available?			
c) Does the Data Management Section have complete software documentation?			If yes, indicate the implementation date and latest revision dates for such documentation.
(d) Do the documentation standards follow the guidance offered by the EPA Software Documentation Protocols?			If no, what protocols are they based on?
e) What is the origin of the software used to process air monitoring data prior to its release into the SAROAD/NADB database?			
I. Purchased?			Supplier Date of latest version
II. Written in-house?			Latest version Date
III. Purchased with modifications in-house?			Latest version Date
(f) Is a user s manual available to data management personnel for all software currently in use at the agency for processing SLAMS/NAMS data?			

Question	Yes	No	Comment
(g) Is there a functional description either: included in the user' s manual?			
separate from it and available to the users?			
(h) Are the computer system contents, including ambient air monitoring data backed up regularly?			Briefly describe, indicating at least the media, frequency, and backup-media storage location
(I) What is the recovery capability (how much time and data would be lost) in the event of a significant computer problem?			
(j) Are test data available to evaluate the integrity of the software?			
Is it properly documented?			

3. Data Validation and Correction

Question	Yes	No	Comment
(a) Have validation criteria, applicable to all pollutant data processed by the reporting organization been established and documented?			If yes, indicate document where such criteria can be found (title, revision date).
(b) Does documentation exist on the identification and applicability of flags (i.e., identification of suspect values) within the data as recorded with the data in the computer files?			
(c) Do documented data validation criteria employ address limits on and for the following:			
I. Operational parameters, such as flow rate measurements or flow rate changes			
II. Calibration raw data, calibration validation and calibration equipment tests.			
III. All special checks unique to a measurement system			
IV. Tests for outliers in routine data as part of screening process			
V. Manual checks such as hand calculation of concentrations and their comparison with computer-calculated data			
(d) Are changes to data submitted to NADB documented in a permanent file?			If no, why not?

Question	Yes	No	Comment
(e) Are changes performed according to a documented Standard Operating Procedure or your Agency Quality Assurance Project Plan?			If not according to the QA Project Plan, please attach a copy of your current Standard Operating Procedure
(f) Who has signature authority for approving corrections? (Name) (Program Function)			
(g) Are data validation summaries prepared at each critical point in the measurement process or information flow and forwarded with the applicable block of data to the next level of validation?			Please indicate the points where such summaries are performed.
(h) What criteria are applied for data to be deleted? Discuss briefly.			
(I) What criteria are applied to cause data to be reprocessed ? Discuss.			
(j) Is the group supplying data provided an opportunity to review data and correct erroneous entries?			If yes, how?
(k) Are corrected data resubmitted to the issuing group for cross-checking prior to release?			

4. Data Processing

Question	Yes	No	Comment
(a) Does the agency generate data summary reports?			
Are the data used for in-house distribution and use?			
Publication ?			Other (specify)

(b) Please list at least three (3) reports routinely generated, providing the information requested below

Report Title	Distribution	Period Covered

Question	Yes	No	Comment
(c) Have special procedures been instituted for pollution index reporting?			If yes, provide brief description.
(d) Who at the agency has the responsibility for submitting data to AIRS? Name Title			
Is the data reviewed and approved by an officer of the agency prior to submittal?			
(e) Are those persons different from the individuals who submit data to PARS?			
If yes, provide name and title of individual responsible for PARS data submittal. Name Title PARS data review and approval (name)			
(f) How often are data submitted to: AIRS ? PARS?			
(g) How and/or in what form are data submitted? TO AIRS? TO PARS?			
(h) Are the recommendations and requirements for data coding and submittal, in the AIRS User's Manual?			Comment on any routine deviations in coding procedures.
(f) Are the recommendations and requirements for data coding and submittal, in the PARS User's Guide, followed closely?			Comment on any routine deviations in coding and/or computational procedures.
(j) Does the agency routinely request a hard copy printout on submitted data:			
from AIRS?			
from PARS?			
(k) Are records kept for at least 3 years by the agency in an orderly, accessible form?			If yes, does this include raw data__, calculation__, QC data__, and reports__? If no, please comment.
(l) In what format are data received at the data processing center? (Specify appropriate pollutant.) (a) concentration units ___ (b) % chart___ (c) voltages____ (d) other_____			

Question	Yes	No	Comment
(m) Do field data include the following documentation?			
Site ID?			
Pollutant type?			
Date received at the center?			
Collection data (flow, time date)?			
Date of Laboratory Analysis /if applicable)			
Operator/Analyst?			
(n) Are the appropriate calibration equations submitted with the data to the processing center?			If not, explain.
(o) Provide a brief description of the procedures and appropriate formulae used to convert field data to concentrations prior to input into the data bank.			
SO_2			
NO_2			
CO			
O_3			
PM 2.5			
CH_4THC			
Pb			
PM 10			
(p) Are all concentrations corrected to EPA standard (298 K, 760 mm Hg) temperature and pressure condition before input to the AIRS?			If no, specify conditions used
(q) Are data reduction audits performed on a routine basis?			If yes, at what frequency?
are they done by an independent group?			
(r) Are there special procedures available for handling and processing precision, accuracy, calibrations and span checks?			If no, comment
If yes, provide a brief description: Span checks Calibration data Precision data Accuracy data			

Question	Yes	No	Comment
(s) Are precision and accuracy data checked each time they are recorded, calculated or transcribed to ensure that incorrect values are not submitted to EPA?			Please comment and/or provide a brief description of checks performed
(t) Is a final data processing check performed prior to submission of any data?			If yes, document procedure briefly If no, explain

5. Internal Reporting

(a) What reports are prepared and submitted as a result of the audits required under 40 CFR Appendix A?	
Report Title	Frequency
(Please include an example audit report and, by attaching a coversheet, identify the distribution such reports are given within the agency.)	

b) What internal reports are prepared and submitted as a result of precision checks also required under 40 CFR 58 Appendix A?	
Report Title	Frequency
(Please include an example of a precision check report and, identify the distribution such reports receive within the agency.)	

Question	Yes	No	Comment
(c) Do either the audit or precision reports indicated include a discussion of corrective actions initiated based on audit or precision results?			If yes, identify report(s) and section numbers
(d) Does the agency prepare Precision and Accuracy summaries other than Form 1?			If no, please attach examples of recent summaries including a recent Form 1.

(e) Who has the responsibility for the calculation and preparation of data summaries? To whom are such P and A summaries delivered?			
Name	Title	Type of Report	Recipient

(f) Identify the individual within the agency who receives the results of the agency's participation in the NPAP and the internal distribution of the results once received.	
Principal Contact for NPAP is (name, title)	
Distribution	

6. External Reporting

(a) For the current calendar year or portion thereof which ended at least 90 calendar days prior to the receipt of this questionnaire, please provide the following percentages for required data submitted

%Submitted on Time*							
Monitoring Qtr.	**SO_2**	**CO**	**O_3**	**NO_2**	**PM2.5**	**PM-10**	**Pb**
1 (Jan 1-March 31)							
2 (Apr 1- June 30)							
3 (July 1-Sept. 30)							
4 (Oct.1-Dec. 31)							

*"On-Time" = within 90 calendar days after the end of the quarter in which the data were collected.

(b) Identify the individual within the agency with the responsibility for preparing the required 40 CFR 58 Appendix F and G reporting inputs.

Name Title

(c) Identify the individual within the agency with the responsibility for reviewing and releasing the data.

Name Title

(d) Does the agency regularly report the Pollutant Standard Index (PSI)? Briefly describe the media, coverage, and frequency of such reporting.

(e) What fraction of the SLAMS sites (by pollutant) reported less than 75% of the data (adjusted for seasonal monitoring and site start-ups and terminations)?

Percent of Sites <75% Data Recovery FY____

Pollutant	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Ozone				
Nitrogen Dioxide				
Sulfur Dioxide				
Carbon Monoxide				

PM-10				
PM2.5				
Lead				

Question	Yes	No	Comment
(f) Does the agency's annual report (as required in 40 CFR 58.26) include the following?			
Data summary required in Appendix F			
Annual precision and accuracy information described in Section 5.2 of Appendix A.			
Location, date, pollution source and duration of all episodes reaching the significant harm levels.			
Certification by a senior officer in the State or his designee.			
(g) Please provide the dates at which the annual reports have been submitted for the last 2 years.			

E. QUALITY ASSURANCE/QUALITY CONTROL

1. Status of Quality Assurance Program

Question	Yes	No	Comment
(a) Does the agency have an EPA-approved quality assurance program plan?			
If yes, have changes to the plan been approved by the EPA?			
Please provide: Date of Original Approval	Date of Last Revision		Date of Latest Approval
b) Do you have any revisions to your QA Program Plan still pending?			
(c) Is the QA Plan fully implemented?			
(d) Are copies of QA Plan or pertinent sections available to agency personnel?			If no, why not?
(e) Which individuals routinely receive updates to QA Plan?			

2. Audits and Audit System Traceability

Question	Yes	No	Comment
(a) Does the agency maintain a separate audit/calibration support facility laboratory?			
(b) Has the agency documented and implemented specific audit procedures?			
(c) Have audit procedures been prepared in keeping with the requirements of Appendix A to 40 CFR 58?			
(d) Do the procedures meet the specific requirements for independent standards and the suggestions regarding personnel and equipment?			
(e) Are SRM or CRM materials used to routinely certify audit materials?			
(f) Does the agency routinely use NIST-SRM or CPM materials?			For audits only?__ For calibrations only?__ For both?__ For neither, secondary standards are employed__
(g) Does the agency audit the Meteorological sites?			

(g) Please list below areas routinely covered by this review, the date of the last review, and changes made as a direct result of the review.

Pollutants	Audit Method	Audit Standard
CO		
O_3		
NO_2		
SO_2		
PM-10		
PM 2.5		

Question	Yes	No	Comment
(h) Are SRM or CRM materials used to establish traceability of calibration and zero/span check materials provided to field operations personnel?			
(I) Specifically for gaseous standards, how is the traceability of audit system standard materials established?			
Are they: purchased certified by the vendor?			
certified by the QA support laboratory which is part of this agency?			
(j) Are all agency traceability and standardization methods used documented?			Indicate document where such methods can be found.
(k) Do the traceability and standardization methods conform with the guidance of VOL. II of the Handbook for Air Pollution Measurement Systems?			
For permeation devices?			
For cylinder gases?			
(l) Does the agency have identifiable auditing equipment (specifically intended for sole use) for audits?			If yes, provide specific identification
(m) How often is auditing equipment certified for accuracy against standards and equipment of higher authority?			

(n) As a result of the audit equipment checks performed, have pass/fail (acceptance criteria) been decided for this equipment? Indicate what these criteria are with respect to each pollutant. Where are such criteria documented?

Pollutant	Criteria

3. National Performance Audit Program (NPAP) And Additional Audits

(a) Identify the individual with primary responsibility for the required participation in the National Performance Audit Program.

For gaseous materials? (name, title)

For laboratory materials? (name, title)

Question	Yes	No	Comment
(b) Does the agency currently have in place any contracts or similar agreements either with another agency or outside contractor to perform any of the audits required by 40 CFR 58?			
If yes, has the agency included QA requirements with this agreement?			
Is the agency adequately familiar with their QA program?			
(c) Date last systems audit was conducted	Date:	By Whom:	

(d) Please complete the table below	
Parameter Audited	**Date of Last NPAP**
SO_2	
CO	
Pb	
PM-10	
O_3	
NO_2	

Question	Yes	No	Comment
(e) Does the agency participate in the National Performance Audit Program (NPAP) as required under 40 CFR 58 Appendix A?			If no, why not? Summarize below.

4. Documentation and Data Processing Review

Question	Yes	No	Comment
(a) Does the agency periodically review its record-keeping activities?			

Please list below areas routinely covered by this review, the date of the last review, and changes made as a direct result of the review.

Area/Function	Date of Review	Changes? (Y/N)	Discuss Changes

Question	Yes	No	Comment
(b) Are data audits (specific re-reductions of strip charts or similar activities routinely performed for criteria pollutants data eported by the agency?			If no, please explain.
(c) Are procedures for such data audits documented?			
(d) Are they consistent with the recommendations of Sections 16.4.2.3 of Vol. II of the QA Handbook for Air Pollution Measurement Systems?			If no, why not?

(e) What is the frequency and level (as a percentage of data processed of these audits?

Pollutant	Audit Frequency	Period of Data Audited	% of Data Rechecked

(f) Identify the criteria for acceptable/non-acceptable result from a data processing audit for each pollutant, as appropriate

Pollutant	Acceptance Criteria	Data Concentration Level

Question	Yes	No	Comment
(g) Are procedures documented and implemented for corrective actions based on results of data audits which fall outside the established limits?			If yes, where are such corrective action procedures documented?

5. Corrective Action System

Question	Yes	No	Comment
(a) Does the agency have a comprehensive Corrective Action program in place and operational?			
b) Have the procedures been documented?			
As a part of the agency QA Plan?			
As a separate Standard Operating Procedure?			Briefly describe it or attach a copy
(c) How is responsibility for implementing corrective actions on the basis of audits, calibration problems, zero/span checks, etc assigned? Briefly discuss.			
(d) How does the agency follow up on implemented corrective actions?			
(e) Briefly describe two (2) recent examples of the ways ;n which the above corrective action system was employed to remove a problem area with I. Audit Results: Il. Data Management:			

6. Audit Result Acceptance Criteria

Question	Yes	No	Comment
(a) Has the agency established and has it documented criteria to define agency-acceptable audit results?			

Please complete the table below with the pollutant, monitor and acceptance criteria.	
Pollutant	**Audit Result Acceptance Criteria**
CO	
O_3	
NO_2	
SO_2	
PM-10.	
PM2.5	

Question	Yes	No	Comment
(b) Were these audit criteria based on, or derived from, the guidance found in Vol./. II of the QA Handbook for Air Pollution Measurement System, Section 2.0.12?			If no, please explain. If yes, please explain any changes or assumptions made in the derivation.

(c) What corrective action may be taken if criteria are exceeded? If possible, indicate two examples of corrective actions taken within the period since the previous systems audit which are based directly on the criteria discussed above.

Corrective Action # 1

Corrective Action #2

(d) As a goal, the 95 percent probability limits for precision (all pollutants) and PM-10 accuracy should be less than + 15 percent. At 95 percent probability limits, the accuracy for all other pollutants should be less than +20 percent. Using a short narrative and a summary table, compare the reporting organizations performance against these goals over the last year. Explain any deviations.

NOTE: Precision and accuracy are based on reporting organizations; therefore this question concerns the reporting organizations that are the responsibility of the agency. Complete the tables below indicating the number of reporting organizations meeting the goal stated above for each pollutant by quarter

I. Precision Goals (Report level 2 checks unless otherwise directed by Regional Office.)					
Pollutant	**# of Reporting Organization**	**Qtr/Yr**	**Qtr/Yr**	**Qtr/Yr**	**Qtr/Yr**
CO					
O_3					
NO_2					
SO_2					
PM-10.					
PM2.5					
Pb					

I. Accuracy Goals (Report level 2 checks unless otherwise directed by Regional Office.)					
Pollutant	**# of Reporting Organization**	**Qtr/Yr**	**Qtr/Yr**	**Qtr/Yr**	**Qtr/Yr**
CO					
O_3					
NO_2					
SO_2					
PM-10.					
PM2.5					
Pb					

(e) To the extent possible, describe problems preventing the meeting of precision and accuracy goals.

Section 3
State and Local Audit Procedures

40 CFR 58, Appendix A[1] outlines the minimum quality assurance requirements for state and local air monitoring stations (SLAMS). All subsequent revisions to Appendix A have been included in the preparation of this document[2]. Quality assurance guidelines for PSD monitoring are found in 40 CFR 58, Appendix B[3].

This section describes performance audit procedures for each automated and manual monitoring method referenced in Appendix A[1]. In addition, quality assurance and quality control are defined, standard traceability procedures are discussed, and data interpretation procedures are specified relative to the requirements of Appendix A[1].

Quality Assurance and Control

Emphasis on quality assurance is increasing in the environmental community. Since its introduction in the manufacturing industry 30 years ago, quality assurance has expanded in scope to include all phases of environmental monitoring.

Quality assurance consists of two distinct and equally important functions. One function is the assessment of the quality of the monitoring data by estimating their precision and accuracy. The other function is the control and improvement of data quality by implementing quality control policies and procedures and by taking corrective actions. These two functions form a control loop where the assessment indicates when data quality is inadequate and where the control effort must be increased until the data quality is acceptable. Each agency should develop and implement a quality control program consisting of policies, procedures, specifications, standards, corrective measures, and documentation necessary to : 1) provide data of adequate quality to meet monitoring objectives and, 2) minimize loss of air quality data because of malfunctions and out- of-control conditions.

The selection and degree of specific control measures and corrective actions depend on a number of factors such as the monitoring methods and equipment, field and laboratory conditions, monitoring objectives, level of data quality required, expertise of assigned personnel, cost of control procedures, and pollutant concentration levels.

Standard Traceability

Traceability is the process of transferring the accuracy or authority of a primary standard to a field-usable standard. Gaseous standards (permeation tubes and devices and cylinders of compressed gas) used to obtain audit concentrations of CO, SO_2, and NO_2 must be working standards certified by comparison to NIST--SRM's. Traceability protocols are available for certifying a working standard by direct comparison to an NIST-SRM[4,5]. Direct use of an NIST-SRM is discouraged because of the limited supply and expense. NIST-SRM availability and ordering procedures are given in Reference 6.

Test concentrations for O_3 must be obtained by means of a UV photometric calibration procedure (Subsection A.10.4) or by a certified transfer standard[7]. Flow measurements must be made by an instrument that is traceable to an authoritative volume or other standard[8,9].

General Discussion of Audit Procedures

The benefits of a performance audit are twofold. From a participant standpoint, agencies are furnished a means of rapid self-evaluation of a specific monitoring operation. The EPA is furnished a continuing index of the validity of the data reported to the air quality data bank. The performance audit is used to validate and document the accuracy of the data generated by a measurement system. A list of the specific audit procedures which are outlined in this section is contained in Table A-1. Procedures which use the principles of dynamic dilution, gas phase titration, UV photometry, and flow rate measurement are presented. The general guidelines for performance audits are the same for all procedures.

Table A-1 Audit Procedures

Pollutant	Audit procedure
Sulfur dioxide	Dynamic dilution--permeation tube Dynamic dilution--compressed gas cylinder
Nitrogen dioxide	Gas phase titration
Carbon monoxide	Dynamic dilution--compressed gas cylinder Multiple compressed gas cylinders
Ozone	Ultraviolet photometry
Total suspended particulate	Flow rate measurement

1. A performance audit should be conducted only if calibration data are available for the analyzers or samplers being audited.
2. A performance audit should be conducted only if the site operator or representative is present, unless written permission is given to the auditor before the audit.
3. Before the audit, a general procedures protocol, including the audit policy and special instructions from the auditor, should be provided to the agency being audited.
4. A signed acknowledgment that the audit has been completed should be obtained from the station operator.
5. The auditor should discuss the audit results with the site operator or representative at the conclusion of the audit. A form showing the audit concentrations, station responses, and other pertinent data recorded by the auditor should be given to the site operator or representative; the form must indicate that the results are not official until the final report is issued. If the site operator or representative is not on-site at the conclusion of the audit, the auditor should contact the agency before leaving the area or promptly when returning to the base of operations.
6. The auditor should document the verification of his equipment before and after the audit; this verification includes calibration and traceability data. This information and a written record of the audit should be kept in a bound notebook in a secure location.
7. The auditor should use specific procedures that are consistent with the performance audit procedures manual. Any deviation from these must be approved by the agency performing the audit.
8. All audit equipment and standards including standard gases, permeation tubes, flow measuring apparatus, and temperature and pressure monitors should be referenced to primary standards.
9. Verification of the total audit system output by performing an audit on calibrated instrumentation should be conducted before the audit. The verification instrumentation should be calibrated using an independent set of equipment and standards.

10. Upon arrival at the audit site, all equipment should be inspected for transit damage. Each auditor should have a quality control checklist or a specified procedure that can be used to verify system integrity.

Performance Audit by

PEDCo Environmental, Inc.
11499 Chester Road
Cincinnati, Ohio 45246-0100

Date _____ *Auditor* _____

Start _____ *Parameter*

Figure A.1 Audit identification stamp

Before starting the audit, the auditor should record the following data: the site address, operating agency, type of analyzer being audited, zero and span settings, type of in-station calibration used, and general operating procedures. These data may be used later to determine the cause of discrepancies between the audit concentrations and station responses. The auditor should also mark the data record with a stamp similar to the one shown in Figure A.1 to verify that the audit was performed and to prevent the audit data from being transcribed and mistaken for ambient monitoring data. Before disconnecting a monitor or sampler from its ambient sampling mode, have the station operator make a note on the data acquisition system to indicate that an audit is being performed.

All station responses should be converted by the station operator to engineering units (e.g., ppm or ug/m^3) by using the same procedures used to convert the actual ambient data. This procedure allows evaluation of the total monitoring system--the station operator, equipment, and procedures.

Upon completion of the audit, all monitoring equipment must be reconnected and returned to the configuration recorded before initiating the audit. Before the auditor leaves the station, audit calculations should be performed to ensure that no extraneous or inconsistent differences exist in the data. Sometimes a recording mistake is found after leaving the station, and the error cannot be rectified without returning to the test site.

1. Sulfur Dioxide Audit Procedure Using Dynamic Permeation Dilution

1.1 Principle-Audit concentrations are generated by a dynamic system which dilutes an SO_2 permeation source with clean, dry air. This method can be used to audit all commercially available SO_2/total sulfur analyzers. Several variations in clean, dry air must be made to accommodate operating characteristics of certain analyzers. The procedure, its applicability, precision and accuracy, and apparatus requirements are discussed in the following subsections.

1.2 Applicability-The dynamic dilution method can be used to supply SO_2 audit concentrations in the range of 0 to 0.5 ppm. Concentrations for challenging other operating ranges such as 0 to 50 ppb, 0 to 0.2 ppm, 0 to 1.0 ppm, and 0 to 5 ppm can also be generated by using this procedure.

1.3 Accuracy-The accuracy of the audit procedure should be within $\pm$2.5% if the SO_2 permeation source is referenced and if gas flow rates are determined using EPA recommended procedures.

1.4 Apparatus-An audit system which uses a dynamic permeation dilution device to generate concentrations is illustrated in Figure A.2. The eight components of the system are discussed below.

1. Permeation Chamber--A constant-temperature chamber capable of maintaining the temperature around the permeation tube to an accuracy of ±0.10 C is required. The permeation oven should be equipped with a readout that is sensitive enough to verify the temperature of the permeation device during normal operation.

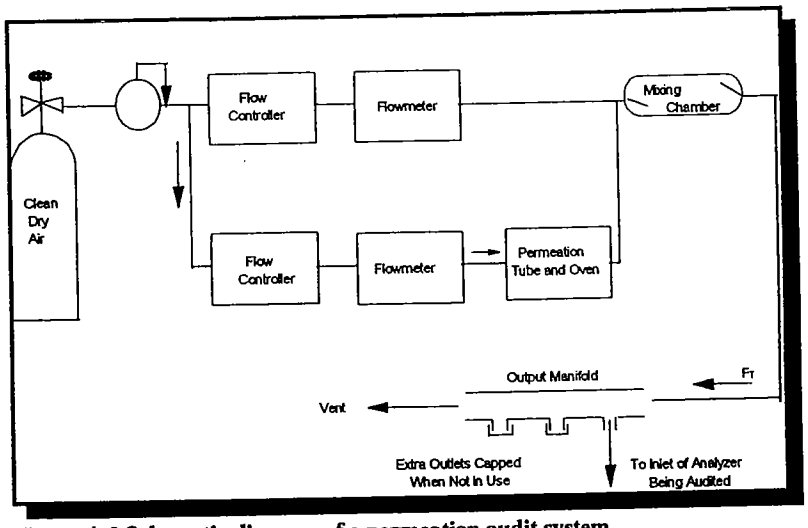


Figure A.2 Schematic diagram of a permeation audit system

2. Flow Controllers--Devices capable of maintaining constant flow rates to within ± 2% are required. Suitable flow controllers include stainless steel micro metering valves in tandem with a precision regulator and with mass flow controllers, capillary restrictors, and porous plug restrictors.

3. Flowmeters--Flowmeters capable of measuring pollutant and diluent gas flow rates to within ±2% are required. NIST-traceable soap bubble flowmeters, calibrated mass flow controllers or mass flowmeters, and calibrated orifice, capillary, and porous plug restrictors are suitable.

4. Mixing Chamber--A glass chamber is used to mix SO_2 with dilution air. The inlet and outlet should be of sufficient diameter so that the chamber is at atmospheric pressure under normal operation, and sufficient turbulence must be created in the chamber to facilitate thorough mixing. Chamber volumes in the range of 100 to 500 cm^3 are sufficient. Glass Kjeldahl connecting flasks are suitable mixing chambers.

5. Output Manifold and Sample Line--An output manifold used to supply the analyzer with an audit atmosphere at ambient pressure should be of sufficient diameter to ensure a minimum pressure drop at the analyzer connection, and the manifold must be vented so that ambient air will not mix with the audit atmosphere during system operations. Recommended manifold materials are glass or Teflon. The sample line must be nonreactive and flexible; therefore, Teflon tubing is preferred.

6. Dilution Air Source--The diluent source must be free of sulfur contaminants and water vapor; clean dry air from a compressed gas cylinder (Grade 0.1) may be used. When auditing a flame photometric analyzer, a diluent source which contains approximately 350 ppm CO_2 is required. A clean air system may be used; however, the system must not remove the CO_2 from the ambient airstream.

In all cases, the O_2 content of the diluent air must be 20.9 ±0.2%. Gas manufacturers that blend clean dry air do not always adhere to the exact ambient proportions of O_2 and N_2; in these cases, the O_2 content should be verified by paramagnetic response.

7. Sulfur Dioxide Permeation Tube--An SO_2 permeation tube with NIST traceability is used as the pollutant source. Permeation rates between 0.5 to 1.5 ug/min fulfill the auditing requirements. Traceability is established by referencing the permeation device to an NIST-SRM (number 1625. 1626. or 1627)

8. Permeation Tube Storage--A storage device capable of keeping the permeation tube encased in dry air is required; small cases containing Drierite or silica gel will serve this purpose. The useful life of a permeation tube will vary among vendor types (a 9-mo life can be used for estimating purposes); low temperature (2 to 5 C) will prolong the tube life. Do not freeze the permeation tube.

1.5 Procedure

Equipment Setup --Remove the permeation tube from the storage case, insert it into the permeation chamber, and start the carrier flow (approximately 50 cm^3/min) across the tube. Set the permeation temperature at the desired setting and allow the permeation source to equilibrate. For changes of 1 or 2 C, an equilibrium period of 3 h should suffice. For changes of 10 C or when the source is removed from low temperature storage, an equilibrium period of 24 h is advisable. Several commercially available permeation calibrators use a carrier flow to maintain a constant temperature around the tube during transport. In this instance, equilibration is not necessary because the oven temperature is continuously maintained within 0.10 C of the desired permeation temperature.

Audit sequence--After all the equipment has been assembled and set up, have the station operator mark the strip chart recorder to indicate that an audit is beginning. The auditor's name, start time, date, and auditing agency should be entered; if it is not possible to record written comments on the chart, record the start and stop times to preclude the use of audit data as monitoring data. After recording these data, disconnect the analyzer sample line from the station manifold and connect it to the audit manifold, as shown in Figure A.3. Cap the sample port on the station manifold. The audit atmosphere must be introduced through any associated filters or sample pretreatment apparatus to duplicate the path taken by an ambient sample. Record the analyzer type and other identification data on the data form (Table A-2). Conduct the audit as shown in steps 1-5 below.

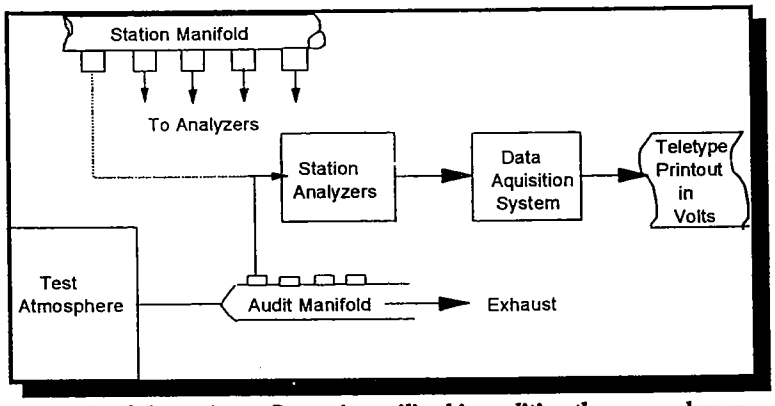


Figure A.3 Schematic configuration utilized in auditing the gas analyzers

1. Introduce into the audit manifold a clean dry air gas at a flow rate in excess of 10% to 50% of the analyzer sample demand. Allow the analyzer to sample the clean dry air until a stable response is obtained; that is, until the response does not vary more than 12% of the measurement range over a 5-min period. Obtain the station response and concentration from the station operator, and record the data in the appropriate blanks on the data form.

Audit Point	Concentration Range (ppm)
1	0.03 - 0.08
2	0.15 - 0.20
3	0.35 - 0.45
4	0.80 - 0.90

2. Generate SLAMS audit concentrations (which are compatible with the analyzer range) as audit atmospheres consistent with the requirements in Appendix A[1].

Generate the concentrations by adjusting the dilution air flow rate (F_D) and the permeation device air flow rate (F_C) to provide the necessary dilution factor. Calculate the concentrations as follows.

$$[SO_2] = \frac{P_R \ x \ 10^3}{F_C + F_D} \ x \ 3.82 \ x \ 10^{-4} \qquad \text{Equation 1-1}$$

where:

$[SO_2]$ = SO_2 audit concentration, ppm,
P_R = permeation flow rate at the specified temperature, ug SO_2/min,
F_C = carrier flow rate over the permeation tube, standard liters/min, and
F_D = diluent air flow rate, standard liters/min.

10^3 converts liters to m^3, and the 3.82×10^{-4} converts ug SO_2/cm^3 to ppm SO_2 at 25 C and 760 mm Hg

3. Generate the highest audit concentration first, and consecutively generate audit points of decreasing concentration. Allow the analyzer to sample the audit atmosphere until a stable response is obtained. Obtain the station response and concentration from the station operator, and record the data in the appropriate spaces in Table A-2.

4. If desired, additional points at upscale concentrations different from those specified in step 2 may be generated. Generation of these audit concentrations plus a post audit clean dry air response will enhance the statistical significance of the audit data regression analysis.

5. After supplying all audit concentrations and recording all data, reconnect the analyzer sample line to the station manifold. Make a notation of the audit stop time and have the station operator make a note on the data recorder to indicate the stop time. Have the station operator check all equipment to ensure that it is in order to resume normal monitoring activities.

1.6 Calculations-Tabulate the data in Table A-2 in the appropriate blank spaces.

% difference--The % difference is calculated as follows.

$$\%\ Difference = \frac{C_M - C_A}{C_A} \ x \ 100 \qquad \text{Equation 1-2}$$

where:

C_M = the station measured concentration, ppm
C_A = the calculated audit concentration, ppm.

Regression analysis-- Calculate by the method of least squares the slope, intercept, and correlation coefficient of the station analyzer response data (y) versus the audit concentration data (x). These data can be used to interpret the analyzer performance.

1.7 Reference- References 4 through 6 and 10 and 11 provide additional information on this SO_2 audit procedure.

Table A-2 Sulfur Dioxide Data Report

Station _____ Date: _____

Address _____ Start Time: _____

T_A _____ °C; P_A _____ mm Hg; P_{H2O} _____ mm Hg Auditor: _____

Analyzer _____ Serial Number _____

Calibration standard _____ Span source _____

Last calibration date _____ Frequency _____ Range _____

Calibration Comments _____

Zero setting _____ Data acquisition system _____

Span setting _____ Recorder _____

Audit system _____ Bubble flowmeter serial number _____

Audit standard _____; P _____ psig; [ ] = _____ ppm

Clean, dry air _____ Catalytic oxidizer Yes No

Flow correction $\left(\frac{P_A - P_{H_2O}}{760\ mm}\right) x \left(\frac{298\ K}{T_A + 273}\right)$ = _____ = (C_F)

Dilution air response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point I

Dilution flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point II

Dilution flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Table A-2 continued

Audit Point III

Dilution flow measurement

Volume _____ cm^3 Flowmeter _____

T1_____

T2_____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____cm3/min

T3_____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response_____

Audit Point IV

Dilution flow measurement

Volume _____ cm^3 Flowmeter _____

T1_____

T2_____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____cm3/min

T3_____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response_____

Audit Point V

Dilution flow measurement

Volume _____ cm^3 Flowmeter _____

T1_____

T2_____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____cm3/min

T3_____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response_____

Method

_____

_____

_____

Permeation temperature _____ °C Permeation rate _____ ug/min

Table A-2 continued

Point Number	Gas flow rates std cm^3/min		Audit Concentration ppm	Analyzer response		Difference	
	QC	QD		ppm	% MV/chart	Analyzer-audit ppm	%

Regression analysis [audit concentration (x) vs. Analyzer response (y)]

$y = mx + b$

Slope (m) _____

Intercept (b) _____

Correlation (r) _____

Comments:

2. Sulfur Dioxide Audit Procedure Using Dynamic Dilution of a Gas Cylinder

2.1 Principle- A dynamic dilution system is used to generate SO_2 concentrations in air for auditing continuous ambient analyzers. The audit procedure consists of diluting a gas cylinder of low SO_2 concentration with clean dry dilution air. Traceability is established by referencing the gas cylinder to an NIST-SRM. This procedure can be used to audit all commercially available SO_2/total sulfur analyzers. Variations in clean dry air must be made to accommodate operating characteristics of certain analyzers. The procedure, its applicability, accuracy, and apparatus requirements are discussed in the following subsections.

2.2 Applicability-Dynamic dilution can be used to supply SO_2 audit concentrations in the range of 0 to 0.5 ppm. Concentrations for challenging other operating ranges such as 0 to 50 ppb, 0 to 0.2 ppm, 0 to 1.0 ppm, and 0 to 5 ppm can also be readily generated by using this procedure.

2.3 Accuracy-The accuracy of the audit procedure should be within $\pm$2.5% if the SO_2 gas cylinder concentration is referenced and if gas flow rates are determined using EPA recommended procedures.

2.4 Apparatus-An audit system which uses a dynamic dilution device to generate audit concentrations is illustrated in Figure A.4. The seven components of the device are discussed below.

1. Gas Cylinder Regulator--A stainless steel gas regulator is acceptable. A low dead space, two stage regulator should be used to achieve rapid equilibration. A purge assembly is helpful.

2. Flow Controllers--Devices capable of maintaining constant flow rates to within +2% are required. Suitable flow controllers include stainless steel micro metering valves in tandem with a precision regulator, mass flow controllers, capillary restrictors, and porous plug restrictors.

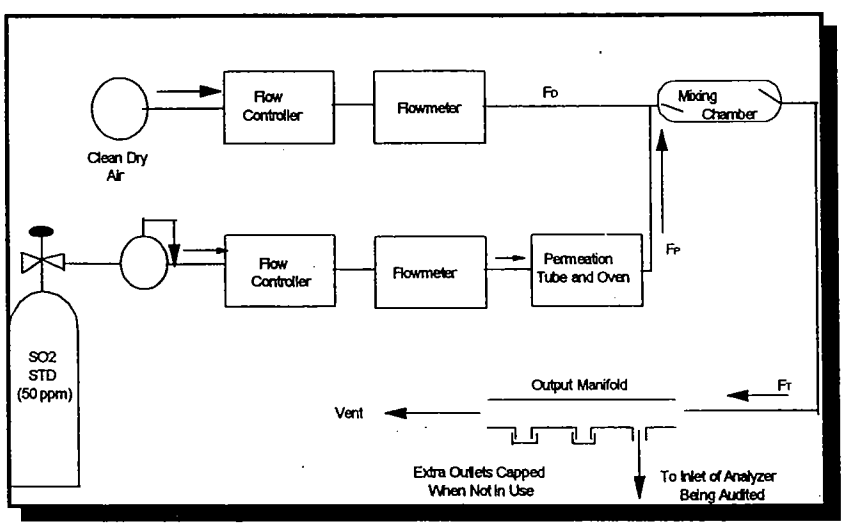


Figure A.4 Schematic diagram of a dilution audit system

3. Flowmeters--Flowmeters capa ble of measuring pollutant and diluent gas flow rates to within $\pm$2% are required. NIST-traceable soap bubble flowmeters, calibrated mass flow controllers or mass flowmeters, and calibrated orifice, capillary, and porous plug restrictors are suitable for flow determination.

4. Mixing Chamber--A glass or Teflon chamber is used to mix the SO_2 with dilution air. The inlet and outlet should be of sufficient diameter so that the chamber is at atmospheric pressure under normal operation, and sufficient turbulence must be created in the chamber to facilitate thorough mixing. Chamber volumes in the range of 100 to 500 cm^3 are sufficient. Glass Kjeldahl connecting flasks are suitable mixing chambers. –

5. Output Manifold and Sample Line--An output manifold used to supply the analyzer with an audit atmosphere at ambient pressure should be of sufficient diameter to ensure a minimum pressure drop at the analyzer connection, and the manifold must be vented so that ambient air will not mix with the audit atmosphere during system operations. Recommended manifold materials are glass or Teflon. The sample line must be nonreactive and flexible; therefore, Teflon tubing is preferred.

6. Dilution Air Source--The diluent source must be free of sulfur contaminants and water vapor; clean dry air from a compressed gas cylinder (Grade 0.1) may be used. When auditing a flame photometric analyzer, a diluent source which contains approximately 350 ppm CO_2 is required. A clean air system may be used; however, the system must not remove the CO_2 from the ambient airstream.

In all cases, the O_2 content of the diluent air must be 20.9 $\pm$0.2%. Gas manufacturers that blend clean dry air do not always adhere to the exact ambient proportions of O_2 and N_2; in these cases, the O_2 content should be verified by paramagnetic response.

7. Sulfur Dioxide Gas Cylinder--A compressed gas cylinder containing 50 to 100 ppm SO_2 in air is used as the dilution source. This cylinder must be traceable to an NIST-SRM (number 1661, 1662, 1663, or 1664).

2.5 Procedure--Equipment setup--Assemble the audit equipment as required, and verify that all equipment is operational. If a dilution air system equipped with a catalytic oxidizer is used, allow the oxidizer to warm up for 30 min. Connect the gas regulator to the SO_2 cylinder, and evacuate the regulator as follows:

1. With the cylinder valve closed, connect a vacuum pump to the evacuation outlet on the regulator and start the pump.
2. Open and close the evacuation port.
3. Open and close the cylinder valve.
4. Open and close the evacuation port.
5. Repeat steps 2 through 4 five more times to be sure all O_2 impurities are removed from the regulator.

If the regulator does not have an evacuation port but has a supported diaphragm, the procedure can be conducted at the gas exit port. For regulators that do not have an evacuation port but have an unsupported diaphragm, use the following procedure:

1. Connect the regulator to the cylinder, and close the gas exit port.
2. Open and close the cylinder valve to pressurize the regulator.
3. Open the gas exit port, and allow the gas to purge the regulator. Repeat steps 2 and 3 five more times; then close the gas exit port, and open the cylinder valve. The regulator should remain under pressure. Connect the gas cylinder to the audit device. Repeat the procedure for each cylinder.

Audit sequence--Before disconnecting the analyzer from the station manifold, mark the data recorder to indicate that an audit is beginning. The auditor's name, start time, date, and auditing organization should be recorded. If it is not possible to record written comments, the start and stop times should be recorded to preclude the use of audit data as monitoring data. After recording these data, disconnect the analyzer sample line from the station manifold, and connect it to the audit manifold, as shown in Figure A.5. Cap the sample port on the station manifold. The audit atmosphere must be introduced through any associated filters or sample pretreatment apparatus to duplicate the path taken by an ambient sample. Record the analyzer type and other identification data on the data form (Table A-3). Conduct the audit by following steps 1 through 5 below.

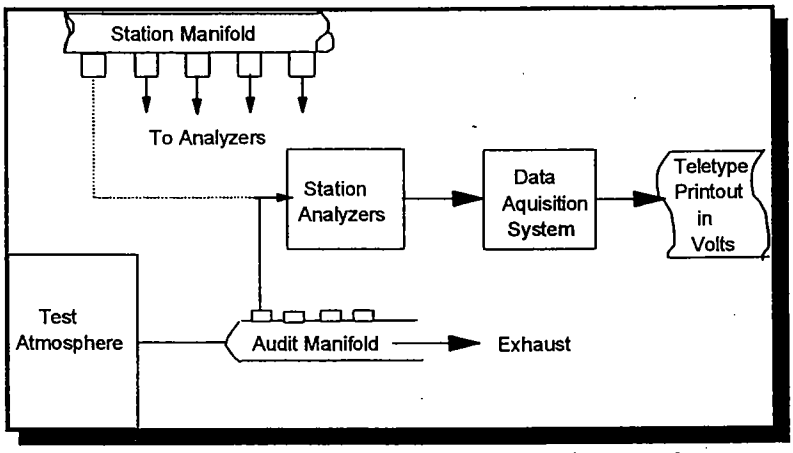


Figure A.5 Schematic configuration utilized in auditing the gas analyzers

1. Introduce into the audit manifold a clean dry air-gas at a flow rate in excess of 10% to 50% of the analyzer sample demand. Allow the analyzer to sample the clean dry air until a stable response is obtained; that is, until the response does not vary more than +2% of the measurement range over a 5-min period. Obtain the station response and concentration from the station operator and record the data in the appropriate blanks on the data form.

Audit point	Concentration range (ppm)
1	0.03-0.08
2	0.15-0.20
3	0.35-0.45
4	0.80-0.90

2. Generate the SLAMS audit concentrations (which are compatible with the analyzer range) as audit atmospheres consistent with the requirements in Appendix A[1].

Generate the audit concentrations by adjusting the pollutant flow rate (Fp) and the total flow rate (Ft) to provide the necessary dilution factor.
Calculate the audit concentration as follows:

$$[SO_2] = \frac{F_P}{F_T} \times [SO_2]_{STD} \qquad \text{Equation 1-3}$$

where:
$[SO_2]$ = audit concentration of SO_2, ppm,
F_P = pollutant flow rate, cm^3/min
F_T =total flow rate, cm^3/min [equal to the sum of the pollutant flow rate (F_P) and the dilution flow rate (F_D)
$[SO_2]_{STD}$=concentration of the standard cylinder, ppm.

3. Generate the highest audit concentration first, and consecutively generate audit points of decreasing concentration. Allow the analyzer to sample the audit atmosphere until a stable response is obtained. Obtain the station response and concentration from the station operator, and record the data in the appropriate spaces in Table A-3.

4. If desired, additional points at upscale concentrations different from those specified in step 2 may be generated. Generation of these audit concentrations plus a post audit lean dry air response will enhance the statistical significance of the audit data regression analysis.

5. After supplying all audit sample concentrations and recording all data, reconnect the analyzer sample line to the station manifold. Make a notation of the audit stop time. Have the station operator make a note on the data recorder to indicate the stop time, and check all equipment to ensure that it is in order to resume normal monitoring activities.

2.6 Calculations- Record the data in Table A-3 in the appropriate spaces.

% difference--The % difference is calculated as follows.

$$\%\ Difference = \frac{C_M - C_A}{C_A} \times 100 \qquad \text{Equation 1-4}$$

where:
C_M = the station measured concentration, ppm
C_A = the calculated audit concentration, ppm.

Regression analysis--Calculate by the method of least squares the slope, intercept, and correlation coefficient of the station analyzer response data (y) versus the audit concentration data (x). These data can be used to interpret the analyzer performance.

2.7 References

References 4 through 6 and 10 and 11 provide additional information on this SO_2 audit procedure.

Table A-3 SO_2 Audit Data Report

Station _____ Date: _____

Address _____ Start Time: _____

T_A _____ °C; P_A _____ mm Hg; P_{H2O} _____ mm Hg Auditor: _____

Analyzer _____ Serial Number _____

Calibration standard _____ Span source _____

Last calibration date _____ Frequency _____ Range _____

Calibration Comments _____

Zero setting _____ Data acquisition system _____

Span setting _____ Recorder _____

Audit system _____ Bubble flowmeter serial number _____

Audit standard _____; P _____ psig; [ ] = _____ ppm

Clean, dry air _____ Catalytic oxidizer Yes No

Flow correction $\left(\frac{P_A - P_{H_2O}}{760\ mm}\right) x \left(\frac{298\ K}{T_A + 273}\right)$ = _____ = (C_F)

Dilution air flow

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\mathcal{T}$ _____ min $(C_F)\left(\frac{Volume}{\mathcal{T}}\right)$ = _____ cm3/min

T3 _____

Dilution air response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point I

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\mathcal{T}$ _____ min $(C_F)\left(\frac{Volume}{\mathcal{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point II

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point III

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point IV

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point V

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Table A-3 continued

Point Number	flow rates		Audit Concentration ppm	Analyzer response		Difference	
	Pollutant cm^3/min	Total cm^3/min		ppm	% MV/chart	Analyzer-audit ppm	%

Regression analysis [audit concentration (x) vs. Analyzer response (y)]

$y = mx + b$

Slope (m) _____

Intercept (b) _____

Correlation (r) _____

Comments:

Auditor_____

Audit Method _____

Zero Setting _____ Span setting _____ Equivalency reference no. _____

Station Calibration source_____

_____

3. Nitrogen Dioxide Audit Procedure Using Gas Phase Titration

3.1 Principle-The auditing procedure is based on the gas phase reaction between NO and O_3

$NO + O_3 \rightarrow NO_2 + O_2$ - Equation 1-5

The generated NO_2 concentration is equal to the NO concentration consumed by the reaction of 0_3 with excess NO. The NO and NO_X channels of the chemiluminescence $_{NOX}$ analyzer are audited with known NO concentrations produced by a dynamic dilution system which uses clean dry air to dilute a gas cylinder containing NO in nitrogen. After completion of the NO-NO_X audits, stoichiometric mixtures of NO_2 in combination with NO are generated by adding 0_3 to known NO concentrations. These audit data are used to evaluate the calibration of the NO-NO_X-NO_2 analyzer channels and to calculate analyzer converter efficiency.

3.2 Applicability-The procedure can be used to supply audit concentrations of NO-NO_2-NO_X in the range of 0.010 to 2.0 ppm.

3.3 Accuracy-The accuracy of the audit procedure should be within ±2.5% if the NO gas cylinder concentration is referenced and if the gas flow rates are determined by using EPA-recommended procedures.

3.4 Apparatus--Audit system

A typical gas phase titration system is illustrated in Figure A.6. All connections and components downstream from the 0_3 generator and the pollutant source must be constructed of nonreactive (glass or Teflon) material. The seven components of the system are discussed below.

1. Flow Controllers--Devices capable of maintaining constant flow rates to within ±2% are required. Suitable flow controllers include brass (for air) or stainless steel (for NO_X) micro metering valves in tandem with a precision regulator, mass flow controllers, capillary restrictors, and porous plug restrictors.

2. Flowmeters--Flowmeters capable of measuring pollutant and diluent gas flow rates to within ±2% are required. NIST-traceable soap bubble flowmeters, calibrated mass flow controllers or mass flowmeters, and calibrated orifice, capillary, and porous plug restrictors are all suitable for flow determination.

3. Gas Cylinder Regulator--A noncorrosive two-stage stainless steel regulator with an evacuation port is suggested.

4. Ozone Generator--An 0_3 generator that produces a stable concentration is required during the gas phase titration sequence of the audit. An ultraviolet lamp generator is recommended.

5. Reaction Chamber--A glass chamber used for the quantitative reaction of 0_3 with NO should have sufficient volume, 100 to 500 cm^3, for the residence time to be ≤ 2 min. Elongated glass bulbs such as Kjeldahl connecting flasks are suitable.

6. Mixing Chamber--A glass or Teflon chamber is used to mix the NO, NO_2, or 0_3 with dilution air. The inlet and outlet should be of sufficient diameter so that the chamber is at atmospheric pressure under normal operation, and sufficient turbulence must be created in the chamber to facilitate thorough mixing. Chamber

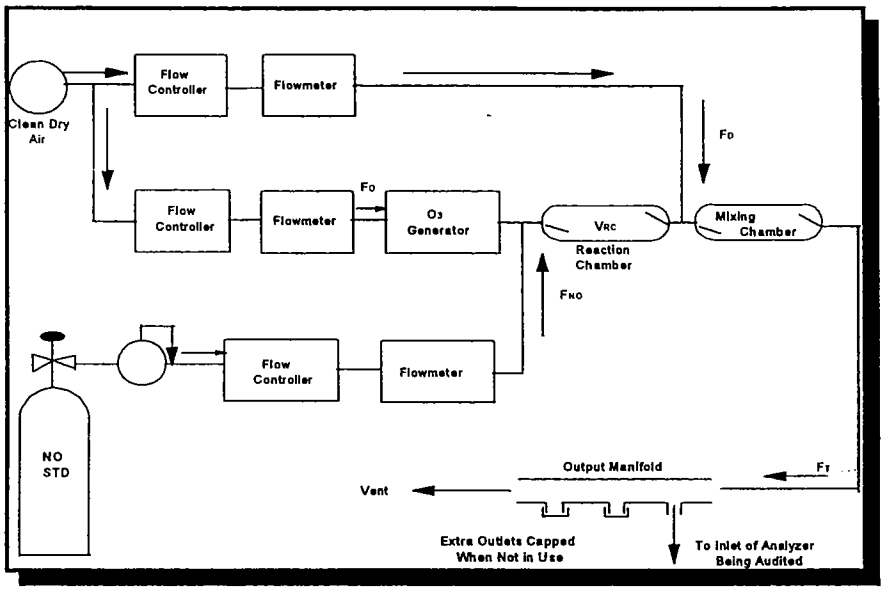


Figure A.6 Schematic diagram of a gas phase titration audit system

volumes in the range of 150 to 250 cm^3 are sufficient. Glass Kjeldahl connecting flasks are suitable mixing chambers.

7. Output Manifold and Sample Line--An output manifold used to supply the analyzer with an audit atmosphere at ambient pressure should be of sufficient diameter to ensure a minimum pressure drop at the analyzer connection, and the manifold must be vented so that ambient air will not mix with the audit atmosphere during system operations. Recommended manifold materials are glass or Teflon. The sample line must be nonreactive and flexible; therefore, Teflon is preferred.

Dilution air system--Clean dry air from a compressed gas cylinder (Grade 0.1) is a suitable source for dilution air; however, if large volumes of clean dry air (≥5 liters/min) are required, purified compressed air is preferred. The clean dry air must be free of contaminants such as NO, $N0_2$, 0_3 or reactive hydrocarbons that would cause detectable responses on the NO_X analyzer or that might react with NO or NO_2 in the audit system. The air can be purified to meet these specifications by passing it through silica gel for drying, by treating it with 0_3 to convert any NO to NO_2, and by passing it through activated charcoal (6-14 mesh) and a molecular sieve (6-16 mesh, type 4A) to remove NO_2, O_3, or hydrocarbons.

Silica gel maintains its drying efficiency until it has absorbed 20% of its weight; it can be regenerated indefinitely at 120 C. Addition of cobalt chloride to the surface of the gel provides a water absorption indicator. A transparent drying column is recommended. The activated charcoal and molecular sieve have a finite absorption capability; because it is difficult to determine when the capability has been exceeded, both should be replaced either before each audit or after 8 hrs of use.

Nitric oxide gas cylinder--A compressed gas cylinder containing 50 to 100 ppm NO in N_2 is used as the NO dilution source. This cylinder must be traceable to an NIST-SRM (number 1683, 1684, 1685, 1686, or 1687).

3.5 Procedure

Equipment setup--Assemble the audit equipment as required, and verify that all equipment is operational. If a clean, dry air system equipped with a catalytic oxidizer and/or O_3 lamp is used, allow the oxidizer and/or O_3 lamp to warm up for 30 minutes. Connect the gas regulator to the NO cylinder, and evacuate the regulator as follows:

1. With the cylinder valve closed, connect a vacuum pump to the evacuation outlet on the regulator, and start the pump.
2. Open and close the evacuation port.

3. Open and close the cylinder
4. Open and close the evacuation port.
5. Repeat steps 2 through 4 five more times to be sure all O_2 impurities are removed from the regulator. If the regulator does not have an evacuation port but has a supported diaphragm, the procedure can be conducted at the gas exit port.

For regulators that do not have an evacuation port but have an unsupported diaphragm, use the following procedure:
1. Connect the regulator to the cylinder, and close the gas exit port.
2. Open and close the cylinder valve to pressurize the regulator.
3. Open the gas exit port, and allow the gas to purge the regulator.
4. Repeat steps 2 and 3 five more times, close the gas exit port, and open the cylinder valve. Connect the dilution air source and NO cylinder to the audit device as shown in Figure A.6. Use 1/8-in. o.d. tubing of minimum length for the connection between the NO cylinder and the audit device.

Dynamic parameter specifications--The flow conditions used in the GPT audit system are selected to assure a complete NO-O_3 reaction. The gas flow rates must be adjusted according to the following relationships:

$$P_R = [NO]_{RC} \times t_R \quad 2.75 \ ppm\text{-min} \qquad \text{Equation 1-6}$$

$$[NO]_{RC} = [NO]_{STD} \times \frac{F_{NO}}{F_O + F_{NO}} \qquad \text{Equation 1-7}$$

$$t_R = \frac{V_{RC}}{F_O + F_{NO}} \quad 2 \text{ min} \qquad \text{Equation 1-8}$$

where:
P_R =dynamic parameter specification, determined empirically, to ensure complete reaction of the available 0_3, ppm-min,
$[NO]_{RC}$ = NO concentration in the reaction chamber, ppm,
t_R = residence time of the reactant gases in the reaction chamber, min,
$[NO]_{STD}$ = concentration of the NO gas cylinder, ppm.
F_{NO} = NO flow rate, standard cm^3/min,
F_O = O_3 generator air flow rate, standard cm^3/min, and
V_{RC} =volume of the reaction chamber, cm^3.

The flow conditions to be used in the GPT audit system are selected according to the following sequence:

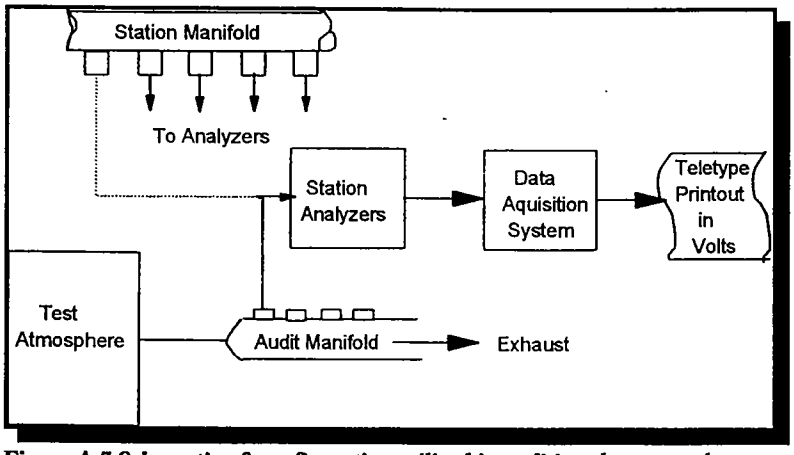


Figure A.7 Schematic of configuration utilized in auditing the gas analyzers

1. Determine F_T, the total flow rate required at the output manifold (F_T = analyzer(s) demand plus 10% to 50% excess).

2. Determine F_{NO}. the flow rate of NO required to generate the lowest NO concentration required at the output manifold during the GPT (approximately 0.15 ppm).

$$F_{NO} = \frac{0.15 \ x \ F_T}{[NO]_{STD}} \qquad \text{Equation 1-9}$$

3. Measure the system's reaction chamber volume; must be in the range of approximately 100 to 500 cm^3.

4. Compute FO.

$$F_O = \sqrt{\frac{[NO]_{STD} \ x \ F_{NO} \ x \ V_{RC}}{2.75}} - F_{NO} \qquad \text{Equation 1-10}$$

5. Compute t_R, using Equation 1-8; verify that $t_R \leq 2$ min.

6. Compute F_D

$$F_D = F_T - F_O - F_{NO} \qquad \text{Equation 1-11}$$

where:
F_D = diluent air flow, standard cm^3/min.

Adjust F_O to the value determined above. F_O should not be further adjusted during the NO-NO_X or NO_2 audit procedures; only F_{NO} (or F_D) and the O_3 generator settings are adjusted during the course of the audit.

Audit sequence--After all the equipment has been assembled and set up, have the station operator mark the strip chart recorder to indicate that the audit is beginning. Information such as the auditors' name, start time, date, and auditing organization should be entered. If it is not possible to enter written comments, the start and stop times should be recorded to preclude the use of audit data as monitoring data. After recording the data, disconnect the analyzer sample line from the station manifold, and connect it to the audit manifold, as shown in Figure A.7. Cap the sample port on the station manifold. The audit atmosphere must be introduced

through any associated filters or sample pretreatment apparatus to duplicate the path taken by an ambient sample. Record the analyzer type and other identification data on the data form (Table A-4).

Conduct the NO-NO_X and NO_2 audits as follows:

NO-NO_X Audit--The NO-NO_X audit involves generating concentrations to challenge the calibration of the NO and NO_X channels of the analyzer. Data collected during this audit are used to construct a calibration curve that will be used later for calculating the NO_2 audit concentrations.

NO-NO_X Audit Procedure--

1. Introduce clean dry air into the audit manifold at a flow rate in excess of 10% to 50% of the analyzer sample demand. Allow the analyzer to sample the clean dry air until a stable response is obtained; that is, until the response does not vary more than $\pm$ 2% of the measurement range over a 5-min period. Record the readings for the NO, NO_X, and NO_2 channels, and have the station operator report the audit responses in concentration units. Record these data and the responses of all three channels in Table A-4.

2. Generate upscale NO audit concentrations corresponding to 10%, 20%, 40%, 60%, and 90% of the full-scale range of the analyzer by adjusting the flow rate of the NO standard. For each audit concentration level generated, calculate the NO concentration

$$[NO] = \frac{F_P}{F_T} \times [NO]_{STD} \qquad \text{Equation 1-12}$$

where
[NO] = NO-NO_X audit concentration, ppm (the NO_2 impurity in the stock standard should be negligible),
F_P = pollutant flow rate, cm^3/min,
F_T = total flow rate, cm^3/min, and
$[NO]_{STD}$ = concentration of the standard cylinder, ppm.

NOTE: Alternatively, the upscale NO audit concentrations may be generated by maintaining a constant pollutant flow rate (F_P) and varying the dilution air flow rate (F_D). In this case, the entries for dilution air flow and pollutant flow in Table A-4 should be reversed and clearly indicated.

3. Generate the lowest audit concentration level first and consecutively generate audit points of increasing concentration. Allow the analyzer to sample the audit atmosphere until a stable response is obtained. Record the audit concentration. Obtain the station response and concentration from the station operator for the NO, NO_X, and NO_2 channels, and record the data in the appropriate spaces in Table A-4.

4. Prepare audit calibration curves for the NO and NO_X channels by using least squares. Include the zero air points. (The audit concentration is the x variable; the analyzer response in % chart is the y variable.) The NO audit calibration curve will be used to determine the actual audit concentrations during the generation of the NO_2 atmospheres.

The NO_X audit calibration curve will be used to determine NO_2 converter efficiency.

NO_2 Audit--The NO_2 audit involves generating NO_2 concentrations in combination with approximately 0.10 ppm of NO to challenge the calibration of the NO_2 channel of the analyzer. The NO_2 audit concentrations are calculated from the responses of the NO channel of the analyzer using the NO audit calibration equation obtained during the NO/NO_X audit.

NO_2 Audit Procedure--

1. Verify that the O_3 generator air flow rate (F_O) is adjusted to the value determined earlier (Dynamic parameter specifications).

2.Generate the SLAMS audit concentrations (which are compatible with the analyzer range) consistent with the Appendix A' requirements.

Audit point	Concentration range (ppm)
1	0.03-0.08
2	0.15-0.45
3	0.35-0.45
4	0.80-0.90

3. Generate an NO concentration which is approximately 0.08 to 0.12 ppm higher than the NO_2 audit concentration level required. Allow the analyzer to sample this concentration until a stable response is obtained; that is, until the response does not vary more than ± 2 % of the measurement range over a 5-minute period. Record the NO and NO_X responses on the data form. Calculate and record $[NO]_{ORIG}$ and $[NO_X]_{ORIG}$ using the NO and NO_X audit calibration equations derived during the $NO\text{-}NO_X$ audit.

4. Adjust the 0_3 generator to generate sufficient 0_3 to produce a decrease in the NO concentration equivalent to the NO_2 audit concentration level required. After the analyzer response stabilizes, record the NO and NO_X responses on the data form. Calculate and record $[NO]_{REM}$ and $[NO_X]_{REM}$ using the NO and NO_X audit calibration equations derived during the $NO\text{-}NO_X$ audit. (Note: $[NO]_{REM}$ should be approximately 0.08 to 0.12 ppm for each audit point).

5. Calculate and record the NO_2 audit concentration $[NO_2]_A$.

$$[NO_2]_A = [NO]_{ORIG} - [NO]_{REM} \qquad \text{Equation 1-13}$$

6. Obtain the NO_2 station response and concentration from the station operator and record on the data form.

7. Generate the highest audit concentration level first, and consecutively generate audit points of decreasing NO_2 concentration. Allow the analyzer to sample the audit atmospheres until stable responses are obtained. Obtain the necessary data and record in the appropriate spaces in Table A-4.

8. If desired, additional points at upscale concentrations different from those specified in step 2, may be generated. These additional audit points plus the zero air point (obtained at the start of the audit) will enhance the statistical significance of the audit data regression analysis.

9. After supplying all audit sample concentrations and recording all data, reconnect the analyzer sample line to the station manifold. Make a notation of the audit stop time. Have the station operator make a note on the data recorder to indicate the stop time, and check all equipment to ensure that it is in order to resume normal monitoring activities.

Converter efficiency--$[NO_2]_{CONV}$ is calculated for each audit point using Equation 1-14 and is used to determine the NO_X analyzer converter efficiency using Equation 1-15. $[NO_X]_{ORIG}$ and $[NO_X]_{REM}$ are calculated from the NO_X audit calibration equation.

$$[NO_2]_{CONV} = [NO_2]_A - [NO_X]_{ORIG} - [NO_X]_{REM} \qquad \text{Equation 1-14}$$

$$\text{\% converter efficiency} = \frac{[NO_2]_{CONV}}{[NO_2]_A} \times 100 \qquad \text{Equation 1-15}$$

3.6 Calculations-Record the audit data in the appropriate spaces of Table A-4.

Percent difference--The % difference is calculated as follows:

$$\%\ difference = \frac{C_M - C_A}{C_A} \times 100 \qquad \text{Equation 1-16}$$

where:
C_M = station-measured concentration, ppm, and
C_A = calculated audit concentration, ppm

Regression analysis--Calculate by least squares the slope, intercept and correlation coefficient of the station analyzer response data (y) versus the audit concentration data These data can be used to interpret analyzer performance.

3.7 Reference- References 4 through 6, 8, 10, and 12 provide additional information on the NO_2 audit procedure.

Table A-4 Gas Phase Audit Data Report

Station _____ Date: _____

Address _____ Start Time: _____

T_A _____ °C; P_A _____ mm Hg; P_{H2O} _____ mm Hg Auditor: _____

Analyzer _____ Serial Number _____

Calibration standard _____ Span source _____

Last calibration date _____ Frequency _____ Range _____

Calibration Comments _____

Flow settings _____

Zero setting NO _____ NO_X _____ NO_2 _____

Span setting NO _____ NO_X _____ NO_2 _____

Other settings _____

Audit system _____ Bubble flowmeter serial number _____

Audit standard _____; P _____ psig; [ ] = _____ ppm

Clean, dry air _____

Flow correction $\left(\frac{P_A - P_{H_2O}}{760\ mm}\right) x \left(\frac{298\ K}{T_A + 273}\right)$ = _____ = $F^{(C)}$

Dilution air flow

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____ cm3/min

T3 _____

Ozone generator flow

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____ cm3/min

T3 _____

Analyzer response clean dry air

	% Chart	Vdc	( )	ppm
NO	_____	_____	_____	_____
NO_X	_____	_____	_____	_____
NO_2	_____	_____	_____	_____

Table A-4 continued

Part 1 NO-NO_X AUDIT

NO-NO_X Audit point I (10%)

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1_____

T2_____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____cm3/min

T3_____

NO, NO_X audit concentration _____ ppm

Analyzer response

	% Chart	Vdc	( )	ppm
NO	_____	_____	_____	_____
NO_X	_____	_____	_____	_____
NO_2	_____	_____	_____	_____

NO-NO_X Audit point II (20%)

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1_____

T2_____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____cm3/min

T3_____

NO, NO_X audit concentration _____ ppm

Analyzer response

	% Chart	Vdc	( )	ppm
NO	_____	_____	_____	_____
NO_X	_____	_____	_____	_____
NO_2	_____	_____	_____	_____

NO-NO_X Audit point I (40%)

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1_____

T2_____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____cm3/min

T3_____

NO, NO_X audit concentration _____ ppm

Analyzer response

	% Chart	Vdc	( )	ppm
NO	_____	_____	_____	_____
NO_X	_____	_____	_____	_____
NO_2	_____	_____	_____	_____

Table A-4 continued
$NO\text{-}NO_X$ Audit point II (60%)

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1_____

T2_____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____cm3/min

T3_____

NO, NO_X audit concentration _____ ppm

Analyzer response

	% Chart	Vdc	( )	ppm
NO	_____	_____	_____	_____
NO_X	_____	_____	_____	_____
NO_2	_____	_____	_____	_____

$NO\text{-}NO_X$ Audit point II (90%)

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1_____

T2_____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____cm3/min

T3_____

NO, NO_X audit concentration _____ ppm

Analyzer response

	% Chart	Vdc	( )	ppm
NO	_____	_____	_____	_____
NO_X	_____	_____	_____	_____
NO_2	_____	_____	_____	_____

$NO\text{-}NO_X$ audit calibration equation ($y = mx + b$)

NO audit concentration (x) vs. Analyzer response in % chart (y)

Slope (m) = _____

Intercept (b) = _____

Correlation (r) = _____

NO audit concentration (x) vs. Analyzer response in % chart (y)

Slope (m) = _____

Intercept (b) = _____

Correlation (r) = _____

Table A-4 continued
Part II NO_2 Audit

NO_2 Audit Point I

Analyzer response

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

O_3 generator setting = _____

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

$[NO_2]_A = [NO]^*_{ORIG} - [NO]^*_{REM} =$ _____ *ppm*

	% Chart	V_{DC}	( )	ppm	
NO_2	_____	_____	_____	_____	ppm

NO_2 Audit Point II
Analyzer response

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

O_3 generator setting = _____

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

$[NO_2]_A = [NO]^*_{ORIG} - [NO]^*_{REM} =$ _____ *ppm*

	% Chart	V_{DC}	( )	ppm	
NO_2	_____	_____	_____	_____	ppm

NO_2 Audit Point III

Analyzer response

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

O_3 generator setting = _____

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

$[NO_2]_A = [NO]^*_{ORIG} - [NO]^*_{REM} =$ _____ *ppm*

	% Chart	V_{DC}	( )	ppm	
NO_2	_____	_____	_____	_____	ppm

Table A-4 continued

NO_2 Audit Point IV

Analyzer response

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

O_3 generator setting = _____

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

$[NO_2]_A = [NO]^*_{ORIG} - [NO]^*_{REM} =$ _____ *ppm*

	% Chart	V_{DC}	( )	ppm	
NO_2	_____	_____	_____	_____	ppm

NO_2 Audit Point V

Analyzer response

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

O_3 generator setting = _____

	% Chart	V_{DC}	( )	[ ]*	ORIG
NO	_____	_____	_____	_____	ppm
NO_X	_____	_____	_____	_____	ppm

$[NO_2]_A = [NO]^*_{ORIG} - [NO]^*_{REM} =$ _____ *ppm*

	% Chart	V_{DC}	( )	ppm	
NO_2	_____	_____	_____	_____	ppm

* Calculated concentration from NO or NO_X audit calibration equation $(y = mx + b)$

Part III Data Tabulation

NO Channel

Point	Audit Conc. ppm	Analyzer-NO		Difference	
		Concentration ppm	Response	Analyzer-audit ppm	%
Zero					
10%					
20%					
40%					
60%					
90%					

Analyzer response (ppm) = m (audit) + b
Slope (m)= _____; Intercept (b) = _____; Correlation (r) = _____

Table A-4 continued

NO_X Channel

Point	Audit Conc. ppm			Analyzer-NO_X		Difference	
	NO	NO_2	NO_XTotal	Concentration ppm	Response	Analyzer-audit ppm	%
Zero							
10%							
20%							
40%							
60%							
90%							

Analyzer response (ppm) = m (audit) + b

Slope (m)= _____; Intercept (b) = _____; Correlation (r) = _____

NO_2 Channel

Point	Audit Conc. ppm	Analyzer-NO_2		Difference	
		Concentration ppm	Response	Analyzer-audit ppm	%
Zero					
1					
2					
3					
4					
5					

Analyzer response (ppm) = m (audit) + b

Slope (m)= _____; Intercept (b) = _____; Correlation (r) = _____

Converter efficiency

Point Number	$[NO_2]_A$, ppm	$[NO_2]_{CONV}$, ppm	Percent converter efficiency
1			
2			
3			
4			
5			

4. Carbon Monoxide Audit Procedure Using Dynamic Dilution of a Gas Cylinder

4.1 Principle--A dynamic calibration system used to generate CO concentrations for auditing continuous ambient analyzers, consists of diluting a CO gas cylinder with clean dry air.

4.2 Applicability-Dynamic dilution can be used to audit all types of CO analyzers; CO concentrations in the range of 0 to 100 ppm can be generated.

4.3 Accuracy-The accuracy of the audit procedure should be within ±2.5% if the CO gas cylinder concentration is referenced and if gas flow rates are determined using recommended procedures.

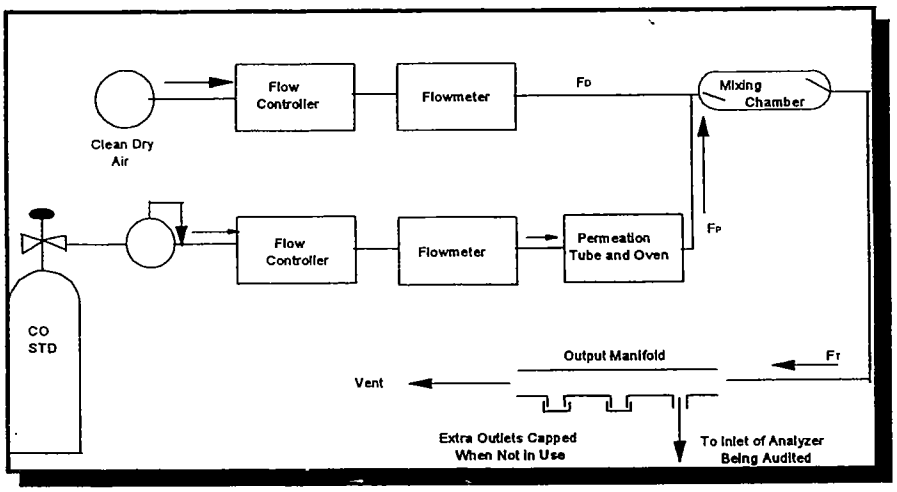


Figure A.8 Schematic diagram of a dilution audit system

4.4 Apparatus-An audit system which uses a dynamic dilution device to generate audit concentrations is illustrated in Figure A.8. The seven components of the system are discussed below.

1. Gas cylinder regulator. A brass regulator is acceptable. A low dead space, two-stage regulator should be used to achieve rapid equilibration.

2. Flow controllers. Devices capable of maintaining constant flow rates to within ±2% are required. Suitable flow controllers include brass micro metering valves in tandem with a precision regulator, mass flow controllers, capillary restrictors, and porous plug restrictors.

3. Flowmeters. Flowmeters capable of measuring pollutant and diluent gas flow rates to within ±2% are required. NIST-traceable soap bubble flowmeters, calibrated mass flow controllers mass flowmeters, and calibrated orifice, capillary, and porous plug restrictors are suitable.

4. Mixing chamber. A glass or Teflon chamber is used to mix the CO with dilution air. The inlet and outlet should be of sufficient diameter so that the chamber is at atmospheric pressure under normal operation, and sufficient turbulence must be created in the chamber to facilitate thorough mixing. Chamber volumes in the range of 100 to 250 cm^3 are sufficient. Glass Kjeldahl connecting flasks are suitable mixing chambers.

5. Output manifold and sample line. An output manifold used to supply the analyzer with an audit atmosphere at ambient pressure should be of sufficient diameter to ensure a minimum pressure drop at the analyzer connection, and the manifold must be vented so that ambient air will not mix with the audit atmosphere during system operations. Recommended manifold materials are glass or Teflon. The sample line must be nonreactive and flexible; therefore, Teflon tubing is preferred .

6. Dilution air source. The diluent source must be free of CO and water vapor. Clean dry air from a compressed gas cylinder is suitable choices for dilution air. A catalytic oxidizer connected in line is one method of scrubbing CO from the dilution air.

7. CO gas cylinder. A compressed gas cylinder containing 100 to 200 ppm CO in an air or N_2 matrix is used as the CO dilution source. If the CO standard is contained in a N_2 matrix the zero air dilution ratio cannot be less than 100:1. This cylinder must be traceable to an NIST-SRM (number 1677, 1678 1679, 1680, or 1681).

4.5 Procedure

Equipment setup- Assemble the audit equipment as required, and verify that all the equipment is operational. If a clean dry air system equipped with a catalytic oxidizer is used, allow the oxidizer to warm up for 30 min. Connect the gas regulator to the CO cylinder, and evacuate the regulator as follows:

1. With the cylinder valve closed connect a vacuum pump to the evacuation outlet on the regulator, and start the pump.
2. Open and close the evacuation port.
3. Open and close the cylinder valve.
4. Open and close the evacuation port.
5. Repeat steps 2 through 4 five more times to be sure all 2 impurities are removed from the regulator. If the regulator does not have an evacuation port but has a supported diaphragm, the procedure can be conducted at the gas exit port..

For regulators that do not have an evacuation port but have an unsupported diaphragm, use the following procedure:

1. Connect the regulator to the cylinder, and close the gas exit port.
2. Open and close the cylinder valve to pressurize the regulator.
3. Open the gas exit port, and allow the gas to purge the regulator.
4. Repeat steps 2 and 3 five more times; then close the gas exit port, and open the cylinder valve. The regulator should remain under pressure. Connect the gas cylinder to the audit device. Repeat the procedure for each cylinder.

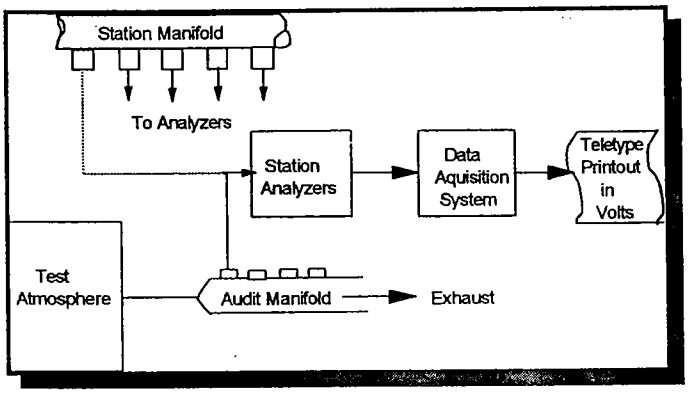


Figure A.9 Schematic of configuration utilized in auditing the gas analyzers

Audit sequence-After all the equipment has been assembled and set up, have the station operator mark the strip chart recorder to indicate that an audit is beginning. Information such as the auditor's name start time, date, and auditing organization should be entered. If it is not possible to enter written comments, the start and stop times should be recorded to preclude the use of audit data as monitoring data. After recording the data, disconnect the analyzer sample line from the station manifold, and connect it to the audit manifold, as shown in Figure A.9. Cap the sample port on the station manifold. The

audit atmosphere must be introduced through any associated filters or sample pretreatment apparatus to duplicate the path taken by an ambient sample. Record the analyzer type and other identification data on the data form (Table A-5). Conduct the audit as follows:

1. Introduce into the audit manifold a clean dry air at a flow rate in excess of 10% to 50% of the analyzer sample demand. Allow the analyzer to sample the clean dry air until a stable response is obtained; that is, until the response does not vary more than ± 2% of the measurement range over a 5-min period. Obtain the station response and concentration from the station operator, and record the data in the appropriate spaces on the data form.

Audit point	Concentration Range (ppm)
1	3-8
2	15-20
3	35-45
4	80-90

2. Generate the SLAMS audit concentrations (which are compatible with the analyzer range) as audit atmospheres consistent with the Appendix A[1] requirements.

Generate the audit concentrations by adjusting the pollutant flow rate (F_P) and the total flow rate (F_T) to provide the necessary dilution factor. Calculate the audit concentration as follows:

$$[CO] = \frac{F_P}{F_T} \times [CO]_{STD} \qquad \text{Equation 1-17}$$

where:
[CO] = audit concentration of CO, ppm
F_P = pollutant flow rate, cm^3/ min
F_T = total flow rate, cm^3/min [equal to the sum of the pollutant flow rate (F_P) and the dilution flow rate (F_D)], and
$[CO]_{STD}$ = concentration of the standard cylinder, ppm.

3. Generate the highest audit concentration level first. and consecutively generate audit points of decreasing concentrations. Allow the analyzer to sample the audit atmosphere until a stable response is obtained. Obtain the station response and concentration from the station operator, and record the data in appropriate spaces in Table A-5.

4. If desired, additional points at upscale concentrations different from those specified in step 2 may be generated. Generation of these audit concentrations plus a post audit clean dry air response will enhance the statistical significance of the audit data regression analysis

5. After supplying all audit sample concentrations and recording all data, reconnect the analyzer sample line to the station manifold. Make a notation of the audit stop time. Have the station operator make a note on the data recorder to indicate the stop time, and check all equipment to ensure that it is in order to resume normal monitoring activities.

4.6 Calculations-Record the audit data in the appropriate spaces of Table A-4.

Percent difference--The % difference is calculated as follows

$$\%\ difference = \frac{C_M - C_A}{C_A} \times 100 \qquad \text{Equation 1-18}$$

where
C_M = station-measured concentration, ppm, and
C_A = calculated audit concentration, ppm

Regression analysis--Calculate by least squares the slope, intercept and correlation coefficient of the station analyzer response data (y) versus the audit concentration data These data can be used to interpret analyzer performance.

4.7 Reference- References 4 through , 10, and 13 provide additional information on the CO audit procedure.

Table A-5 Carbon Monoxide Audit Data Report

Station _____ Date: _____

Address _____ Start Time: _____

T_A _____ °C; P_A _____ mm Hg; P_{H2O} _____ mm Hg Auditor: _____

Analyzer _____ Serial Number _____

Calibration standard _____ Span source _____

Last calibration date _____ Frequency _____ Range _____

Calibration Comments _____

Zero setting _____ Data acquisition system _____

Span setting _____ Recorder _____

Audit system _____ Bubble flowmeter serial number _____

Audit standard _____; P _____ psig; [ ] = _____ ppm

Clean, dry air _____ Catalytic oxidizer Yes No

Flow correction $\left(\frac{P_A - P_{H_2O}}{760\ mm}\right) x \left(\frac{298\ K}{T_A + 273}\right)$ = _____ = (C_F)

Dilution air flow

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____ cm3/min

T3 _____

Clean dry air response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point I

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ T _____ min $(C_F)\left(\frac{Volume}{T}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Table A-5 continued

Audit Point II

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point III

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point VI

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

Audit Point V

Pollutant flow measurement

Volume _____ cm^3 Flowmeter _____

T1 _____

T2 _____ $\bar{T}$ _____ min $(C_F)\left(\frac{Volume}{\bar{T}}\right)$ = _____ cm3/min

T3 _____

Audit concentration _____ ppm

Analyzer response _____ % Chart; _____ V_{DC}; _____ ppm

Other response _____

TableA-5 continued

Part 1

Location _____ Date _____

Analyzer/model number _____

Serial number _____ Pollutant cylinder no. _____

Auditor _____ Pollutant cylinder concentration _____

Start time _____ Stop time _____

Zero setting _____ Span setting _____ Time constant _____

Part II

Point Number	F_P, cm^3/min	F_r, cm^3/min	Audit Concentration ppm	Analyzer response	Analyzer concentration, ppm	% difference
Zero		Zero				
1						
2						
3						
4						
5						

Part III REGRESSION ANALYSIS

Analyzer response (ppm) = m (audit) + b

Slope (m) =_____ ; Intercept (b) _____; Correlation (r) = _____

Comments:

_____

5. Carbon Monoxide Audit Procedure Using Multiple Concentration Gas Cylinders

5.1 Principle-Separate compressed gas cylinders which contain various CO concentrations are supplied in excess to a vented manifold; the analyzer which is being audited samples each concentration until a stable response results.

5.2 Applicability- The procedure can be used to audit all types of CO analyzers. Concentrations of CO in the range of 0 to 100 ppm can be generated.

5.3 Accuracy-The accuracy of the audit procedure should be within ±2.5% if the CO gas cylinder concentration is referenced and if gas flow rates are determined using recommended procedures.

5.4 Apparatus-A system used to generate audit concentrations is illustrated in Figure A.10. The *six* components of the system are discussed below.

1. Gas cylinder regulator. A brass regulator is acceptable. A low dead space, two-stage regulator should be used to achieve rapid equilibration.

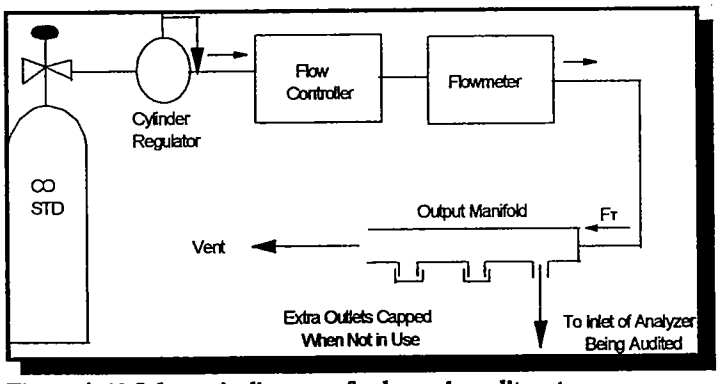


Figure A.10 Schematic diagram of a dynamic audit system

2. Flow controllers. Devices capable of maintaining constant flow rates to within ±2% are required. Suitable flow controllers include brass micro metering valves in tandem with a precision regulator, mass flow controllers, capillary restrictors, and porous plug restrictors.

3. Flowmeters. Flowmeters capable of measuring pollutant and diluent gas flow rates to within ±2% are required. NIST-traceable soap bubble flowmeters, calibrated mass flow controllers mass flowmeters, and calibrated orifice, capillary, and porous plug restrictors are suitable.

4. Output manifold and sample line. An output manifold used to supply the analyzer with an audit atmosphere at ambient pressure should be of sufficient diameter to ensure a minimum pressure drop at the analyzer connection, and the manifold must be vented so that ambient air will not mix with the audit atmosphere during system operations. Recommended manifold materials are glass or Teflon. The sample line must be nonreactive and flexible; therefore, Teflon tubing is preferred .

5. CO gas cylinder. A compressed gas cylinder containing CO in an air matrix is used as the audit gas. These cylinders must be traceable to an NIST-SRM (number 1677, 1678 1679, 1680, or 1681), and must be within the following concentration ranges: 3 to 8 ppm, 15 to 20 ppm, 35 to 45 ppm, and 80 to 90 ppm.

6. Dilution air source. The diluent source must be free of CO and water vapor. Clean dry air from a compressed gas cylinder is suitable choices for dilution air. A catalytic oxidizer connected in line is one method of scrubbing CO from the dilution air.

5.5 Procedure

Equipment setup- Assemble the audit equipment as required and verify that all the equipment is operational. If a clean dry air system equipped with a catalytic oxidizer is used for a zero air source, allow the oxidizer to warm up for 30 min. Connect the gas regulator to a CO cylinder, and evacuate the regulator as follows:

1. With the cylinder valve closed, connect a vacuum pump to the evacuation outlet on the regulator and start the pump.
2. Open and close the evacuation port.
3. Open and close the cylinder valve.
4. Open and close the evacuation port.
5. Repeat steps 2 through 4 five more times to be sure all O_2 impurities are removed from the regulator. If the regulator does not have an evacuation port but has a supported diaphragm, the procedure can be conducted at the gas exit port.

For regulators that do not have an evacuation port but have an unsupported diaphragm, use the following procedure:

1. Connect the regulator to the cylinder, and close the gas exit port.
2. Open and close the cylinder valve to pressurize the regulator.
3. Open the gas exit port, and -allow the gas to purge the regulator.
4. Repeat steps 2 and 3 five more times; then close the gas exit port, and open the cylinder valve. (The regulator should remain under pressure.) Connect the gas cylinder to the audit device.

Repeat the procedure for each cylinder.

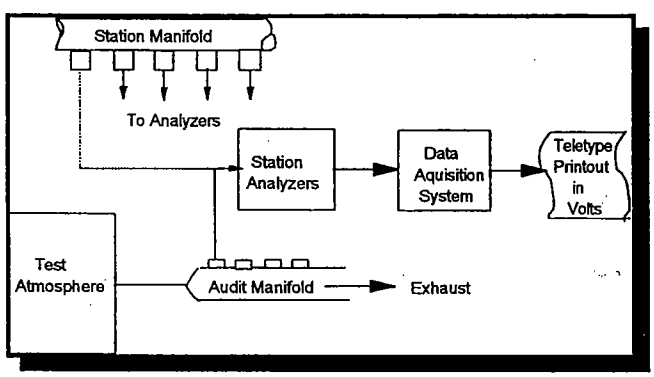


Figure A.11 Schematic of configuration in auditing the gas analyzers

Audit sequence--After all the equipment has been assembled and set up, have the station operator mark the strip chart recorder to indicate that an audit is beginning. Information such as the auditor's name, start time, date, and auditing organization should be entered. If it is not possible to enter written comments, the Start and stop times should be recorded to preclude the use of audit data as monitoring data. After recording the data, disconnect the analyzer sample line from the station manifold, and connect it to the audit manifold, as shown in Figure A.11. Cap the sample port on the station manifold. The audit atmosphere must be introduced through any associated filters or sample pretreatment apparatus to duplicate the path taken by an ambient sample. Record the analyzer type and other identification data on the data form (Table A-6).

Conduct the audit as follows:

1. Introduce into the audit manifold a zero air gas at a flow rate in excess of 10% to 50% of the analyzer sample demand. Allow the analyzer to sample the zero air until a stable response is obtained; that is, until

the response does not vary more than +2% of the measurement range over a 5-min period. Obtain the station response and concentration from the station operator, and record the data in the appropriate spaces on the data form.

2. Generate the SLAMS audit concentrations (which are compatible with the analyzer range) as audit atmospheres consistent with the Appendix A[1] requirements.

Audit point	Concentration range, (ppm)
1	3-8
2	15-20
3	35-45
4	80-90

3. Generate the highest audit concentration level first, and consecutively generate decreasing concentrations. The audit concentration equals the CO gas cylinder concentration.

4. If desired, additional points at upscale concentrations different from those specified in step 2 may be generated. Generation of these audit concentrations plus a post audit clean dry air response will enhance the statistical significance of the audit data regression analysis.

5. After supplying all audit concentrations and recording all data, reconnect the analyzer sample line to the station manifold. Make a notation of the audit stop time. Have the station operator make a note on the data recorder to indicate the stop time, and check all equipment to ensure that it is in order to resume normal monitoring activities.

5.6 Calculations-Record the audit data in the appropriate spaces of Table A-4.

Percent difference--The % difference is calculated as follows:

$$\%\ difference = \frac{C_M - C_A}{C_A} \times 100 \qquad \text{Equation 1-19}$$

where:
C_M = station-measured concentration, ppm, and
C_A = calculated audit concentration, ppm

Regression analysis--Calculate by least squares the slope, intercept and correlation coefficient of the station analyzer response data (y) versus the audit concentration data These data can be used to interpret analyzer performance.

5.7 References-References 4 through 6, 10, and 13 provide additional information on the CO audit procedure.

Table A-6 Carbon Monoxide Audit Data Report

Part 1

Location _____ Date _____

Analyzer/model number _____

Serial number _____ Pollutant cylinder no. _____

Auditor _____ Pollutant cylinder concentration _____

Start time _____ Stop time _____

Zero setting _____ Span setting _____ Time constant _____

Part II

Point Number	Audit cylinder number	NIST reference conc. ppm	Analyzer response	Analyzer concentration , ppm	% difference
Zero	Zero				
1					
2					
3					
4					
5					

Part III REGRESSION ANALYSIS

Analyzer response (ppm) = m (audit) + b

Slope (m) =_____ ; Intercept (b) _____; Correlation (r) = _____

Comments:

6. Ozone Audit Procedure Using Ultraviolet Photometry

6.1 Principle- O_3 concentrations are generated by using a UV generator (transfer standard), and each atmosphere is verified by using UV photometry. The UV photometry procedure for O_3 audits is based on the Lambert-Beer absorption law:

$$Transmittance = \frac{I}{I_O} = e^{-acl} \qquad \text{Equation 1-20}$$

where:
a= the absorption coefficient of O_3 at 254 nm = 308 $\pm$ 4atm^{-1} cm^{-1} at 0° C and 760 torr,
c= the O_3 concentration, atm and
l= the optical path length, cm.

6.2 Applicability- The procedure can be used to audit all types of commercially available O_3 analyzers which operate in a range of 0 to 1ppm

6.3 Accuracy- The accuracy of the audit procedure should be within $\pm$ 2.5% if the O_3 source is a photometer or transfer standard, and flow rates are determined to using EPA-recommended procedures.

6.4 Apparatus- An UV photometric system which is used for auditing O_3 analyzers is illustrated in Figure A.12. The system consists of an O_3 source and a standard UV photometer. Components of the system are discussed below.

1. Ozone generator. An O_3 generator that produces a stable O_3 concentration is required. An UV lamp generator is recommended.

2. Flow controllers. Devices capable of maintaining constant flow rates to within $\pm$2% are required. Suitable flow controllers include brass micro metering valves in tandem with a precision regulator, mass flow controllers, capillary restrictors, and porous plug restrictors.

3. Flowmeters. Flowmeters capable of measuring pollutant and diluent gas flow rates to within $\pm$2% are required. NIST-traceable soap bubble flowmeters, calibrated mass flow controllers mass flowmeters, and calibrated orifice, capillary, and porous plug restrictors are suitable

4. Mixing chamber. A glass or Teflon chamber is used to mix the O_3 with dilution air. The inlet and outlet should be of sufficient diameter so that the chamber is at atmospheric pressure under normal operation, and sufficient turbulence must be created in the chamber to facilitate thorough mixing. Chamber volumes in the range of 100 to 500 cm^3 are sufficient. Glass Kjeldahl connecting flasks are suitable mixing chambers.

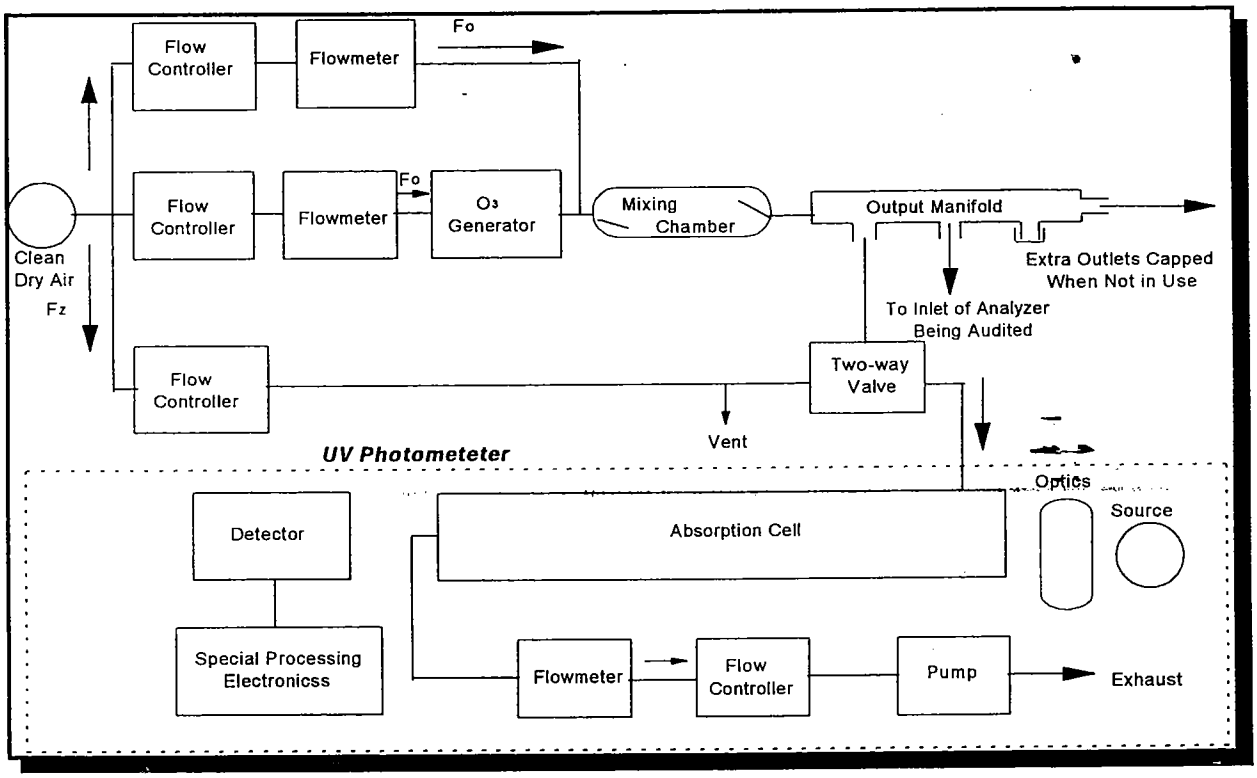


Figure A.12 Schematic diagram of an ultraviolet photometric audit system

5. Output manifold. An output manifold used to supply the analyzer with an audit atmosphere at ambient pressure. The manifold should be of sufficient diameter to ensure minimum pressure drop at the output ports, and the manifold must be vented so that ambient air will not mix with the audit atmosphere during system operations. Recommended manifold materials are glass or Teflon.

6. Sample line and connecting lines. The sample lines and connecting lines downstream of the O_3 generator must be made of non-reactive material such as Teflon.

7. Dilution air system. Clean dry air from a compressed gas cylinder (Grade 0.1) is a suitable source of dilution air; however, if large volumes of air (5 liters/min or greater) are required, purified compressed air is preferred. The clean dry air must be free of contaminants, such as such as NO, NO_2, O_3 or reactive hydrocarbons that would cause detectable responses on the NO_X analyzer or that might react with NO or NO_2 in the audit system. The air can be purified to meet these specifications by passing it through silica gel for drying, by treating it with O_3 to convert any NO to NO_2, and by passing it through activated charcoal (6-14 mesh) and a molecular sieve (6-16 mesh, type 4A) to remove NO_2, O_3, or hydrocarbons.

Silica gel maintains its drying efficiency until it has absorbed 20% of its weight; it can be regenerated indefinitely at 120 C. Addition of cobalt chloride to the surface of the gel provides a water absorption indicator. A transparent drying column is recommended. The activated charcoal and molecular sieve have a finite absorption capability; because it is difficult to determine when the capability has been exceeded, both should be replaced either before each audit or after 8 hrs of use.

8. Ultraviolet photometer- The UV photometer consists of a low-pressure mercury discharge lamp, collimator optics, an absorption cell, a detector, and signal-processing electronics. as illustrated in Figure A.12. The photometer must be capable of measuring the transmittance, I/I_O, at a wavelength of 254 NM with sufficient precision for the standard deviation of concentration measurements not to exceed the greater of 0.005ppm or 3% of the concentration. Because the low pressure mercury lamp radiates at several wavelengths, the photometer must incorporate suitable means to be sure that no O_3 is generated in the cell by the lamp and at least 99.5% of the radiation sensed by the detector is 254-nm radiation. This goal can be achieved by prudent selection of the optical filter and detector response characteristics. The length of the light path through the absorption cell must be known with an accuracy of at least 99.5% In addition, the cell and associated plumbing O_3 from contact with cell walls and gas handling components.

9. Barometer. A barometer with an accuracy of ± torr is required to determine the absolute cell pressure.

10. Temperature indicator. A temperature indicator accurate to ±1° C is required to determine cell temperature.

6.5 Procedure

Equipment setup- Assemble the audit equipment according to figure A.12. Allow the photometer and O_3 generator to warm up for approximately 1 h or until the normal operating cell temperature, 6° to 8° C above ambient, is attained.

Photometer adjustment (Dasibi)- Several checks are made after the photometer has reached normal operating temperature.

1. Switch the photometer to sampling frequency. Using Table A-7, record and calculate the mean of five consecutive readouts. The mean sample frequency should be between 45.0 and 49.0.
2. Switch the photometer to control frequency. Using table A-7, record and calculate the mean of five consecutive readouts. the mean control frequency should be between 23.0 and 28.0
3. Switch the photometer to span. Record this span number and calculate the new span number as follows.

$$Span\ number = 45.684\ x \left(\frac{760}{P_b}\right) x \left(\frac{T_c + 273.16}{273.16}\right) \qquad \text{Equation 1-21}$$

where:
P_b = barometric pressure, mm Hg, and
T_c = cell temperature ,° C.

Dial in the new span number on the photometer, and display the correct entry.

4. Switch the selector to the operate position, and adjust the flowmeter to 2 l/min. Using the offset adjust control on the front panel of the photometer, set the instrument to read between 0.005 and 0,010 while sampling clean dry air.

5. Determine the true zero display reading by recording 10 consecutive display updates from the panel meter. Calculate the mean of these 10 readings.

Audit sequence-Adjust the clean dry airflow rate through the O_3 generator to meet the range specifications. of the station analyzer and the O_3 output capability of the generator. Adjust the dilution clean dry air flow rate pf 10 to 50% of the station analyzer and photometer sample demand is generated. Mark the data acquisition system to indicate that an audit is beginning, and disconnect the sample line from the station manifold. Plug the disconnected sample port to the station manifold.

2. Connect the audit analyzer and photometer to the output manifold as shown in Figure A.12. Allow the station analyzer and photometer to sample the clean dry air until the station response is obtained; That is, until the response does not vary by more then $\pm$ 2% of the measurement range over a 5-min period. Obtain the analyzer response from the station operator, and record the data and the photometer response in the appropriate spaces in table A-7.

3. Generate the following SLAMS audit concentrations (which are compatible with the analyzer range) as audit atmospheres consistent with the Appendix A[1] requirements.

Audit point	Concentration range, (ppm)
1	0.03 - 0.08
2	0.15 - 0.20
3	0.35 - 0.45
4	0.80 - 0.90

Record ten consecutive display updates of the photometer for each audit point. Calculate and record the mean of these ten updates. Record the station analyzer response. Both the photometer and station analyzer readings should be taken only after a stable response is exhibited by both instruments. Calculate the audit concentrations:

$$[O_3] = R_D - R_Z. \quad \text{Equation 1-22}$$

where:
$[O_3]$ = the audit concentration of O_3, ppm,
R_D = the mean of the 10 photometer display updates, and
R_Z = the average photometer clean dry air offset

4. Generate the highest audit concentration level first by adjusting the O_3 output of the generator, the amount of dilution air, or the amount of clean dry air flowing through the generator. Then consecutively generate the decreasing concentrations.

5. If desired, additional points at upscale concentrations different from those specified in step 3 may be generated. Generation of these audit concentrations plus a post audit clean dry air response will enhance the statistical significance of the audit data regression analysis.

6. After supplying all audit concentrations and recording all data, reconnect the analyzer sample line to the station manifold. Make a notation of the audit stop time. Have the station operator make a note on the data recorder to indicate the stop time, and check all equipment to ensure that it is in order to resume normal monitoring activities.

6.6 Calculations-Record the audit data in the appropriate spaces of Table A-4.

Percent difference--The % difference is calculated as follows:

$$\%\ difference = \frac{C_M - C_A}{C_A} \times 100 \qquad \text{Equation 1-23}$$

where:
C_M = station-measured concentration, ppm, and
C_A = calculated audit concentration, ppm

Regression analysis--Calculate by least squares the slope, intercept and correlation coefficient of the station analyzer response data (y) versus the audit concentration data These data can be used to interpret analyzer performance.

Table A-7 Ozone Audit Data Report

Station _____ Date: _____

Address _____ Start Time: _____

T_A _____ °C; P_A _____ mm Hg; P_{H2O} _____ mm Hg Auditor: _____

Analyzer _____ Serial Number _____

Calibration standard _____ Span source _____

Last calibration date _____ Frequency _____ Range _____

Calibration Comments _____

Zero setting _____ Data acquisition system _____

Span setting _____ Recorder _____

Audit system _____ Serial number _____

Clean, dry air _____

Sample frequency _____ Cell temperature (T_C) _____ °C

Control frequency _____

Span number calculation: $45.684 \; x \left(\frac{760 \; mm}{P_A} \right) x \left(\frac{T_C + 273}{273} \right) =$ _____

Observed span number _____

Dilution air

Photometer display _____ _____ _____ _____

_____ _____ _____ _____ _____ _____

Average _____

Analyzer response _____ Chart; _____ V_{DC}; _____ ppm

Other Response _____

Audit Point I

Photometer display _____ _____ _____ _____

_____ _____ _____ _____ _____ _____

Average _____

Analyzer response _____ Chart; _____ V_{DC}; _____ ppm

Other Response _____

Audit Point II

Photometer display _____ _____ _____ _____

_____ _____ _____ _____ _____ _____

Average _____

Analyzer response _____ Chart; _____ V_{DC}; _____ ppm

Other Response _____

Audit Point III

Photometer display _____ _____ _____ _____

_____ _____ _____ _____ _____ _____

Average _____

Analyzer response _____ Chart; _____ V_{DC}; _____ ppm

Other Response _____

Audit Point IV

Photometer display _____ _____ _____ _____

_____ _____ _____ _____ _____ _____

Average _____

Analyzer response _____ Chart; _____ V_{DC}; _____ ppm

Other Response _____

Audit Point V

Photometer display _____ _____ _____ _____

_____ _____ _____ _____ _____ _____

Average _____

Analyzer response _____ Chart; _____ V_{DC}; _____ ppm

Other Response _____

Point Number	Audit concentration, ppm	Analyzer		
		Response	Concentration ppm	% difference
1				
2				
3				
4				
5				
6				

Regression (y = mx + b)
Analyzer response (ppm) = m(audit) + b Slope(m) = _____ Intercept (b) = _____ Correlation (r)= _____

7. Total Suspended Particulate Sampler Audit Procedure Using a Reference Flow Device (ReF)

7.1 Principle-An ReF device is one type of orifice transfer standard and is used to audit a TSP hi-vol sampler. The ReF device uses orifice plates to audit the sampler flow rate by measuring the pressure drop caused by the flow of air through a restricting orifice. A calibration equation is used to translate this pressure drop into a flow rate at either standard or actual conditions.

7.2 Applicability- The procedure can be used to audit hi-vol samplers with or without flow controllers operating in the flow range of 0.5 to 2.4 std m^3/min. Other types of orifice transfer standards may be used following the same procedures.

7.3 Accuracy-The accuracy of the audit procedure is approximately 2% when traceability is established by calibrating the ReF device to a Rootsmeter or other primary volume measurement device.

7.4 Apparatus-

1.ReF device- An ReF device is an interfacing unit that attaches to the filter holder of a TSP hi-vol sampler. The device typically exhibits a sensitivity of 0.01 m^3/ min per 0.1-in. pressure change. The ReF device is equipped with five air-restricting orifice plates which are used one at a time to vary the flow rate of the hi-vol sampler. A slack tube water manometer accompanies the ReF device and measures the pressure drop caused by the flow restriction of the plates. A cylindrical plexiglass windflow deflector should be attached to the top of the ReF device to protect it from ambient air flow.

2. Differential manometer--A tube manometer capable of measuring at least 16 in. of water is required.

3. Barometer--A barometer capable of measuring atmospheric pressure with an accuracy of ± 2 torr is required.

4. Temperature indicator--An indicator accurate to ± 1 C is required to determine ambient temperature.

5 Glass fiber filter--Glass fiber filters with at least 99% efficiency for collection of 0.3-um diameter particles are suitable.

7.5 Procedure-

Samplers equipped with flow controllers--A hi-vol sampler equipped with a flow controller is typically calibrated in terms of standard flow rate. Audit calculations are performed as shown in Section 12.11.6. Note: It is imperative to know whether the hi-vol was calibrated in terms of actual conditions at the time of calibration, seasonal average conditions, or the flow rates have been corrected to standard temperature and pressure. The comparison between audit and station flow rates MUST be made with the same units and corrections.

Conduct the audit as follows:

1. Remove the filter holder clamp from the sampler. If a filter is in place for an upcoming sampling period, have the station operator remove the filter and store it until the audit is completed. Attempt to schedule audits so they do not interfere with normal sampling runs.
2. Place a clean glass fiber filter on the filter screen, and place the ReF device on top of the filter. Securely fasten the ReF device to the holder using the four wingnuts at each corner of the sampler filter holder.

3. With no resistance plate in the ReF device, close the lid and fasten it using the two wingnuts. Place the wind deflector in position, and then connect and zero the water manometer.
4. Start the sampler motor and allow it to stabilize. A warm-up time of 25 min should be allowed. Record the pressure drop shown on the manometer (in. H2O), ambient temperature l C), barometric pressure (mm Hg), and station flow rate (obtained from the station operator) on the data form in Table A-8. If the barometric pressure cannot be determined by an audit barometer (because of high elevations that exceed the limits of the barometer), determine the barometric pressure (PA) as follows:

PA = 760 - (elevation in meters x 0.076). Equation 1-24

5. At the conclusion of the audit, have the station operator replace the filter and reset the sampler timer as it was before the audit.

Samplers without flow controllers --A hi-vol sampler not equipped with a constant flow controller is typically calibrated in terms of actual flow rates. Audit calculations are performed as shown in Subsection 7.6.

Note: It is imperative to know whether the hi-vol was calibrated in terms of actual conditions at the time of calibration, seasonal average conditions, or the flow rates have been corrected to standard temperature and pressure. The comparison between audit and station flow rates MUST be made with the same units and corrections.

Conduct the audit as follows.:
1. Remove the filter holder clamp from the sampler. If a filter is in place for an upcoming sampling period, have the station operator remove the filter and store it until the audit is completed. Attempt to schedule audits so they do not interfere with normal sampling runs.
2. Place the ReF device on the filter holder, and secure the device to the holder by tightening the four wingnuts at each corner of the sample filter holder.
3. Place the 18-hole resistance plate in the ReF device, close the lid, and fasten the lid using the two wingnuts. Place the wind deflector in position, and then connect and zero the water manometer.
4. Start the sampler motor and allow it to stabilize. A warm-up time of ~5 min should be allowed. Record the pressure drop shown on the manometer (in. H2O), ambient temperature (C), barometric pressure (mm Hg), and station flow rate (obtained from the station operator) on the data form in Table A-8. If the barometric pressure cannot be determined by an audit barometer (because of high elevations that exceed the limits of the barometer), determine the barometric pressure by using Equation A-24.
5. Repeat steps 3 and 4 using the remaining resistance plates.
6. At the conclusion of the audit, have the station operator replace the filter and reset the sampler timer as it was before the audit.

7.6 Calculations

Calculate the audit flow rate at standard conditions for those hi-vols with flow rates corrected to standard temperature and pressure.

$$Q_{STD} = \frac{1}{m}\left[\sqrt{\Delta H\left(\frac{P_b}{760}\right)\left(\frac{298}{T_a}\right)} - b\right] \qquad \text{Equation 1-25}$$

where:
Q_{STD} =standard flow rate, m3/min
m and b =calibration coefficients determined during calibration of the ReF device, using flow rates corrected to standard conditions
ΔH = pressure drop shown on the manometer, in. H_2O
Pb = barometric pressure, mm Hg, and
T_a = ambient temperature in degrees Kelvin (273.16 + C)

Perform this calculation for each flow rate comparison and calculate the % difference for each audit point as follows:

$$\%\ difference = \frac{F_S - F_A}{F_A} \times 100 \qquad \text{Equation 1-26}$$

where:
F_S = the station-measured flow rate, std m^3/min, and
F_A = the audit flow rate, std m^3/min.

For samplers calibrated in terms of actual or seasonal average conditions, calculate the audit flow rate in terms of actual conditions:

$$Q_{ACT} = Q_{STD}\left(\frac{760}{P_b}\right)\left(\frac{T_a}{298.16}\right) \qquad \text{Equation 1-29}$$

where:
Q_{ACT} = the actual flow rate, m^3/min
Q_{STD} = the standard flow rate, m^3/min
P_b = the barometric pressure, mm Hg, and
T_a = the ambient temperature in degrees Kelvin (273.16 + C).

Note: If seasonal temperature and barometric pressure were used in the calibration of the hi-vol sampler, then:

P_b = seasonal barometric pressure, mm Hg, and
T_a = seasonal ambient temperature in degrees Kelvin (273.16 + C)

convert from m^3/min to ft^3/min by multiplying by 35.31.

7.7 References- References 8 and 9 provide additional information on the TSP audit procedure.

Table A-8 Hi-vol Sampler Audit Data Report

Station location _____

Date _____ Barometric pressure _____

Time _____ Temperature _____

Sampler serial number _____ Serial number _____

Flow controller number _____

Plate Number	Audit manometer reading in. H_2O	Audit Flow	Analyzer		Difference	
			Response	Flow	m^3/min	%
No plate						
18						
13						
10						
7						
5						

Audit device ID number _____ Regression coefficient

Q_{std}; Slope (m) = _____ Intercept (b) = _____

$Q_{ac}t$; Slope (m) = _____ Intercept (b) = _____

Other information:

Audited by: _____ Authorized by : _____

8 Data Interpretation

Interpretation of quality assurance audit results is not well defined, and audit data must be assembled and presented so that interpretation is possible. Subsection 8.1 discusses the data reporting requirements specified in Appendix A1. In addition to these requirements, optional data interpretation methods, including case examples, are in Subsection 8.2.

8.1 SLAMS Reporting Requirements- Reference 1 specifies the minimum data reporting procedures for automated and manual methods. Compare the station responses obtained for each audit point.

$$\%\ difference = \frac{C_M - C_A}{C_A} \times 100 \qquad \text{Equation 1-29}$$

where:
C_M = station-measured concentration, ppm, and
C_A = calculated audit concentration,

This comparison indicates the % difference for each audit concentration generated and each analyzer response recorded.

Table A-9 contains example audit data for an SO_2 analyzer operating on a 0- to 0.5-ppm range. As indicated by the data set, the station analyzer shows a negative deviation of approximately 4% when compared to the audit concentrations.

Table A-9. Example Audit Data for an SO_2 Analyzer

SLAMS concentration range ppm	Audit concentration ppm	Station analyzer response, ppm	% difference
0.03 to 0.08	0.044	0.042	-4.6
0.15 to 0.20	0.165	0.159	-3.6
0.35 to 0.45	0.412	0.394	-4.4

A % difference calculation is used to evaluate manual method audit data. For example, a hi-vol sampler with a flow controller is audited using an ReF device. A one-point audit is performed at the normal operating flow rate with a glass fiber filter on the device. The audit and station flow rates are compared on the basis of % difference using Equation 1-29 and are designated as C_A and C_M, respectively.

Table A-10 Least Squares Calculations

$$\bar{x} = \text{average } x \text{ value} = \frac{x}{N}$$

$$\bar{y} = \text{average } y \text{ value} = \frac{y}{N}$$

$$\text{slope} = m = \frac{xy - \frac{x\ y}{N}}{x^2 - \frac{(\ x)^2}{N}}$$

$$\text{intercept} = b = \bar{y} - m\bar{x}$$

$$\text{correlation coefficient} = r = \frac{ms_x}{S_y}$$

$$S^2_y = \text{variance of the } y \text{ values} = \frac{\left[\frac{y^2}{N} - \bar{y}^2\right]}{(N-1)}$$

$$S^2_x = \text{variance of the } x \text{ values} = \frac{\left[\frac{x^2}{N} - \bar{x}^2\right]}{(N-1)}$$

8.2 Least Squares

The data analysis described in Appendix A[1] calculates the % accuracy of the audit data at specific operating levels within an analyzer's range. Because this method compares the operating differences at a maximum of four points, its use in determining overall analyzer performance is limited.

With an increase in the number and range of audit points generated, linear regression analysis can be used to aid in evaluating analyzer performance data. This method involves supplying a zero concentration and five upscale concentrations corresponding to approximately 10%, 20%, 40%, 60%. and 90% of the analytical range. The regression coefficients are calculated by designating the audit concentration (ppm) as the abscissa (x variable) and the station analyzer response (ppm) as the ordinate (y variable). The resultant straight line (y = mx + b) minimizes the sum of the squares of the deviations of the data points from the line.

Table A.11 Linear Regression Criteria

Slope		
Excellent	≤ ± 5%	between analyzer response and audit conc.
Satisfactory	± 6%- ± 15%	between analyzer response and audit conc.
Unsatisfactory	> ± 15%	between analyzer response and audit conc.
Intercept		
Satisfactory	≤ ± 3%	of analyzer range
Unsatisfactory	> ± 3%	of analyzer range
Correlation coefficient		
Satisfactory	0.9950 to (1.0000)	linear analyzer response to audit conc.
Unsatisfactory	<0.9950	nonlinear analyzer response to audit conc.

Table A-10 summarizes the calculations by the method of least squares, and Table A-11 lists criteria which may be used to evaluate the regression data in terms of analyzer performance. The slope and intercept describe the data set when fitted to a line; the correlation coefficient describes how well the straight line fits the data points. Presently

Point No	Audit Conc. (ppm)	Station Conc. (ppm)	% Difference
1	.000	.000	-
2	.044	.042	-4.6
3	.103	.098	-4.9
4	.165	.159	-3.6
5	.294	.283	-3.7
6	.412	.394	-4.4

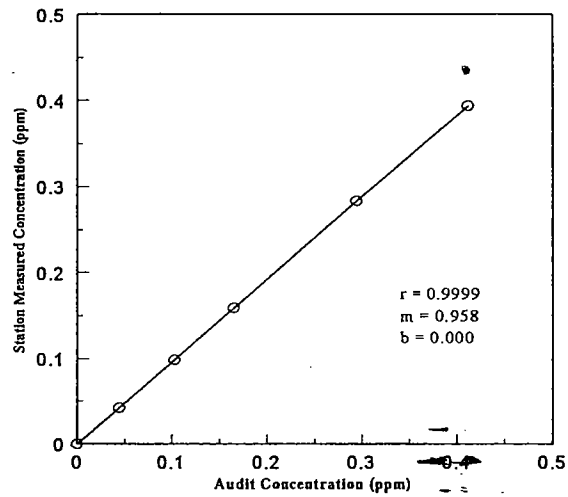


Figure A.13 Example of audit data regression analysis

there are no published criteria for judging analyzer performance. Criteria are normally specified by the operating agency. Figure A.13 shows an example audit data set that is analyzed both by the % difference and least squares technique.

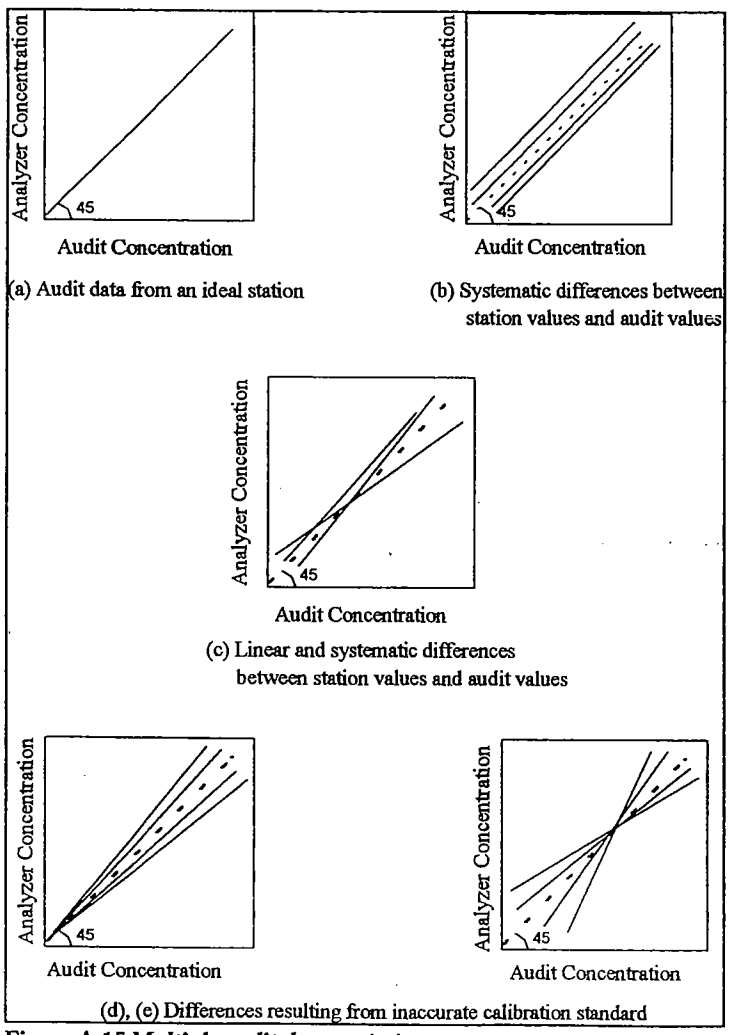


Figure A.15 Multiple audit data variations

The slope shows an average difference of -4.2% which agrees with the % difference data. The zero intercept of 0.000 agrees with the analyzer response during the audit; this indicates a nonbias response. The correlation coefficient of 0.9999 indicates a linear response to the audit points. It can be deduced that the % difference of the slope index is caused by the calibration source (i.e., the standard pollutant source, flow measurement apparatus, and the dilution air source). Figure A.14 illustrates data variations which may be encountered when auditing a monitored network.

Figure A.14(a) represents audit results in which the analyzer response agrees perfectly with the generated audit concentrations. Figure A.14(b) represents data from a group of stations showing constant systematic differences, (i.e., differences independent of concentration levels between stations and between stations and the audit system).

A network of stations showing linear systematic differences that may or may not be independent of concentration is shown in Figure A.14 (c). This example is more representative of audit data resulting from a network of stations. Figure A.14(d) and

A.14(e) illustrates two special cases of the general case shown in Figure A.14(c). Analysis of the data for a grouping of stations, such as for a given State, not only yields precision and accuracy estimates but may also provide clues as to the proper corrective action to take if larger than acceptable differences are observed. For example, Figure A.14(d) shows constant relative differences within stations that vary among stations. Such data patterns can result, for example, from errors in the calibration standards if high concentration cylinders and dilution are used for calibration. Constant systematic (absolute) differences (within stations), such as Figure A.14(b), may indicate contaminated zero and dilution air, in which case all results would tend to be on one side of the 45° line. Figure A.14(e) illustrates a case in which stations were calibrated using a high concentration span level, but not multipoint concentrations or zero point.

The use of regression analysis is not as straightforward when the intercept is significantly different from zero and/or the correlation is low (<0.995). In these instances, the auditor must rely on his experience to draw conclusions about the cause of a high or low intercept, a low correlation, and the subsequent meaning of the results. The five most commonly encountered audit cases are discussed in the following subsections.

Case 1--The data set and data plot in Figure A.15 illustrates a case in which the % difference and the linear regression analysis of audit data must be used jointly to characterize analyzer performance. Inspection of the % difference for each audit point shows large negative differences at the low concentrations and small differences at the upper concentrations. The slope of the regression line indicates an overall slope of +2.2% and a significant intercept of -0.014. The following statements apply to the regression data: 1. Analyzer zero drift may have occurred. 2. The dilution air source used to calibrate the analyzer has a bias (not of sufficient purity). 3. The calibration procedure used by the operator is not correct.

Data for figure A.15

Point No.	Audit Concentration (ppm)	Station Concentration (ppm)	% Difference
1	.000	-.013	-
2	.053	.043	-18.9
3	.119	.103	-13.5
4	.222	.208	- 6.3
5	.269	.263	- 2.2
6	.396	.392	- 1.0

A similar data set is frequently encountered when auditing analyzers that use a calibration system supplying scrubbed ambient air as the diluent source. High ambient concentrations of impurities are often difficult to remove from ambient air without the addition of auxiliary scrubbers. Spent sorbent materials may also generate impure dilution air which causes a detectable absolute analyzer response bias during the audit.

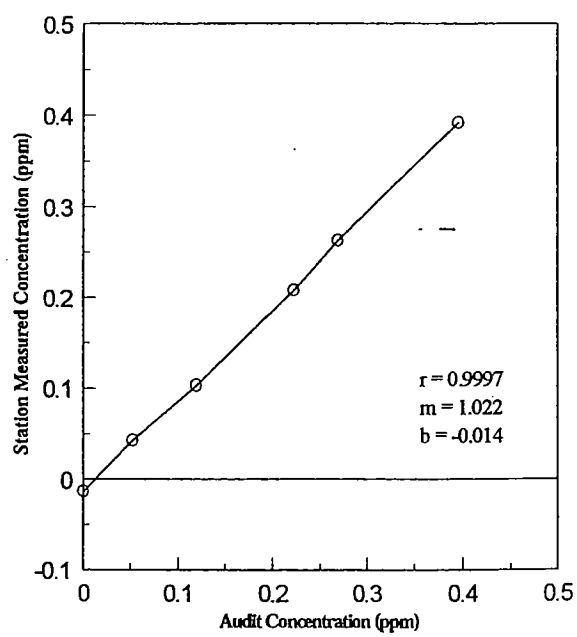


Figure A.15. Audit data interpretation- Case 1.

Case 2--Figure A.16 shows that Case 2 is similar to Case 1, but the zero response is accurate. The percent data range from large negative differences at low concentration levels to negligible differences at high concentration levels. However, the regression slope indicates a difference of 0.2% between the audit concentrations and analyzer responses and a zero intercept of -0.009. Inspection of the individual differences indicates either a nonlinear response or a true negative zero response. Recalculation of the regression coefficients, excluding the zero audit data, indicates the true zero lies at approximately -0.016 ppm.

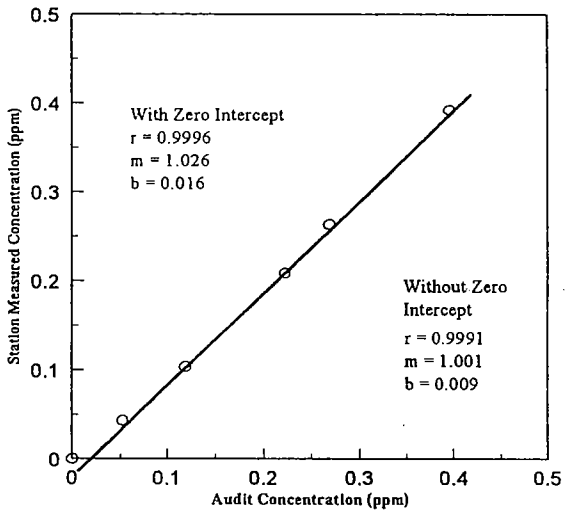


Figure A.16 Audit data interpretation- Case 2

Data for Figure A.16

Point No.	Audit Concentration (ppm)	Station Concentration (ppm)	% Difference
1	.000	.000	-
2	.053	.043	-18.9
3	.119	.103	-13.5
4	.222	.208	- 6.3
5	.269	.263	- 2.2
6	.396	.392	- 1.0

This situation is most commonly encountered when auditing analyzers that use log amplifiers, logic counter circuitry, or data loggers that are incapable of recording a negative response. Flame photometric and UV photometric analyzers may exhibit audit data of this kind.

Case 3--Figure A.17 illustrates a data set which indicates a positive response to the audit zero air concentration. An inspection of the % difference data shows a large positive difference at the lower audit concentrations and negligible differences at the higher audit concentrations. The slope of the regression line indicates a difference between the audit concentrations and analyzer responses of -2.0% with an intercept that is not significantly different from the zero-air response. The data indicate that the audit zero-air source has a positive bias or the problem may be caused by analyzer positive zero drift.

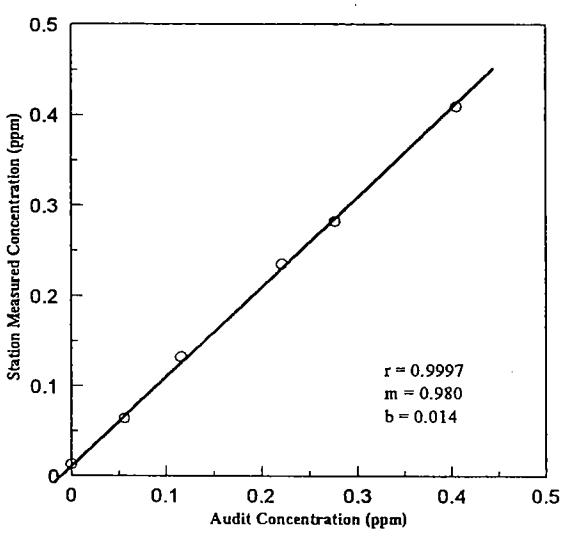


Figure A.17 Audit data interpretation- Case 3

Data for Figure A.17

Point No.	Audit Concentration (ppm)	Station Concentration (ppm)	% Difference
1	.000	.013	-
2	.053	.064	14.3
3	.119	.132	13.8
4	.222	.235	6.3
5	.269	.282	2.2
6	.396	.409	1.0

Case 2--Figure A.16 shows that Case 2 is similar to Case 1, but the zero response is accurate. The percent data range from large negative differences at low concentration levels to negligible differences at high concentration levels. However, the regression slope indicates a difference of 0.2% between the audit concentrations and analyzer responses and a zero intercept of -0.009. Inspection of the individual differences

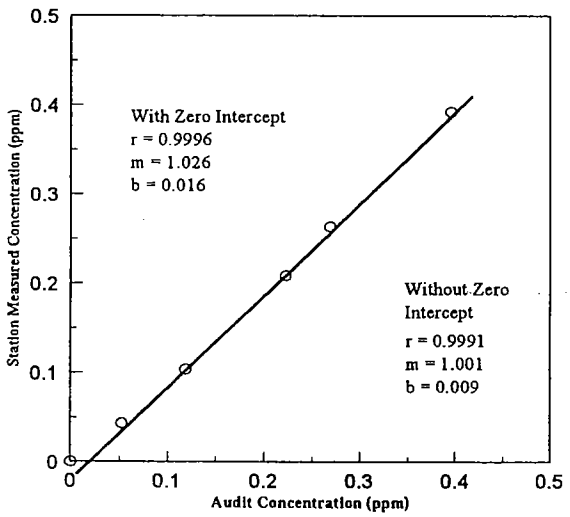


Figure A.16 Audit data interpretation- Case 2

Data for Figure A.16

Point No.	Audit Concentration (ppm)	Station Concentration (ppm)	% Difference
1	.000	.000	-
2	.053	.043	-18.9
3	.119	.103	-13.5
4	.222	.208	- 6.3
5	.269	.263	- 2.2
6	.396	.392	- 1.0

indicates either a nonlinear response or a true negative zero response. Recalculation of the regression coefficients, excluding the zero audit data, indicates the true zero lies at approximately -0.016 ppm.

This situation is most commonly encountered when auditing analyzers that use log amplifiers, logic counter circuitry, or data loggers that are incapable of recording a negative response. Flame photometric and UV photometric analyzers may exhibit audit data of this kind.

Case 3--Figure A.17 illustrates a data set which indicates a positive response to the audit zero air concentration. An inspection of the % difference data shows a large positive difference at the lower audit concentrations and negligible differences at the higher audit

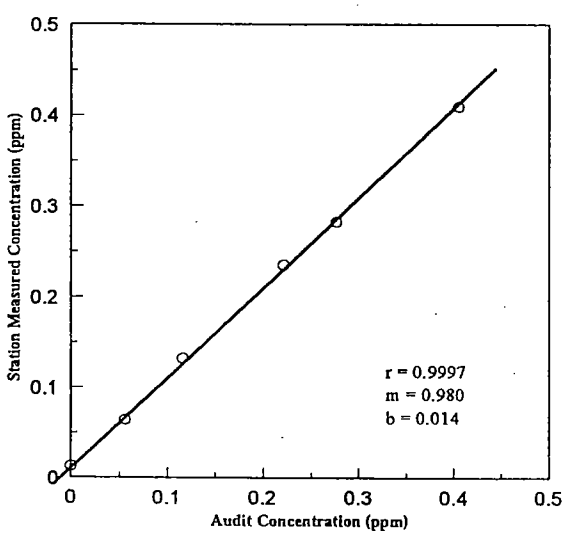


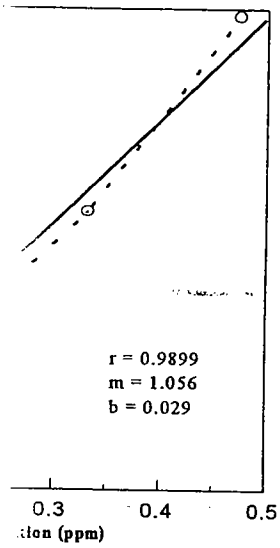
Figure A.17 Audit data interpretation- Case 3

Data for Figure A.17

Point No.	Audit Concentration (ppm)	Station Concentration (ppm)	% Difference
1	.000	.013	-
2	.053	.064	14.3
3	.119	.132	13.8
4	.222	.235	6.3
5	.269	.282	2.2
6	.396	.409	1.0

concentrations. The slope of the regression line indicates a difference between the audit concentrations and analyzer responses of -2.0% with an intercept that is not significantly different from the zero-air response. The data indicate that the audit zero-air source has a positive bias or the problem may be caused by analyzer positive zero drift.

8 illustrate a nonlinear analyzer response. An operating organization may not
analyzer is calibrated using only a zero and one upscale span concentration.
nonlinear fashion, the audit data will show varying percent differences and
show a low correlation coefficient and possibly a significant zero intercept.
ted analyzer nonlinearity.

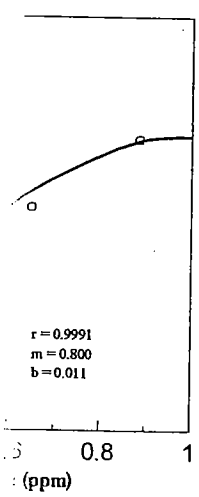


n- Case 4

Data for Figure A.18

Point No.	Audit Concentration (ppm)	Station Concentration (ppm)	% Difference
1	.000	.000	-
2	.072	.064	-25.0
3	.114	.080	-29.8
4	.183	.134	-26.8
5	.332	.296	-10.8
6	.474	.503	6.2

Case 5--The data illustrated in Figure A.19 show the results of an audit performed on a NO_X analyzer. The regression coefficients show an overall difference between the audit concentrations and analyzer responses of -20.0% and an intercept of 0.011 ppm. The analyzer response for the zero concentration and ows a constant bias which would be expected for the entire range. Percent g audit levels become increasingly large. A graphic plot of the audit data fficiency is decreasing with increasing audit concentration.



-Case 5

Data for Figure A.19

Point No.	Audit Concentration (ppm)	Station Concentration (ppm)	% Difference
1	.000	.000	-
2	.056	.049	-12.5
3	.106	.094	-11.3
4	.206	.180	-12.6
5	.313	.273	-12.8
6	.417	.355	-14.9
7	.651	.540	-17.1
8	.885	.703	-19.7

STATE OF CALIFORNIA AIR RESOURCES BOARD

MONITORING AND LABORATORY DIVISION

QUALITY ASSURANCE SECTION

VOLUME V

AUDIT PROCEDURES MANUAL

FOR

AIR QUALITY MONITORING

APPENDIX E

PERFORMANCE AUDIT PROCEDURES

FOR

THRU-THE-PROBE CRITERIA AUDITS

NOVEMBER 1995

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PERFORMANCE AUDIT PROCEDURES
FOR
THRU-THE-PROBE CRITERIA AUDITS

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E.1.0 INTRODUCTION

E.1.0.1 GENERAL INFORMATION

The California Air Resources Board, Air Monitoring Quality Assurance Procedures address the requirements for the set-up and operation of the audit equipment used while conducting performance audits as specified by 40 CFR Part 58, Appendix A. Read the entire procedures before beginning the audit.

The Quality Assurance Section (QAS) conducts thru-the-probe audit by diluting known quantities of National Institute of Standards and Technology (NIST) traceable gases with 25 liters of pure air to achieve ambient levels, then challenging the analyzers through the site's inlet probe. This audit method tests the integrity of the ambient monitoring site's entire ambient air sampling system, from the probe inlet to the air monitoring equipment.

In this method, a gas calibrator is used to control the dilution of high concentration gases from compressed gas cylinders containing CO, NO, S02, CH4; CO, H2S; CO, CH4, and C6H14. The gas calibrator is also used as an ozone source. The API 400 ozone analyzer is used as a transfer standard for auditing the site's ozone analyzer. A TECO 48 CO analyzer is calibrated at two known ambient level concentrations, plus zero, and is used to trace the amount of CO present in the diluted sample. The amount of CO present in the diluted sample is then used to calculate the true concentrations of the other gases in the compressed gas cylinder at each audit level.

The gases and transfer standards used in the audits are certified on a quarterly basis by the Standards Laboratory of the Program Evaluation and Standards Section.

E.1.0.2 EQUIPMENT

The current thru-the-probe audit system utilizes the following equipment:

1. Mobile audit van with auxiliary 12.5 KW AC generator.

2. Elgar 1001SL - II Voltage stabilized line conditioner.

3. Elgar 401SD-001 Selectable frequency oscillator.

4. Compressed gas cylinder traceable to the National Institute of Standards and Technology (NIST).

   a. Carbon Monoxide, 40-45 ppm (High CO).

   b. Carbon Monoxide, 6 - 8 ppm (Low CO).

c. Ultrapure Zero Air.

d. Superblend 1: Carbon Monoxide (CO), Methane (CH4), Sulfur Dioxide (SO2), and Nitric Oxide (NO).

e. Superblend 2: Carbon Monoxide (CO) and Hydrogen Sulfide (H2S).

f. Superblend 3: Carbon Monoxide (CO), Methane (CH4), and Hexane (C6H14).

g. Meta-Xylene.

5. Aadco 737R pure air system with CH4 burner and compressor capable of delivering a constant 20 lpm air supply measured at the output of the audit gas presentation line.

6. Dasibi 1009 CP Gas Calibrator with ozone generator and ozone analyzer or Dasibi 1009 CP Gas Calibrator with ozone generator and an API 400 ozone analyzer.

7. TECO 48 Carbon Monoxide (CO) analyzer.

8. 150 foot 1/2" teflon line with stainless steel braiding.

9. 10 lpm by-pass rotameter and glass mixing tee.

10. PX961 Electronic Barometer.

11. 30 lpm Vol-o-Flo.

12. Portable or rack-mounted computer, printer, and related audit software.

E.1.1 START-UP PROCEDURES

E.1.1.1 GENERATOR

1. Open the generator compartment cover.

2. Check to ensure that the generator oil level is in the safe operating zone.

E.1.1.2 VAN INTERIOR

1. Ensure that the power source selector switch is in the neutral (unloaded) position.

2. Ensure that all circuit breakers are on.

3. Start the generator. After the generator speed is stable (3 - 5 minutes), place the power source selector switch in the generator position.

4. Remove the end cap from the 150 foot audit gas presentation line ("LINE").

5. Turn on the power to the compressor.

6. Turn on the power to the Aadco.

7. Turn on the power to the line conditioner.

8. Turn on the power to the barometric pressure transducer.

9. Turn on the power to the gas calibrator, API 400 ozone analyzer and the CO analyzer. Press the air switch on the Dasibi 1009 CP to the "ON" position.

10. Turn on the power to chart recorder and press "START/STOP". The chart recorder will log in with the current time and the channels that are in use. Ensure that the yellow "POWER" light is lit to indicate the logging mode; if not, press "START/STOP" again.

11. Drain all water from the two (2) compressed air water traps located on the back of the Aadco.

12. Allow a one hour warm-up time for the Dasibi 1009 CP.

13. Allow a 2 1/2 hour warm-up time for the TECO 48.

E.1.1.3 SITE SET-UP

1. Attach approximately 2 to 5 feet of 1/4" teflon tubing to the open end of the 150 foot audit gas presentation line if necessary. This will depend on the site's inlet probe configuration.

2. Check the Aadco compressor and all cooling fans for normal operation. Recheck and purge any residual water from the water traps.

3. Ensure that the air switch on the Dasibi 1009 CP is in the "ON" position and the air flow thumbwheel is set to obtain a flow of 25.0 liters per minute (lpm).

4. Record the site name, site number, date, air monitoring personnel present, and the auditors' names on the van and site charts.

5. Before taking the line up to the site's inlet probe, measure the van's output flow using a Vol-o-Flo or other suitable flow measurement device. The site's inlet flow is determined by totaling the flow of all the instruments in use. Record the flows on the QA Audit Van Data Worksheet (Figure E.1.1.2).

   NOTE: The audit van's line output flow must be a minimum of 1 lpm greater than the station's probe inlet flow.

6. If the audit van's line output flow exceeds the station's inlet flow by more than 10 liters, a by-pass must be used at the end of the line to vent excess flow.

   NOTE: A glass tee of equal interior diameter may be used as a by- pass by inserting the teflon tubing attached to the line into the side port, securing one end of the tee to the station's inlet probe and allowing the excess flow to be vented out the third port. Some stations may contain only a single ozone analyzer, in which case a 10 lpm by-pass rotameter is attached to the end of the line with a 2 foot teflon tubing attached to the rotameter, and the glass tee connected in the same fashion as above.

7. Check for an internal by-pass flow between 0.3 and 0.4 lpm on the by-pass rotameter.

8. Record the station information on the QA Audit Station Data Worksheet (Figure E.1.1.1).

QA AUDIT STATION DATA WORKSHEET

SITE NAME: _____ DATE: _____

SITE NUMBER: _____ CONTACT PERSON/PHONE: _____

SITE ADDRESS: _____

CORRECTION FOR ZEROES: YES[ ] NO [ ] DATA READ BY: AUDITOR [ ] OPERATOR [ ]

DATA READ FROM: CHART [ ] DAS [ ] OTHER [ ] TYPE: _____

INSTRUMENT RANGE AND RESPONSE:

							OZONE OFF		OZONE ON	
INSTRUMENT	O3	CO	THC	CH4	SO2	H2S	NO	NOX	NO	NOX
RANGE: (PPM)									XXXX XXXX	XXXXX XXXXX
RESPONSE: PRE-ZERO									XXXX XXXX	XXXXX XXXXX
HIGH - 1ST PT									XXXX XXXX	XXXXX XXXXX
NOX - 1ST PT MED. - 2ND PT								XXXX XXXX	XXXX XXXX	XXXXX XXXXX
NOX - 2ND PT	XXXXX XXXXX	XXXX XXXX								
LOW - 3RD PT										
M-XYLENE NOX - OPT PT	XXXXX XXXXX	XXXX XXXX							XXXX XXXX	XXXXX XXXXX
POST-ZERO									XXXX XXXX	XXXXX XXXXX

STATION INSTRUMENT INFORMATION:

INSTRUMENTS	OZONE	CO	THC/CH4	SO2	H2S	NO/NOX
MANUFACTURER						
MODEL NUMBER						
PROPERTY NUMBER						
EPA EQUIV. NUM.						
NAMS/SLAMS/SPM						
ZERO SETTING						
SPAN SETTING						
PRESS/VAC (+/-)						
INDICATED FLOW						
CALIBRATION DATE						
MLD-98 REVSED 02/94				CONVERTER TEMP.		

Figure E.1.1.1 QA Audit Station Data Worksheet

4. Select Option 1, "SELECT SITE", from the ARB Van Audit Program's Main Menu and enter the information requested by the computer prompt. This information can be obtained from the Quality Assurance Site List.

5. Press Escape ("ESC") to return to the ARB Van Audit Program's Main Menu.

6. Select Option 2, "DATA ENTRY MENU", from the ARB Van Audit Program's Main Menu. Select Option 1, "VAN OZONE", from the Data Entry Menu to enter the audit van's responses for barometric pressure, pre-zero, audit points, and post-zero. Select Option 3 to enter the station's responses for the audit levels and instrument information.

7. Press Escape ("ESC") to return to the Data Entry Menu.

NOTE: You may continue to access either the Van Ozone or the Station O3 by using the Escape ("ESC") key. This will allow you to update the files as the actual data are entered.

E.1.2.3 OZONE AUDIT

True ozone (ozone concentration at the site's inlet probe) is determined by applying an ozone correction factor to the net display reading from the Dasibi 1009 CP, then applying the altitude correction factor (if applicable), and multiplying by the line loss correction factor (one minus the line loss percentage) as indicated by the following formula.

True Ozone (ppm) = (O3 Display Response [ppm] - O3 Zero Response [ppm] x (Ozone Calibration Correction Factor) x (Altitude Correction Factor) x (Line Loss Correction Factor).

NOTE: If the audit van uses the API 400 ozone analyzer to measure the ozone generated by the Dasibi 1009-CP, true ozone is determined by applying an ozone correction factor to the net display reading from the API 400 ozone analyzer, then multiplying by the line loss correction factor.

True Ozone (ppm) = (O3 Display Response - O3 Zero Response [ppm] x (Ozone Calibration Correction Factor) x (Line Loss Correction Factor).

1. If not in Option 1, "VAN OZONE", of the Data Entry Menu, return there and enter the current barometric pressure. The barometric pressure is taken from the reading of the barometric pressure display. Enter the display reading on the QA Audit Van Data Worksheet (Figure E.1.1.2) and into the computer.

NOTE: If the API 400 Ozone Analyzer is being used to measure the true ozone

concentration,enter "A" when prompted to do so. The API 400 ozone analyzer is corrected internally fortemperature and pressure, so the computer does not correct it further.

2. O3 Audit Point 1 - Make certain that switches on the Dasibi 1009 CP are in the correct audit positions before continuing. These positions are as follows:

   a. The Air Switch is "ON".

   b. The Ozone switch is "OFF".

   c. The Auto/Man switch is in the "MAN" position.

   d. The Latch/Load switch is in the "LOAD" position.

   When the zero has stabilized, take 10 consecutive readings from the Dasibi 1009 CP or the API 400 display and record them on the QA Audit Van Data Worksheet (Figure E.1.1.2). Record the average of the ten readings on the worksheet and enter this average into the computer for the Audit Van "PRE-ZERO" response. Record the site's zero response on the QA Audit Station Data Worksheet (Figure E.1.1.1) and enter it into the computer under the Station O3 "PRE-ZERO" response.

   NOTE: The 10 consecutive readings taken from the van ozone analyzer displays are to be taken at 30 second intervals (5 minute averages).

   NOTE: Normal zero response for the Dasibi 1009 CP or the API 400 is between ±.002 ppm, while the station response is usually between ±.01 ppm.

3. O3 Audit Point 2 - Set the thumbwheel on the Dasibi 1009 CP for a number sufficient to reach the Level 1 ozone response of 0.35 to 0.45 ppm. Press the "OZONE" switch to the "ON" position. When the readings have stabilized, take ten consecutive readings from the appropriate display (Step 2 above). Record these readings on the QA Audit Van Data Worksheet and enter the average of the ten readings into the computer. Record the site's Level 1 ozone response on the QA Audit Station Data Worksheet (Figure E.1.1.1) and into the computer under the Station O3 "HIGH" response.

   NOTE: Stabilization time will vary from site to site, depending on the instrument response, but verify a stable trace/reading for at least 10 minutes. Normal Level 1 ozone is a setting between 35 and 60 on the "MAN O3" thumbwheel on the Dasibi 1009-CP.

4. O3 Audit Point 3 - Set the thumbwheel on the Dasibi 1009 CP for a number sufficient to reach the Level 2 ozone response of 0.15 to 0.20 ppm. When the readings have stabilized, take ten consecutive readings from the appropriate display (Step 2 above). Record these readings on the QA Audit Van Data Worksheet and enter the average of the ten readings into the computer.

Record the site's Level 2 ozone response on the QA Audit Station Data Worksheet (Figure E.1.1.1) and into the computer under the Station O3 "MEDIUM" response.

NOTE: Normal Level 2 ozone is a setting between 20 and 40 on the "MAN O3" thumbwheel on the Dasibi 1009-CP.

5. O3 Audit Point 4 - Set the thumbwheel on the Dasibi 1009 CP for a number sufficient to reach the Level 3 ozone response of 0.03 to 0.08 ppm. When the readings have stabilized, take ten consecutive readings from the appropriate display (Step 2 above). Record these readings on the QA Audit Van Data Worksheet and enter the average of the ten readings into the computer. Record the site's Level 2 ozone response on the QA Audit Station Data Worksheet (Figure E.1.1.1) and into the computer under the Station O3 "MEDIUM" response.

NOTE: Normal Level 3 ozone is a setting between 10 and 20 on the "MAN O3" thumbwheel on the Dasibi 1009-CP.

6. O3 Audit Point 5 - Press the ozone switch to the "OFF" position. When the zero has stabilized, take 10 consecutive readings from the the appropriate display (Step 2 above) and record them on the QA Audit Van Data Worksheet (Figure E.1.1.2). Record the average of the ten readings on the worksheet and enter this average into the computer for the Audit Van "POST-ZERO" response. Record the site's zero response on the QA Audit Station Data Worksheet (Figure E.1.1.1) and enter it into the computer under the Station O3 "POST-ZERO" response.

7. If the site contains only an ozone analyzer, the preliminary ozone audit report may be printed out at this time. Refer to Section E.1.3.1.

E.1.2.4 CARBON MONOXIDE ANALYZER CALIBRATION

The concentrations of CO, NO, CH4, and SO2 present in the diluted gas is determined by certifying the TECO 48 CO analyzer using Ultrapure air, Aadco zero air, and NIST traceable span gases in the 45ppm and 7ppm CO ranges, then tracing the amount of CO present in the diluted sample as indicated by the following formula:

CO Analyzer Slope and Intercept:
Readings From CO Analyzer Display (Y) Vs. Zero and Span Cylinders of Known CO Concentration (X) in ppm

The final pollutant concentrations are based on pre- and post- certification results of the audit van's CO calibration gases.

NOTE: All responses are to be entered into the computer and on the QA Audit Van Data Worksheet under the Van CO Analyzer response.

The three-way valve, located next to the sample manifold, has two positions that are used during the CO Analyzer Calibration Procedure. These will be referred to as POSITION "1" and POSITION "2".

POSITION "1" - 1/4" teflon line from the Instrument Port of the rear manifold through the needle valve to the Calibration Port of the front manifold.

POSITION "2" - 1/8" teflon line from the CO span cylinders/Ultrapure Air to the pressure regulator. 1/4" teflon line from the pressure regulator to the Calibration Port of the front manifold.

1. Ensure that the CO analyzer has swarmed up for a minimum of 2 1/2 hours (can be warming up during ozone audit or while driving to the site).

2. Check the sample flow to the TECO 48 CO Analyzer. It should be set for approximately 1 lpm.

3. Readjust the needle valve on the by-pass rotameter (if necessary) in POSITION "1" to obtain a by-pass flow between 0.3 and 0.4 lpm.

4. Set the zero thumbwheels on the TECO 48 CO Analyzer so the display reads zero (0.0), ± 0.1.

5. When the zero display has stabilized, mark it on the chart and record the reading on the QA Audit Van Data Worksheet under pre-audit Aadco Zero (Figure E.1.1.2).

6. Turn off the valve/pump on the Dasibi 1009 CP.

7. Switch from POSITION "1" to POSITION "2" on the three-way valve. Connect the 45* ppm CO compressed gas cylinder standard and adjust the cylinder's pressure regulator for a by-pass flow between 0.3 and 0.4 lpm.

8. Adjust the span thumbwheels on the TECO 48 CO analyzer until the display matches the actual span value. When the chart recorder indicates a stable trace for CO, record the cylinder number on the chart next to the trace. Record the CO analyzer's response on the QA Audit Van Data Worksheet under pre-audit High CO (Figure E.1.1.2).

9. Disconnect the 45 ppm CO standard and connect the 7** ppm CO standard. Adjust the cylinder's pressure regulator to obtain a by-pass flow between 0.3 and 0.4 lpm. When the chart recorder indicates a stable trace for CO, record the cylinder number on the chart next to the trace. Record the CO analyzer's response on the QA Audit Van Data Worksheet (Figure E.1.1.2).

10. Disconnect the 7 ppm standard and connect the Ultrapure Zero Air Cylinder. Adjust the cylinder's pressure regulator to obtain a by-pass flow between 0.3 and 0.4 lpm. When the chart recorder indicates a stable trace for CO, record the cylinder number on the chart next to the trace. Record the CO analyzer's response on the QA Audit Van Data Worksheet (Figure E.1.1.2).

NOTE: The CO analyzer response should be within ± 0.2 chart divisions of the expected value. If adjustments are made to either the zero or span thumbwheels, the calibration points must be rerun.

11. Disconnect the Ultrapure Zero Air cylinder. Switch from POSITION "2" to POSITION "1" on the three-way valve. Turn the compressed gas cylinders off. Switch the Valve/Pump on the Dasibi 1009 CP "ON". If necessary, readjust the by-pass flow between 0.3 and 0.4 lpm.

12. Select option 2, "DATA ENTRY MENU" from the ARB Van Audit Program's Main Menu. Select Option 2, "VAN CO (Superblend cylinder #1)". Enter the CO analyzer responses for Ultrapure, High CO, Low CO, and AADCO.

NOTE: After entering the chart responses, it is possible to enter estimated chart responses until the best response for each audit level of the performance audit is obtained. It will then be possible to adjust the "GAS" thumbwheel on the Dasibi 1009 CP to obtain these levels during the audit.

E.1.2.5 CO, THC, CH4, NO2, AND SO2 AUDIT

The ambient level concentrations for each pollutant are determined by multiplying a dilution ratio times the concentration value for each pollutant at each audit level. The dilution ratio and ambient level concentrations are determined using the following formulae:

$$\text{Dilution Ratio} = \frac{\dfrac{\text{CO Response (ppm)} - \text{Aadco Zero Response(ppm)}}{\text{CO Analyzer Slope}}}{\text{High CO Standard (ppm)}}$$

Values for CO, THC, CH4, NO, NOX, SO2 (in ppm) =

Dilution Ratio x High Concentration Value*** (in ppm) for that pollutant

IMPORTANT: The status of the methane burner should be monitored throughout the audit. This can be done by checking the heater lights on the monitor to insure that they are cycling on and off.

1. Check the station instruments operating ranges before starting Point 1. If the NO/NOX operating range is 0 - 0.5 ppm or the THC/CH4 operating range is 0 - 10 ppm, disconnect the sample line to the instrument at the manifold and cap the manifold.

NOTE: In the event that an Ozone audit was performed prior to the NO/NOX audit, it is possible to use the thumbwheel settings obtained from the ozone audit to determine the correct levels of ozone necessary to perform the Gas Phase Titration portion of

the NO/NOX audit.

2. Open the valve on the Superblend compressed gas cylinder and adjust the regulator to 15 psi.

3. Superblend Audit Point 1: Record all zero instrument responses on the QA Audit Station Data Worksheet (Figure E.1.1.1) and the QA Audit Van Data Worksheet (Figure E.1.1.2). These responses will also be entered into the computer.

4. Superblend Audit Point 2: Press the Dasibi 1009 CP "GAS" switch "ON", "OZONE" switch is "OFF". Set the "GAS" thumbwheels on the Dasibi 1009 CP to 650 to obtain Level 1 concentrations of CO, SO2, THC/CH4 and NO, provided the NO/NOX instrument operating range is 0-1 ppm and the THC/CH4 operating range is 0-20 ppm. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Worksheet. Enter the analyzer's response into the computer to obtain the actual values. Record the station's responses when the readings have stabilized, and enter them into the computer.

NOTE: All thumbwheel settings are approximate. Thumbwheel adjustment will be necessary to obtain values in the correct audit ranges.

5. Superblend Audit Point 3: Reset the "GAS" thumbwheel on the Dasibi 1009 CP to 300. At this point, Level 1 concentrations of NO/NOX, and Level 2 concentrations of CO, SO2 and THC/CH4 (if the operating range is 0-20 ppm) are obtained. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the readings on the QA Audit Van Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's responses when the readings have stabilized, and enter them into the computer.

6. Superblend Audit Point 4: Press the Dasibi 1009 CP "OZONE" switch "ON", and readjust the "OZONE" thumbwheels to obtain the Level 1 NO2 concentration. The nominal NO2 concentration = [Site NO Response (point 3) - Site NO Response (point 4)] x [1 + True NO (point 3) - Site Net NO Response (point 3)]. Do not make any adjustments to other Dasibi 1009 CP settings. Record the station's NO/NOX responses when stable.

NOTE: If an ozone audit was performed prior to the NO2 audit, it is possible to use the thumbwheel settings obtained during that audit to determine the correct levels of ozone necessary to perform the Gas Phase Titration portion of the NO2 audit. The amount of NO titrated should not exceed 90% of the original NO concentration if possible.

7. Superblend Audit Point 5: Press the "OZONE" switch "OFF". Set the "GAS" thumbwheels to 230 to obtain Level 2 concentrations of NO/NOX only. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the readings on the QA Audit Van Worksheet. Enter the analyzer's response into the computer to obtain the actual values. Record the station's response when the readings have stabilized, and enter them into the computer.

8. Superblend Audit Point 6: Press the Dasibi 1009 CP "OZONE" switch "ON" and readjust the "OZONE" thumbwheels to obtain the Level 2 NO2 concentration. The nominal NO2 concentration = [Site No Response (Point 5) - Site NO Response (point 6)] x [1 + True NO Response (point 5) - Site NO Response (point 5). Do not make any adjustments to other 1009 CP settings. Record the station's NO/NOX responses when stable.

9. Superblend Audit Point 7: Press the Dasibi 1009 CP "OZONE" switch "OFF". Set the "GAS" thumbwheels to 130 to obtain Level 3 concentrations of CO, NO/NOX, SO2, and CH4/THC (Level 1 concentration if the instrument operating range is 0-10 ppm). After the van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Worksheet when the readings have stabilized, and enter them into the computer.

10. Superblend Audit Point 8: Press the Dasibi 1009 CP "OZONE" switch "ON" and readjust the "OZONE" thumbwheels to obtain the Level 3 NO2 concentration. The nominal NO2 concentration = [Site NO Response (point 7) - Site NO response (point 8)] x [1 + True NO Response (point 7) - Site NO Response (point 7). Do not make any adjustments to other 1009 CP settings. Record the station's NO/NOX responses when stable.

11. Superblend Audit Point 9: Press the Dasibi 1009 CP "OZONE" switch "OFF". Set the "GAS" thumbwheels to 50 to obtain an additional NO and THC/CH4 level if the NO/NOX operating range is 0-.5 ppm or the THC/CH4 operating range is 0-10 ppm. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Worksheet when the readings have stabilized, and enter them into the computer.

NOTE: If Superblend Audit Point 9 is not needed for a lower NO and/or THC/CH4 level, proceed to Step 12. This point may be used for Meta-Xylene (Meta-Xylene Procedure, Section E.1.2.7).

12. Superblend Audit Point 10: Press the Dasibi 1009 CP "GAS" switch to "OFF". After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Worksheet when the readings have stabilized, and enter them into the computer.

a. Converter Efficiency: The converted NO2 concentration is used at each point to determine the NO/NOX analyzer converter efficiency. The converter efficiency is calculated as follows:

$$\% \ CE = \frac{NO - NOX}{NO} \ x \ 100$$

Where:
CE = Converter Efficiency
NO = ([NO]orig - [NO]rem) / NO Slope
NOX = ([NOX]orig - [NOX]rem) / NOX Slope

b. In the event that the converter efficiency falls below 96%, an Air Quality Data Action (AQDA) request will need to be issued. All data will be deleted for the period of time that the converter efficiency is out of the correct control limits.

c. In the event that an analyzer fails the performance audit, a diagram of the audit setup should be drawn. This will facilitate the issuing of an AQDA request and make possible troubleshooting easier in the future. The diagram should include the setup of the site's inlet probe, manifold and delivery system. The diagram should also include the analyzers being audited and the method of hook-up to the site's inlet probe. Any other pertinent information should be included that could have affected the audit results. In addition to the diagram, a list of troubleshooting procedures that were used to correct or determine possible problems should be included.

E.1.2.6 H2S AUDIT

NOTE: Turn the three-way valve in the back of the audit van from Superblend cylinder 1 (Super1) to Superblend cylinder 2 (Super 2). Open the valve on Super 2 and adjust the regulator for 15 psi. Close the valve on Super 1.

The ambient level concentrations for each pollutant are determined by multiplying a dilution ratio times the concentration value for each pollutant at each audit level. The dilution ratio and ambient level concentrations are determined using the following formulae:

$$\text{Dilution Ratio} = \frac{\dfrac{\text{CO Chart Value (ppm)} - \text{Aadco Zero Response (ppm)}}{\text{(CO Analyzer Slope)}}}{\text{H2S CO Concentration (ppm)}}$$

Values for H2S (in ppm) = Dilution Ratio x High Concentration Value*

1. Calibrate the CO instrument as described in Section E.1.2.4.

2. H2S Audit Point 1: Select option 2, "DATA ENTRY MENU", from the ARB Van Audit Program's Main Menu. Select option F, "H2S MENU", from the Data Entry Menu. Select Option 1, "VAN CO (Superblend cyl #2)", and enter the CO analyzer responses for Ultrapure Zero Air, High CO, Low CO, and Aadco from the QA Audit Van Data Worksheet (Figure E.1.1.2).

3. H2S Audit Point 2: Press the Dasibi 1009 CP "GAS" switch "ON". Set the "GAS" thumbwheels to 460 to obtain Audit Point 1 concentration for H2S. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Data Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Data Worksheet, and enter them into the computer.

4. H2S Audit Point 3: Set the "GAS" thumbwheels on the Dasibi 1009 CP to 230, to obtain Audit Point 2 concentration for H2S. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Data Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Data Worksheet when the readings have stabilized, and enter them into the computer.

5. H2S Audit Point 4: Set the "GAS" thumbwheels on the Dasibi 1009 CP to 130, to obtain Audit Level 3 concentration for H2S. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Data Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Data Worksheet when the readings have stabilized, and enter them into the computer.

6. H2S Audit Point 5: Press the 1009 CP "GAS" switch to "OFF". After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Data Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Data Worksheet when the readings have stabilized, then enter them into the computer.

E.1.2.7 <u>META-XYLENE CHECK</u>

After completing the last audit point of the Superblend dilution, but prior to the final zero, perform the following steps for meta- xylene if the station being audited has an operating THC/CH4 analyzer. If the station has an SO2 analyzer, interference for SO2 can also be checked at the same time.

1. Press the "GAS" thumbwheel on the Dasibi 1009 CP to "OFF".

2. Switch the Dasibi 1009 CP internal pump to the "OFF" position.

3. If the Station being audited has a Ozone Analyzer, disconnect the line from the sample distribution manifold and cap off the open port.

4. Turn the "AADCO/CYLINDER" Valve, on the front of the audit van's instrument rack, to the "CYLINDER" position.

5. Turn the pressure valve on the Meta-xylene compressed gas cylinder to the "OPEN" position. Increase the regulator pressure until the pressure gauge on the front of the van's instrument rack reads between 15 and 20 psi.

6. Record the station's response on the QA Audit Station Data Worksheet when the readings have stabilized, and enter them into the computer.

7. Turn the pressure valve on the Meta-Xylene cylinder to the "OFF" position.

8. Turn the "AADCO/CYLINDER" valve back to the "AADCO" position.

9. Switch the Dasibi 1009 CP internal pump back to the "ON" position.

10. Reconnect the station Ozone analyzer.

11. When the station's zero response has stabilized, take ten consecutive readings and record the average of the ten readings on the QA Audit Station Data Worksheet. Enter the response into the computer.

E.1.2.8 NON-METHANE HYDROCARBON AUDIT

NOTE: Disconnect the Superblend 1 cylinder in the back of the audit van. Connect Superblend 3 cylinder to the Superblend 1 cylinder line using the connector on the Superblend 3 cylinder.

The ambient level concentrations for each pollutant are determined by multiplying a dilution ratio times the concentration value for each pollutant at each audit level. The dilution ratio and ambient level concentrations are determined using the following formula:

$$\textit{Dilution Ratio} = \frac{\textit{True CO Response}}{\textit{Superblend Bottle Co Concentration}}$$

WHERE:

$$\textit{True CO Response} = \frac{\textit{CO Display Value} - (\textit{Aadco Ultrapure}) - \textit{CO Intercept}}{\textit{CO Slope}}$$

1. Calibrate the CO instrument as described in Section E.1.2.4.

2. NMHC Audit Point 1: Select Option 2, "DATA ENTRY MENU", from the ARB Van Audit Program's Main Menu. Select Option M, "NMHC MENU" from the Data Entry Menu. Select Option 1, "VAN CO (Superblend cyl #2)", and enter the CO analyzer responses for Ultrapure Zero Air, High CO, Low CO, and Aadco Zero from the QA Audit Van Data Worksheet (Figure E.1.1.2).

3. NMHC Audit Point 2: Press the Dasibi 1009 CP "GAS" switch "ON". Set the "GAS" thumbwheels to 460 to obtain Audit Point 1 concentration for NMHC. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Data Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Data Worksheet when the readings have stabilized, then enter them into the computer.

4. NMHC Audit Point 3: Reset the "GAS" thumbwheels on the Dasibi 1009 CP to 230 to obtain Audit Point 2 concentrations for NMHC. After the audit van's chart recorder indicates a stable trace for CO, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Data Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Data Worksheet when the readings have stabilized, then enter them into the computer.

5. NMHC Audit Point 4: Reset the "GAS" thumbwheels on the Dasibi 1009 CP to 130 to obtain Audit Point 3 concentrations for NMHC. After the audit van's chart recorder indicates a stable trace for CO, take ten consecutive readings from the display and record the average of the ten readings on the QA Audit Van Data Worksheet. Enter the analyzer's response into the computer

to obtain actual values. Record the station's response on the QA Audit Station Data Worksheet when the readings have stabilized, then enter them into the computer.

6. NMHC Audit Point 5: Press the Dasibi 1009 CP "GAS" switch to "OFF". After the audit van's chart recorder indicates a stable trace for CO, take ten consecutive readings from the analyzer display and record the average of the ten readings on the QA Audit Van Data Worksheet. Enter the analyzer's response into the computer to obtain actual values. Record the station's response on the QA Audit Station Data Worksheet when the readings have stabilized, then enter them into the computer.

AUDIT STANDARDS DATA SHEET

HIGH CONCENTRATION BLEND	HIGH CONCENTRATION BLEND	AMBIENT LEVEL GASES
CO = 14,500 ppm	CO = 14,800 ppm	7 ppm and 45 ppm-CO
NO = 330 ppm	H2S = 320 ppm	Ultra-Pure Air
CH4 = 6,600 ppm		Nist Traceable
SO2 = 150 ppm		Calibration Standard

HIGH CONCENTRATION BLEND

CO = 15,350 ppm
C6H14 = 557 ppm
CH4 = 6,680 ppm

ALL CYLINDER CONCENTRATIONS ARE APPROXIMATE

DASIBI 1009 CP Calibrator with Ozone Source and Ozone Photometer	API 400 Ozone Analyzer	TECO 48 CO Analyzer (0-50 ppm Range)

AIR FLOW = 25 LITERS PER MINUTE

DILUTED CONCENTRATION

CO, NO, CH4, SO2, H2S, C6H14

AUDIT VAN DELIVERY SYSTEM

$$DILUTION\ RATIO = \frac{True\ CO\ response\ (ppm)}{Superblend\ Cylinder\ CO\ Concentration\ (ppm)}$$

AUDIT MONITORING STATION INLET

TRUE CONCENTRATION = Superblend Concentrations x Dilution Ratio

Figure E.1.2.1 Audit Gas Flow Chart

Table E.1.2.1 - LEVELS OF POLLUTANT CONCENTRATIONS (PPM)

STEP #	O3 (PPM)
1	ZERO
2	0.35 - 0.45
3	0.15 - 0.20
4	0.03 - 0.08
5	ZERO

Point #	O3 OFF		O3 ON		NO2	CO	THC/CH4	SO2	H2S	HEXANE	METHANE
	NO	NOX	NO	NOX							
1	ZERO	ZERO	XXX	XXX	XXX	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO
2	* .900					35-45	15-20	.35-.45	.35-.45	0-10	15-20
3	** .440	.440				15-20		.15-.20	.15-.20	0-10	0-10
4			.O65	.440	.375				.03-.08		
5	.275	.275							ZERO	0-10	0-10
6			.100	.275	.175						
7	.170	.170				03-08	03-08	.03-.08		0-10	0-10
8			.100	.170	.O70						
9	.070		OPTIONAL M-XYLENE				03-08			0-10	0-10
10	ZERO	ZERO	XXX	XXX	XXX	ZERO	ZERO	ZERO		ZERO	ZERO

* Indicates Point 1 for NO/NOX analyzers operating on a 0-1.0 ppm range.
** Indicates Point 1 for NO/NOX analyzers operating on a 0-0.5 ppm range.

LEVEL #	NO/NOX	O3	SO2	THC/CH4	CO	H2S	HEXANE	METHANE
1	0.35-0.45	0.35-0.45	0.35-0.45	* 15-20	35-45	.35-.45	0-10	15-20
2	0.15-0.20	0.15-0.20	0.15-0.20	** 03-08	15-20	.15-.20	0-10	0-10
3	0.03-0.08	0.03-0.08	0.03-0.08	03-08	03-08	.03-.08	0-10	0-10

* Indicates Level 1 for THC/CH4 analyzers operating on a 0-20 ppm range.
** Indicates Level 1 for THC/CH4 analyzers operating on a 0-10 ppm range.

E.1.2.9 POST-AUDIT CARBON MONOXIDE ANALYZER CALIBRATION

1. After taking the final Aadco Zero reading (Section E.1.2.5, step 12), record this reading on the QA Audit Van Data Worksheet (Figure E.1.1.2) under both the Van CO Analyzer Response and the Post-Audit Aadco Response.

2. Switch the sample pump on the Dasibi 1009 CP to the "OFF" position.

3. Turn the three-way valve on the van's sample manifold from POSITION "1" (Section E.1.2.4) to POSITION "2". Connect the 45 ppm CO compressed gas cylinder standard and adjust the by-pass flow for a reading between 0.3 and 0.4 lpm. After the van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record them on the QA Audit Van Data Worksheet (Figure E.1.1.2) under the Post-Audit Hi-CO Analyzer Response. Enter the response into the computer.

4. Disconnect the 45 ppm CO standard and connect the Ultrapure Zero Air Compressed Gas Cylinder. After the audit van's chart recorder trace for CO has stabilized, take ten consecutive readings from the display and record the average on the QA Audit Van Data Worksheet (Figure E.1.1.2) under the Post-Audit Ultrapure Analyzer Response. Enter the response into the computer.

5. Disconnect the Ultrapure cylinder. Switch the three-way valve on the van's sample manifold from POSITION "2" to POSITION "1". Switch the sample pump on the Dasibi 1009 CP to the "ON" position and readjust the needle valve to obtain a by-pass flow reading between 0.3 and 0.4 lpm.

6. After the audit van's chart recorder trace for CO has stabilized, the van's instruments are now ready for the van shut-down procedure (Section E.1.4).

E.1.2.10 PERFORMANCE AUDIT FAILURES

1. If the results of an audit indicate a failed condition, the entire system should be checked for possible failure causes. The System includes everything from the van operation to the station instrument operation.

   NOTE: If the possible cause for the failed condition is determined during any point in the investigation, the problem should be resolved, if possible, and the audit resumed. However, an AQDA will need to be issued to the site operator to indicate an "AS IS" failure, unless the cause of the failure is determined to be the audit van set-up. In this case, the problem should be corrected and the audit restarted with no AQDA issued.

2. Beginning with the audit van, all instruments need to be checked to ensure proper operation. This will include all the following unless the cause for failure is discovered and resolved.

   a. Check the van calibrator. Is the air flow set correctly? What values do the mass flow controllers indicate? If doing an ozone audit, are the switches set correctly? Are the

thumbwheels set to the correct values? Does the display on the API ozone analyzer indicate the correct ozone level?

b. If doing a gaseous audit, is the TECO 48 CO analyzer indicating the correct CO range? Is the methane reactor cycling on and off?

c. Is the compressor running? Is the Aadco cycling? Are the input and output pressures set correctly? Is the by-pass set between 0.3 and 0.4 lpm?

d. Are all the lines connected to the manifolds? Are the lines to the instruments connected? Are any leaks detected?

3. When all of these have been checked for proper operation, the next step is to ensure that the station being audited is receiving enough flow to the inlet probe. The flow can be checked with a Vol-O-Flo to determine whether the station is receiving too much flow (pressurizing the instruments), or not enough flow (starving the instruments).

4. Following this (if necessary), check the path of the audit gas from the probe inlet to the back of the instruments. This can be accomplished by visually examining the probe inlet, probe line, manifold, all related teflon lines, and any in-line filters.

5. If no possible cause can be determined during this examination, the next step is to remove the audit presentation line from the station's inlet probe and connect it to the back of the instrument manifold, then rechecking the instruments for proper response.

6. If the instruments still indicate a failed condition, the last step is to remove the audit presentation line from the instrument manifold and checking for the proper response at the back of the instruments.

E.1.3 POST-AUDIT PROCEDURES

E.1.3.1 PRINTING AUDIT RESULTS

1. After final CO calibration, verify that all the audit van's and station's responses have been correctly entered.

2. Select Option 3, "PRINT MENU", from the ARB Van Audit Program's Main Menu.

3. Select Option 1, "AUDIT RESULTS", from the Print Menu.

4. Verify that the correct site information is being displayed. If not, type in the correct site number. Enter "P" for Preliminary results and then 3 for number of copies to be printed. Enter "Y" if the information is correct, and the computer will recalculate the data and print out the number of copies requested. If the information is not correct, enter "N", and enter the correct information.

5. Give the station operator one copy of the audit report, and retain the other two copies for ARB use.

E.1.3.2 AIR QUALITY DATA ACTION (AQDA)

NOTE: AQDA'S are issued when the audit reveals that the station's instruments are not operating within the prescribed limits. These limits are defined in EPA's Volume II.

If the station being audited has failed the audit or a portion of the audit, it will be necessary to issue an Air Quality Data Action (AQDA).

E.1.4 SHUT DOWN PROCEDURES -- VAN

E.1.4.1 INTERIOR

1. After printing the preliminary audit report, exit the audit program by pressing escape (ESC) until the display on the computer screen reads "ARE YOU SURE YOU WANT TO EXIT?(Y/N) [ ]. Enter "Y" to exit the program, and type "PARK" at the prompt. This parks the heads on the computer and avoids damage to the hard disk. Shut the computer off.

2. Turn off the power to the printer.

3. Turn off the power to the Dasibi 1009 CP.

4. Turn off the power to the TECO 48.

5. Turn off the power to the Elgar.

6. Close all compressed gas cylinders' valves.

7. Turn off the power to the Aadco compressor.

8. Turn off the power to the Methane Reactor.

9. Turn off the air conditioning units, if they were used.

10. After placing the generator power switch in the "UNLOADED" position, shut off the generator.

11. Secure all loose articles or equipment in preparation for transportation to another location.

E.1.4.2 EXTERIOR

1. Remove the audit presentation "LINE" from the site's inlet probe.

2. Reel in the audit presentation "LINE" and cap the end. Tighten the securing bolt on the "LINE" reel to prevent the "LINE" from unrolling while in transit.

3. Secure the ladder and safety cones, if used, in the the audit van.

4. Verify that the van steps are up. If the steps are electric, turn the power off.

E.1.5 CALIBRATIONS CHECKS AND PROCEDURES

E.1.5.1 QUARTERLY "LINE LOSS" START-UP PROCEDURE

The purpose of the line loss test is to determine the actual ozone concentration that is being delivered to the end of the audit presentation line. The line is 150 feet long and there is an expected ozone loss due to the length of the line. By analyzing the ozone concentration before and after the line, it is possible to determine the amount of ozone loss due to the line. This percentage loss is then used to correct for true ozone.

1. Plug in the audit van land line.
2. Place the Generator/Land Line switch in the "LAND LINE" position.
3. Turn on the Aadco.
4. Turn on the compressor.
5. Turn on the Elgar line conditioner power.
6. Turn on the power to the Dasibi 1009 CP and press the air switch to the "ON" position.
7. Turn on the Omega chart recorder power.
8. Press "START" to begin the recorder logging. It will log in with the correct time and the channels in use. Record the date, vehicle, type of test performed, and the name of the person performing the test.
9. Drain the moisture from the compressed air water traps located on the back of the Aadco.

E.1.5.2 QUARTERLY AUDIT PRESENTATION "LINE LOSS" TEST

Two (2) lines are used during the quarterly "LINE LOSS" test, referred to as the "INSIDE" line and the "OUTSIDE" line.

INSIDE - 1/4 Inch teflon line from the Instrument Port of the rear manifold through the needle valve to the Calibration Port of the front manifold.

OUTSIDE- 1/2 Inch by 150 foot stainless steel braided line with 10 lpm by-pass rotameter, glass tee, and two feet of teflon line to connect to the front manifold.

NOTE: Two manifolds are used in the audit vans.

The "FRONT" manifold is used to deliver the diluted sample or the zero and span gases to the van ozone and CO instruments, and utilizes a 0.3 to 0.4 lpm by-pass to keep a slight (one inch of water) positive pressure in the manifold to prevent any dilution with outside air.

The "REAR" manifold is used to deliver the diluted pollutant concentrations of audit gases to the inlet probe of the station being audited. This manifold works under a positive pressure of 30 psi and delivers a flow rate between 15 and 30 lpm.

1. Warm up the Dasibi 1009 CP for a least one hour prior to performing the "LINE LOSS" check.

2. Uncap the OUTSIDE line and connect a 10 lpm by-pass rotameter and a glass tee to it by use of a 1/4 inch teflon line (5 feet is sufficient).

3. Press the air switch on the Dasibi 1009 CP to the "ON" position and adjust the air thumbwheel setting to achieve an output flow of 15 lpm or greater.

4. Connect the INSIDE line to the front manifold on the instrument rack and adjust the by-pass flow for 0.3 to 0.4 lpm using the in-line needle valve(s).

5. Disconnect the INSIDE line from the front manifold and connect the OUTSIDE line. Adjust the by-pass flow rate to 0.3 to 0.4 lpm by partially blocking the open end of the glass tee using masking tape or other suitable material.

6. Disconnect the OUTSIDE line and reconnect the INSIDE line. Readjust the by-pass flow between 0.3 and 0.4 lpm, if needed.

7. Allow the ozone response to establish a stable trace on the chart recorder for at least 10 minutes. When the trace has stabilized, take 10 consecutive readings from the Dasibi 1009 CP display and record them on Quarterly Line Loss Test Form, (Figure E.1.5.1).

8. Disconnect the INSIDE from the front manifold and reconnect the OUTSIDE LINE. Readjust the by-pass flow between 0.3 and 0.4 lpm, if needed.

9. Allow the ozone response to establish a stable trace on the chart recorder for at least 10 minutes. When the trace has stabilized, take ten (10) consecutive readings from the Dasibi 1009 CP display and record them on the Quarterly Line Loss Test Form (Figure E.1.5.1).

10. Repeat steps 6 through 9 for a total of three readings.

11. Adjust the ozone thumbwheel on the Dasibi 1009 CP to achieve Level 1 (Table E.1.2.1) concentrations of ozone. This setting is usually between 30 and 60 on the "MAN" thumbwheel. Press the ozone switch "ON".

12. Repeat steps 6 through 9 for a total of three readings.

13. Adjust the ozone thumbwheel on the Dasibi 1009 CP to achieve Level 2 (Table E.1.2.1) concentrations of ozone. This setting is usually between 20 and 40 on the "MAN" thumbwheel.

14. Repeat steps 6 through 9 for a total of three readings.

15. Adjust the ozone thumbwheel on the Dasibi 1009 CP to achieve Level 3 (Table E.1.2.1) concentrations of ozone. This setting is usually between 10 and 20 on the "MAN" thumbwheel.

16. Repeat steps 6 through 9 for a total of three readings.

17. To figure the quarterly line loss, total the readings for the INSIDE line for each level, and divide this total by the number of readings. Record the results under the average for that level. Repeat this process for the OUTSIDE line. Add the zero correction to each level to arrive at the corrected response. Compare the INSIDE line response to the OUTSIDE line response to arrive at a percent difference for each level. Total all three levels and divide the total by three to arrive at the average percent difference. Add this average percent difference to the previous line loss percent difference (has to be within ± 1%). Divide this by two to arrive at the current quarter line loss.

    NOTE: "QUARTERLY LINE LOSS TEST FORM" ozone response should be within ± 2.5% of the manifold ozone response.

18. Press the ozone on the Dasibi 1009 CP "OFF".

19. Repeat steps 6 through 9 for a total of three readings.

20. Drain the moisture from the Aadco water traps.

21. Turn the compressor off.

22. Turn the Aadco off.

23. Turn the Dasibi 1009 CP off.

24. Turn the Elgar 1001-SL off.

25. Turn the chart recorder off.

26. Disconnect the OUTSIDE line from the front manifold and reconnect the INSIDE line.

27. Remove the 10 lpm by-pass rotameter and glass tee from the OUTSIDE line and recap the line.

28. Rewind the OUTSIDE line back onto the reel.

E.1.5.3 <u>QUARTERLY INSTRUMENT AND GAS RECERTIFICATION</u>

1. Dasibi 1009 CP - The Standards Laboratory recertifies the UV Photometer against a Primary Photometer and checks the mass flow controllers. The slope and intercept derived from the ozone certification are entered into the van standards file and used to calculate true van ozone concentrations.

2. Dasibi 1008 PC - The Standards Laboratory recertifies the UV Photometer against a Primary Photometer. The slope and intercept derived from this certification are used to calculate true ozone concentrations. The Dasibi 1008 PC is used in areas inaccessible to the audit van.

3. Gases - The High and Low Carbon Monoxide Standards, H2S, and Superblend Gas Standards (NO, CH4, SO2, CO and C6H14, CH4, CO) are recertified by the Standards Laboratory. The concentrations obtained from certification are entered into the van standard's file and are used to determine the true values during a performance audit.

E.1.5.4 QUARTERLY AUDIT GAS COMPARISON WITH STANDARDS LABORATORY

At the beginning of each quarter, an in-house audit will be performed with the Program Evaluation and Standards Section. The purpose of this audit is to verify the actual concentration of the gases at the end of the audit presentation line. This audit is to be performed following the standard Performance Audit format outlined in Sections E.1.2.3, E.1.2.4, E.1.3, and E.1.4 of this procedure. The results obtained from this audit can be used to correct the computer generated audit gas concentrations to actual audit gas concentrations in the event that there is a greater than ± 3.6 percent difference between the calculated and actual values.

E.1.5.5 ANNUAL RECERTIFICATION PROCEDURES

1. Annual certifications are performed on the TECO 48 Carbon Monoxide Analyzer, Barometric Pressure Transducer, Thermometers, and Ultrapure Air.

2. TECO 48 CO Analyzer - Certified by the Standards Laboratory against NIST traceable primary CO standards for the 0-50 ppm range only. A linearity check is also performed at the same time to verify that the instrument is linear throughout the entire operating range.

3. Barometric Pressure Transducer - Certified by the Standards Laboratory against a mercury manometer and a Wallace & Tiernan pressure gauge. A slope and intercept are derived from this certification, and entered into the van standards file to be used in the correction of ozone and PM10 data to the standard barometric pressure of 760 mm Hg.

4. Hi-Vol Orifice - Certified by the Standards Laboratory against a Primary Roots Meter. The slope and intercept derived from the certification are entered into the van standards file, and are used to calculate Hi-Vol sampler flow rates.

INSTRUMENT: _____ ID#: _____ DATE: _____

QUARTER 1[ ] 2[ ] 3[ ] 4[ ] . VEHICLE: VAN "A" [ ] VAN "B" [ ]

TRUE OZONE = _____ PREVIOUS QUARTER LINE LOSS = _____

INSIDE												OUTSIDE											
ZERO AIR SET																							ZERO
AVERAGE												% DIFFERENCE											
HIGH O3 SET																							HIGH O3 SET
AVERAGE												% DIFFERENCE											
MED O3 SET																							MED O3 SET
AVERAGE												% DIFFERENCE											
LOW O3 SET																							LOW O3 SET
AVERAGE												% DIFFERENCE											
ZERO AIR SET																							ZERO AIR SET
AVERAGE												% DIFFERENCE											

Quarterly line loss = $\frac{\text{Current Quarter Line Loss/Previous Quarter Line Loss}}{2}$

QA FORM LL1 _____

QUARTERLY LINE LOSS % [ ]

Figure E.1.5.1 Quarterly Line Loss Test Form

Appendix 16

Examples of Reports to Management

The following example of an annual quality assurance report consist of a number of sections that describe the quality objectives for selected sets of measurement data and how those objectives have been met. Sections include:

- Executive Summary,
- Introduction, and
- Quality information for each ambient air pollutant monitoring program..

The report is titled "Acme Reporting Organization, Annual Quality Assurance Report for 2000".

ACME REPORTING ORGANIZATION
ANNUAL QUALITY ASSURANCE REPORT FOR 2000

Prepared by

Quality Assurance Department
Acme Reporting Organization
110 Generic Office Building
Townone XX, 00001

April 2001

ACME REPORTING ORGANIZATION
ANNUAL QUALITY ASSURANCE REPORT FOR 2000
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ACME REPORTING ORGANIZATION
ANNUAL QUALITY ASSURANCE REPORT FOR 2000

EXECUTIVE SUMMARY

This summary describes the Acme Reporting Organization's (ARO's) success in meeting its quality objectives for ambient air pollution monitoring data. ARO's attainment of quantitative objectives, such as promptness, completeness, precision, and bias, are shown in Table 1, below. ARO met these objectives for all pollutants, with the exception of nitrogen dioxide. The failure to meet completeness and timeliness goals for nitrogen dioxide was due to the breakdown of several older analyzers. Replacement parts were installed and the analyzers are now providing data that meet ARO's quality objectives.

Table 1. Attainment of Quantitative Quality Objectives for Ambient Air Monitoring Data

Measurement	Program met objectives for			
	Promptness	Completeness	Precision	Bias
Air Toxics	Yes	Yes	Yes	Yes
Carbon Monoxide	Yes	Yes	Yes	Yes
Lead	Yes	Yes	Yes	Yes
Nitrogen Dioxide	No	No	Yes	Yes
Ozone	Yes	Yes	Yes	Yes
Sulfur Dioxide	Yes	Yes	Yes	Yes
PM_{10}	Yes	Yes	Yes	Yes
$PM_{2.5}$	Yes	Yes	Yes	Yes
Volatile Organic Compounds (VOCs)	Yes	Yes	Yes	Yes

Other quality objectives (for example those concerning siting, recordkeeping, etc.) were assessed via laboratory and field system audits. The results of these audits indicate compliance with ARO's standard operating procedures except for the following:

- The Towntwo site was shadowed by a 20 story office building which was recently completed. This site was closed in July 2000.
- The Townfour site had problems with vandalism. A new, more secure, fence was installed in April and the sheriff's department increased patrols in the area to prevent reoccurrences.
- Newly acquired laboratory analytical instruments did not have maintenance logs. New logs were obtained and personnel were instructed on their use. A spot check, approximately one month later, indicated the new logs were in use.

A review of equipment inventories identified three older sulfur dioxide ambient air monitors that, based on our past experience, are likely to experience problems. Cost information and a schedule for replacement has been prepared and submitted to management for funding. Based on this schedule, the new monitors will be installed before the end of 2001.

INTRODUCTION

The Acme Reporting Organization (ARO) conducts ambient air monitoring programs for the State Bureau of Environmental Quality and local air quality management districts. These programs involve:

- monitoring of criteria pollutants to determine the National Ambient Air Quality Standards (NAAQS) attainment status of state and local air quality. This monitoring is conducted as part of the State and Local Air Monitoring Stations (SLAMS) and National Air Monitoring Stations (NAMS) networks.
- monitoring compounds (volatile organic compounds and nitrogen oxides), referred to as ozone precursors, that can produce the criteria pollutant ozone. This monitoring is conducted as part of the Photochemical Assessment Monitoring Stations (PAMS) network.
- monitoring toxic air pollutants.

The purpose of this report is to summarize the results of quality assurance activities performed by ARO to ensure that the data meets its quality objectives. This report is organized by ambient air pollutant category (e.g., gaseous criteria pollutants, air toxics). The following are discussed for each pollutant category:

- program overview and update
- quality objectives for measurement data
- data quality assessment

DATA QUALITY

Data quality is related to the need of users for data of sufficient quality for decision making. Each user specifies their needed data quality in the form of their data quality objectives (DQOs). Quality objectives for measurement data are designed to ensure that the end user's DQOs are met. Measurement quality objectives are concerned with both with quantitative objectives (such as representativeness, completeness, promptness, accuracy, precision and detection level) and qualitative objectives (such as site placement, operator training, and sample handling techniques).

QUALITY ASSURANCE PROCEDURES

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. In addition to performing tests to determine bias and precision, additional quality indicators (such as sensitivity, representativeness, completeness, timeliness, documentation quality, and sample custody control) are also evaluated. Quality assurance procedures fall under two categories:

- **quality control** - procedures built into the daily sampling and analysis methodologies to ensure data quality, and
- **quality assessment** - which refers to periodic outside evaluations of data quality.

Some ambient air monitoring is performed by automated equipment located at field sites, while other measurements are made by taking samples in the field which are transported to the laboratory for analysis. For this reason, it is useful to divide quality assurance procedures into two parts – field quality assurance and laboratory quality assurance.

Field Quality Assurance

Quality control of automated analyzers and samplers consists of calibration and precision checks. The overall precision of sampling methods is measured using collocated samplers. Quality assurance is evaluated by periodic performance and system audits.

Calibration - Automated analyzers (except ozone) are calibrated by comparing the instrument's response when sampling a cylinder gas standard mixture to the cylinder's known concentration level. The analyzer is then adjusted to produce the correct response. Ozone analyzers are calibrated by on-site generation of ozone whose concentration is determined by a separate analyzer which has its calibration traceable to the U.S. Environmental Protection Agency. The site's analyzer is then adjusted to produce the same measured concentration as the traceable analyzer. Manual samplers are calibrated by comparing their volumetric flow rate at one or more flow rates to the flow measured by a flow rate transfer standard. Calibrations are performed when an instrument is first installed and at semi-annual intervals thereafter. Calibrations are also performed after instrument repairs or when quality control charts indicate a drift in response to quality control check standards.

Precision - Precision is a measure of the variability of an instrument. The precision of automated analyzers is evaluated by comparing the sample's known concentration against the instrument's response. The precision of manual samplers is determined by collocated sampling – the simultaneous operation of two identical samplers placed side by side. The difference in the results of the two samplers is used to estimate the precision of the entire measurement process (i.e., both field and laboratory precision).

Performance Audits - The bias of automated methods is assessed through field performance audits. Performance audits are conducted by sampling a blind sample (i.e., a sample whose concentration is known, but not to the operator). Bias is evaluated by comparing the measured response to the known value. Typically, performance audits are performed annually using blind samples of several different concentrations.

System Audits - System audits indicate how well a sampling site conforms to the standard operating procedures as well as how well the site is located with respect to its mission (e.g., urban or rural sampling, special purpose sampling site, etc.). System audits involve sending a trained observer (QA Auditor) to the site to review the site compliance with standard operating procedures. Some areas reviewed include: site location (possible obstruction, presence of nearby pollutant sources), site security, site characteristics (urban versus suburban or rural), site maintenance, physical facilities (maintenance, type and operational quality of equipment, buildings, etc.), recordkeeping, sample handling, storage and transport.

Laboratory Quality Assurance

Laboratory quality control includes calibration of analytical instrumentation, analysis of blank samples to check for contamination, and analysis of duplicate samples to evaluate precision. Quality assurance is accomplished through laboratory performance and system audits.

Calibration - Laboratory analytical instruments are calibrated by comparing the instrument's response when sampling standards of known concentration level. The difference between the measured and known concentrations is then used to adjust the instrument to produce the correct response.

Blank Analysis - A blank sample is one that has intentionally not been exposed to the pollutant of interest. Analysis of blank samples reveals possible contamination in the laboratory or during field handling or transportation.

Duplicate Analysis - Duplicate analyses of the same sample are performed to monitor the precision of the analytical method.

Performance Audits - Regular performance audits are conducted by having the laboratory analyze samples whose physical or chemical properties have been certified by an external laboratory or standards organization. The difference between the laboratory's reported value and the certified values is used to evaluate the analytical method's accuracy.

System Audits - System audits indicate how well the laboratory conforms to its standard operating procedures. System audits involve sending a trained observer (QA Auditor) to the laboratory to review compliance with standard operating conditions. Areas examined include: record keeping, sample custody, equipment maintenance, personnel training and qualifications, and a general review of facilities and equipment.

GASEOUS CRITERIA POLLUTANTS

The Acme Reporting Organization monitors the ambient concentrations of the gaseous criteria pollutants carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and sulfur dioxide (SO_2) to determine attainment of Federal (NAAQS) and State ambient air quality standards. Monitoring of these pollutants is conducted continuously by a network of automated stations.

PROGRAM UPDATE

At the beginning of 2000, the Acme Reporting Organization operated 38 ambient air monitoring stations that measured gaseous criteria pollutants. On March 1, 2000, a station was opened at Townone to monitor CO, NO_2, O_3, and SO_2 . The station at Towntwo, which monitored NO_2, O_3, and SO_2, was closed in April 2000.

QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the Acme Reporting Organization's ambient air monitoring of gaseous criteria pollutants are shown in Table 2, below.

Table 2. Quality Objectives for Gaseous Criteria Pollutants

Data Quality Indicator	Objective
Precision	±10%
Bias	±15%
Completeness	75%
Promptness	100%

DATA QUALITY ASSESSMENT

Summary

Assessment of the data quality for ARO gaseous criteria pollutants showed that all instruments met goals for accuracy, precision, completeness, and promptness. System audits showed siting problems at three sites, two of these were corrected promptly, while the third site had to be closed due to the construction of a nearby large office building.

Promptness and Completeness

At least 75 percent of scheduled monitoring data must be reported for purposes of determining attainment of NAAQS. All data must be submitted within 90 days after the end of the reporting quarter. Table 3 summarizes promptness and completeness for gaseous criteria pollutant data.

Table 3. Data Quality Assessment for Promptness and Completeness

Pollutant	Promptness	Completeness
Carbon monoxide	100%	95%
Nitrogen dioxide	100%	97%
Ozone	100%	94%
Sulfur dioxide	100%	96%

Precision

At least once every two weeks, precision is determined by sampling a gas of known concentration. Table 4 summarizes the precision checks for gaseous criteria pollutants.

Table 4. Data Quality Assessment for Precision

Pollutant	Precision checks completed	Percentage within limits
Carbon monoxide (CO)	98%	98%
Nitrogen dioxide (NO_2)	100%	97%
Ozone (O_3)	97%	98%
Sulfur dioxide (SO_2)	100%	98%

Bias

The results of annual performance audits conducted by ARO personnel are shown in Figure 1, below. The center line for each pollutant represents the average bias across all analyzers (i.e., with all analyzers weighted equally). The lower and upper probability limits represent the boundaries within which 95 percent of the individual bias values are expected to be distributed.

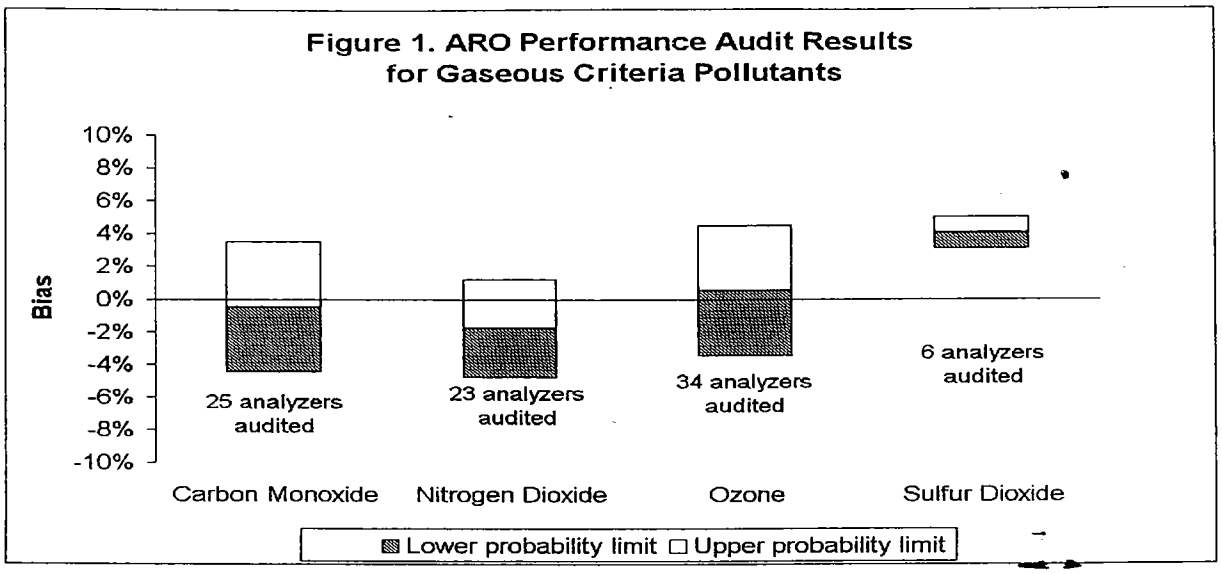
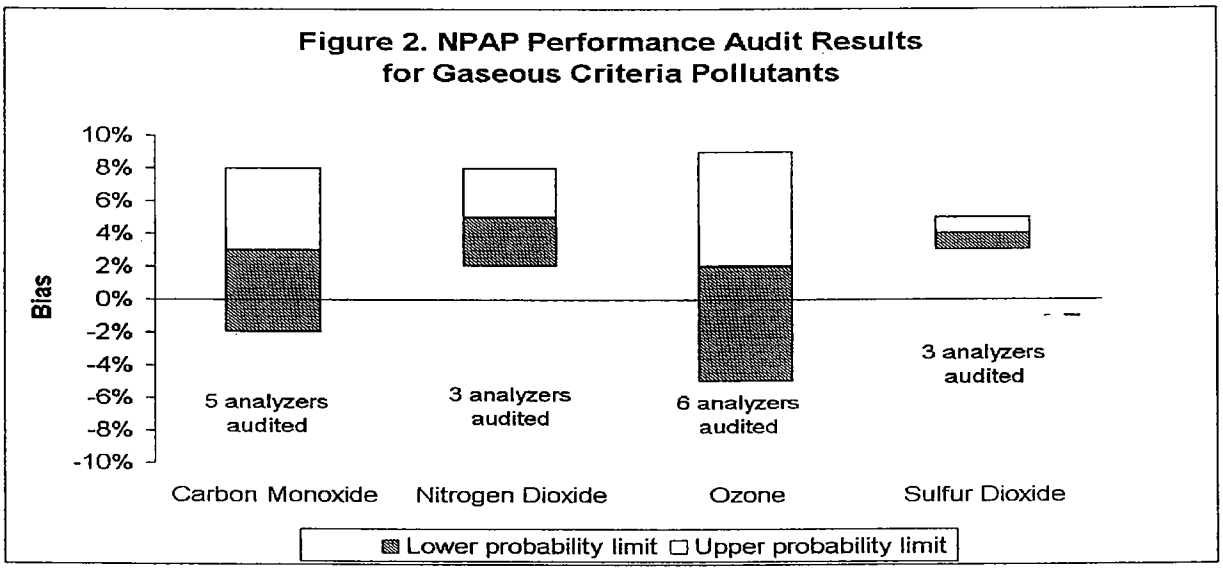


Figure 2 shows the results of external performance audits performed with the National Performance Audit Program (NPAP), administered by the U.S. EPA.



System Audits

Systems audits were performed at approximately 25 percent of the sites during the calendar year 2000. These audits evaluated areas such as siting criteria, analyzer operation and maintenance, operator training, recordkeeping, and serve as a general review of site operations. No significant problems were observed, except for the following:

- The Towntwo site was shadowed by a 20 story office building which was recently completed. This site was closed in July 2000.
- The Townfour site had problems with repeated vandalism. A new, more secure, fence was installed in April and the sheriff's department increased patrols in the area to prevent reoccurrences.
- The Townsix site had vegetation which had grown too close to the analyzer inlet probes. The vegetation was removed within one week after the problem was reported. Personnel from the County Parks and Recreation Department provided assistance removing the vegitation.

PARTICULATE CRITERIA POLLUTANTS

The Acme Reporting Organization monitors the ambient concentrations of three particulate criteria pollutants:

- lead,
- PM_{10} (particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers, and
- $PM_{2.5}$ (particles with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers)

This monitoring is used to determine attainment of Federal (NAAQS) and State ambient air quality standards. Monitoring of these pollutants is conducted by sampling for 24 hours every six days by a network of manually operated samplers.

PROGRAM UPDATE

At the beginning of 2000, the Acme Reporting Organization operated 22 ambient air monitoring stations that measured particulate criteria pollutants. On March 1, 2000, a station was opened at Townone to monitor PM_{10}, $PM_{2.5}$, and lead. The station at Towntwo, which monitored PM_{10}, $PM_{2.5}$, and lead, was closed in April 2000.

QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the Acme Reporting Organization's ambient air monitoring of particulate criteria pollutants are shown in Table 5, below.

Table 5. Quality Objectives for Particulate Criteria Pollutants

Data Quality Indicator	Objective
Precision	±7%
Bias	±10%
Completeness	75%
Promptness	100%

DATA QUALITY ASSESSMENT

Summary

Assessment of the data quality for ARO particulate criteria pollutants showed that all samplers met goals for accuracy, precision, completeness, and promptness. System audits showed siting problems at three sites. Two of these were corrected promptly, while the third site had to be closed due to the construction of a large office building, nearby.

Promptness and Completeness

At least 75 percent of scheduled monitoring data must be reported for purposes of determining attainment of NAAQS. All data must be submitted within 90 days after the end of the reporting quarter. Table 6 summarizes promptness and completeness data for particulate criteria pollutants.

Table 6. Data Quality Assessment for Promptness and Completeness

Pollutant	Promptness	Completeness
Lead	100%	93%
PM_{10}	100%	95%
$PM_{2.5}$	100%	92%

Precision

Precision is determined by operating collocated samplers (i.e., two identical samplers operated in the identical manner). Due to the anticipated poor precision for very low levels of pollutants, only collocated measurements above a minimum level (0.15 g/m^3 for lead, 20 g/m^3 for PM_{10}, and 6 g/m^3 for $PM_{2.5}$) are used to evaluate precision. Table 7 summarizes the results of collocated measurements made during the calendar year 2000.

Table 7. Data Quality Assessment for Precision

Pollutant	Collocated precision measurements completed	Collocated measurements within limits
Lead	98%	98%
PM_{10}	100%	97%
$PM_{2.5}$	97%	98%

Flow rate precision

A flow rate precision check is conducted at least every two weeks for PM_{10} and $PM_{2.5}$ samplers. The flow should be within ±10% of the specified value. Results are shown in Table 8.

Table 8. Flow Rate Precision Checks for Particulate Criteria Pollutants

Pollutant	Precision Checks completed	Precision Checks within limits
Lead	98%	98%
PM_{10}	100%	97%
$PM_{2.5}$	97%	98%

Flow rate bias

Results of the annual flow rate audits conducted by ARO personnel are shown in Figure 3, below. The center line for each pollutant represents the average bias across all sampler (i.e., with all sampler weighted equally). The lower and upper probability limits represent the boundaries within which 95 percent of the individual bias values are expected to be distributed.

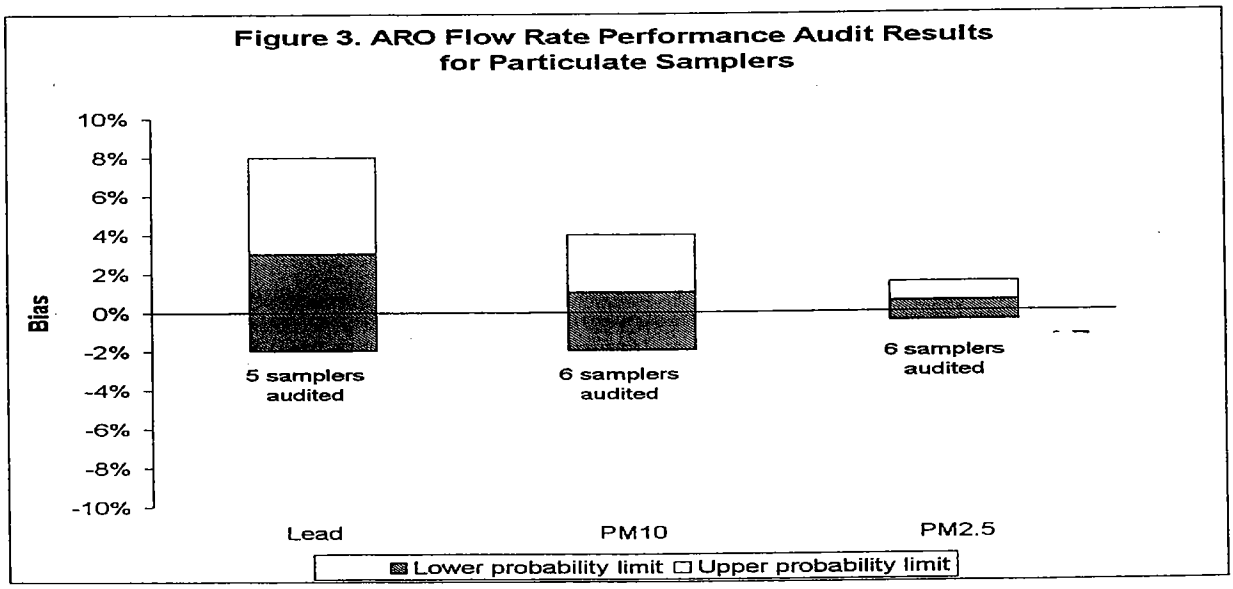
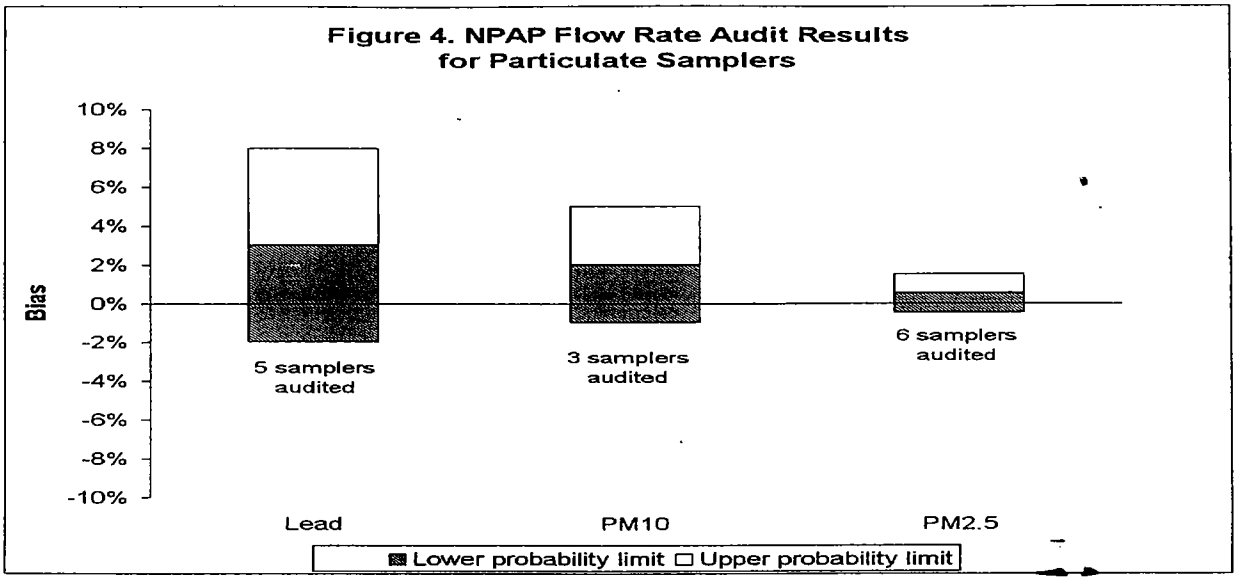


Figure 4 shows the results of external flow rate audits for PM_{10} and lead samplers performed with the National Performance Audit Program (NPAP) which is administered by the U.S. EPA. Currently NPAP audits of $PM_{2.5}$ samplers involve sampler collocation rather than flow rate checks.



Measurement Bias

Measurement bias is evaluated for $PM_{2.5}$ analyzers by collocated sampling using a audit sampler. For internal audits, the collocated measurements provide an estimate of bias resulting from sampler operations. For external NPAP audits, the collocated measurements provide an estimate of bias resulting from both sampler and laboratory operations. Measurement bias for lead is evaluated by use of standard lead test samples. This provides an estimate of the bias resulting from laboratory operations. The results of the annual performance audits of $PM_{2.5}$ and lead conducted by ARO personnel are shown in Figure 5, below.

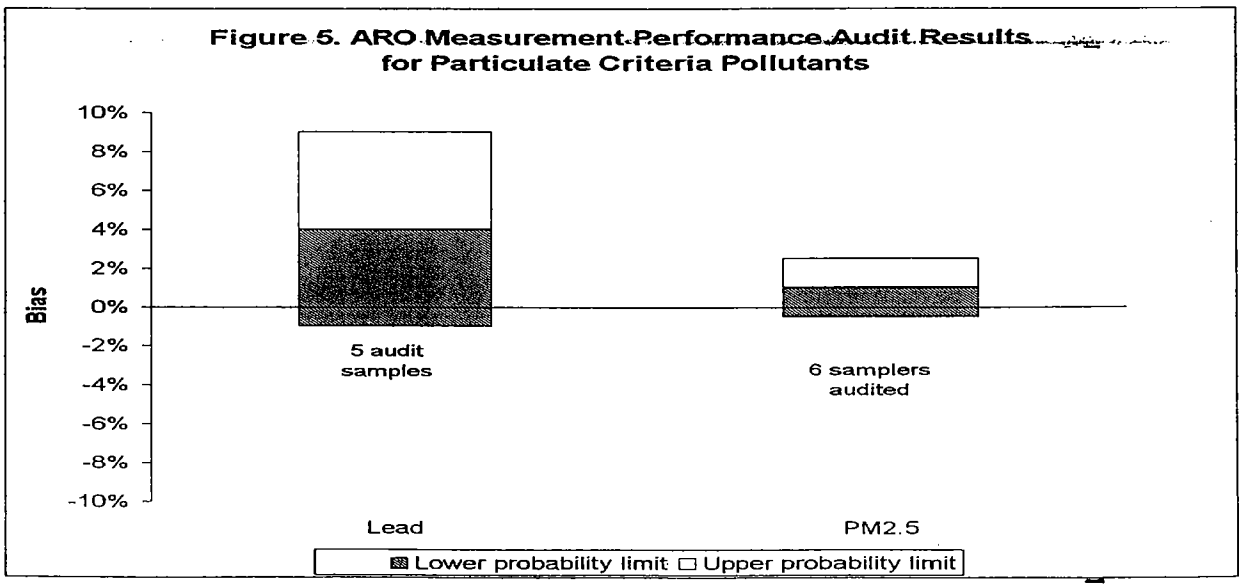
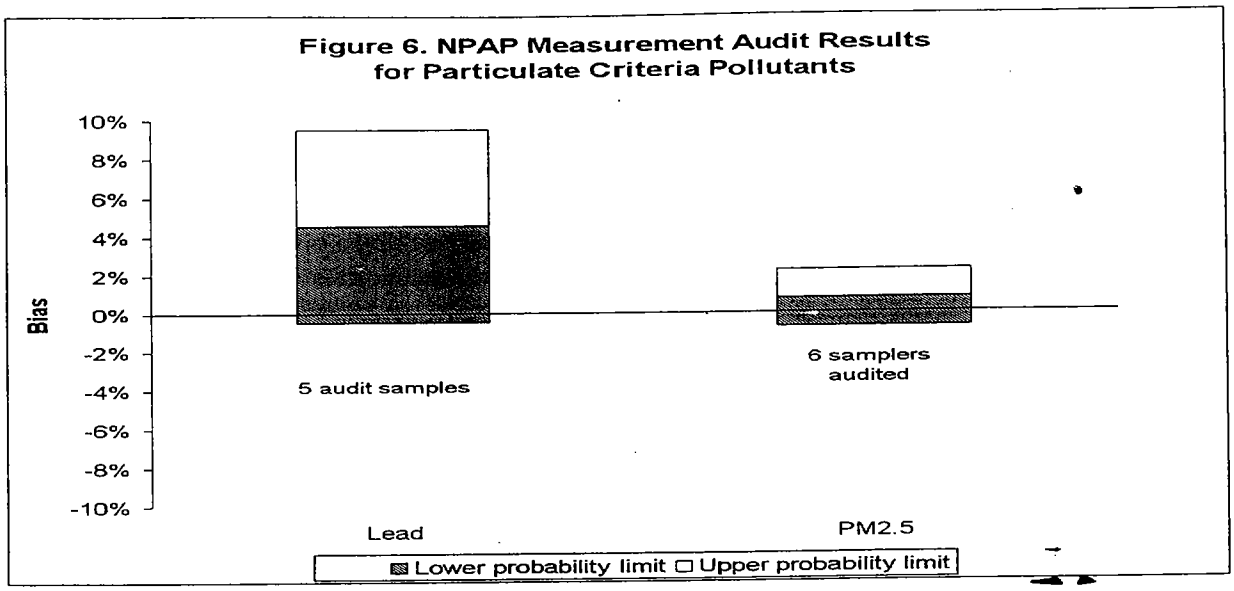


Figure 6 shows the results of external performance audits for PM_{10} and lead performed with the National Performance Audit Program (NPAP) which is administered by the U.S. EPA.



System Audits

Systems audits were performed at approximately one fourth of the sites and at the central analytical laboratory during calendar year 2000. These audits evaluated areas such as siting criteria, equipment operation and maintenance, operator training, recordkeeping, and served as a general review of site operations. No significant problems were observed, except for the following:

- The Towntwo site was shadowed by a 20 story office building which was recently completed. This site was closed in July 2000.
- The Townfour site had problems with repeated vandalism. A new, more secure, fence was installed in April and the sheriff's department increased patrols in the area to prevent reoccurrences.

No significant problems were found in the laboratory audits, except for failure to keep maintenance logs on several newly acquired analytical instruments. New logs were obtained and personnel instructed on their use. A spot check, approximately one month later, indicated the logs were in use.

TOTAL AND SPECIATED VOLATILE ORGANIC COMPOUNDS (PAMS)

The Acme Reporting Organization monitors the ambient concentrations of ozone precursors (volatile organic compounds [VOCs], carbonyls, and nitrogen oxides that can produce the criteria pollutant ozone). This monitoring is conducted as part of the Photochemical Assessment Monitoring Stations (PAMS) network. Nitrogen dioxide (one of the nitrogen oxides measured in PAMS) is also a criteria pollutant and its measurement is described under the gaseous criteria pollutant section, above. Total nitrogen oxides (NO_x) measurements are obtained continuously by a network of automated stations. Volatile organic compounds (VOCs), excluding carbonyls, are measured by continuous analyzers (on-line gas chromatographs) at selected sites. The remaining sites use automated samplers to collect VOC canister samplers which are then transported to the laboratory for analysis. Carbonyls are collected in adsorbent sampling tubes, which are transported to the laboratory for analysis.

PROGRAM UPDATE

At the beginning of 2000, the Acme Reporting Organization operated 5 ambient air monitoring stations that measured ozone precursors. On March 1, 2000, a station was opened at Townone to monitor VOCs, carbonyls, and NO_x.

QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the Acme Reporting Organization's ambient air monitoring of ozone precursors are shown in Table 9, below.

Table 9. Quality Objectives for Ozone Precursors

Data Quality Indicator	Objective
Precision (NO_x)	±10%
Precision (VOC, Carbonyls)	±25%
Bias (NO_x)	±15%
Bias (VOC, Carbonyls)	±20%
Completeness	75%
Promptness	100%

DATA QUALITY ASSESSMENT

Summary

Assessment of the data quality for ozone precursors showed that all instruments met goals for accuracy, precision, completeness, and promptness. System audits showed siting problems at two sites, both of these were corrected promptly.

Promptness and Completeness

At least 75 percent of scheduled monitoring data must be reported. All data must be submitted within six months after the end of the reporting quarter. Table 10 summarizes promptness and completeness data for ozone precursors.

Table 10. Data Quality Assessment for Promptness and Completeness

Ozone precursor	Promptness	Completeness
Carbonyls	100%	80%
Nitrogen Oxides (NO_x)	100%	96%
Total VOCs (Total non-methane hydrocarbons)	100%	87%
Speciated VOCs	100%	83%

Precision

At least once every two weeks, precision for nitrogen oxides (NO_x) and automated VOC analysis were determined by sampling a gas of known concentration. Precision for manual VOC sampling and carbonyl sampling is obtained by analysis of duplicate samples. Duplicates are taken at a frequency of one duplicate for every 10 samples. Table 11 summarizes the precision check results for 2000.

Table 11. Data Quality Assessment for Precision

Ozone precursor	Precision checks completed	Precision checks within limits
Carbonyls	91%	90%
Nitrogen Oxides (NO_x)	98%	97%
Total VOCs (Total non-methane hydrocarbons)	90%	91%
Speciated VOCs	95%	80%

Bias

The results of the annual performance audits conducted by ARO personnel are shown in Figure 7, below. For NO_x and the automated VOC analyzers, the center line represents the average bias across all sites (i.e., with all sites weighted equally). For the carbonyl and manual VOC analyses, the center line represents the average of all audit samples for the central analytical laboratory. The lower and upper probability limits represent the boundaries within which 95 percent of the individual bias values are expected to be distributed. Carbonyl and Total VOC measurements represent the average of all audit species.

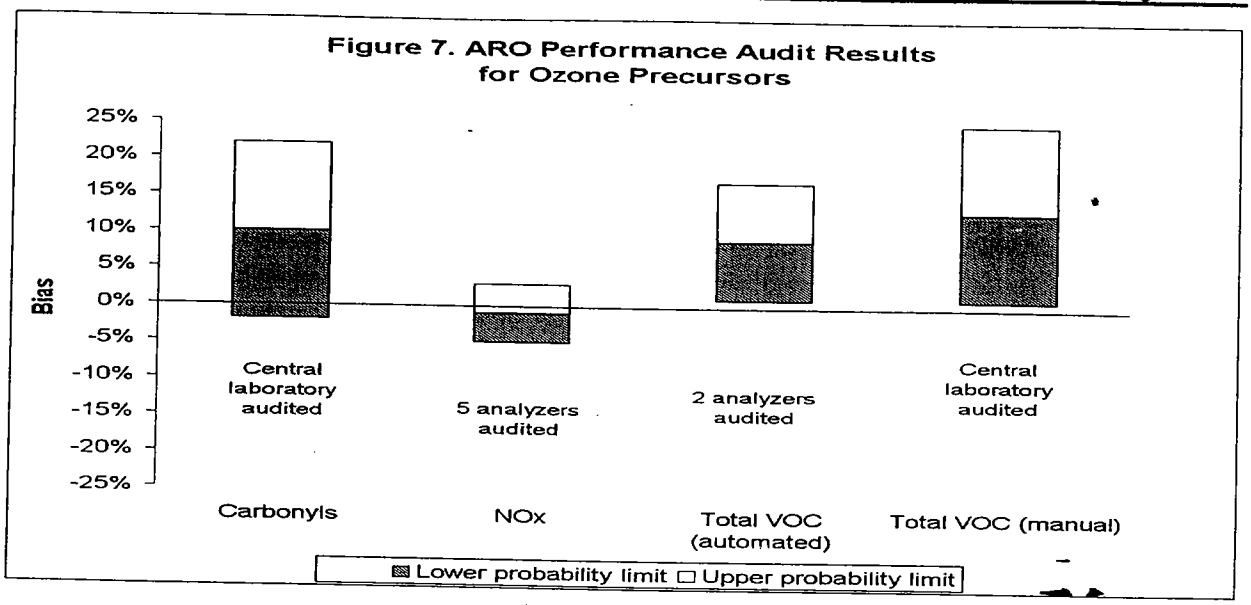
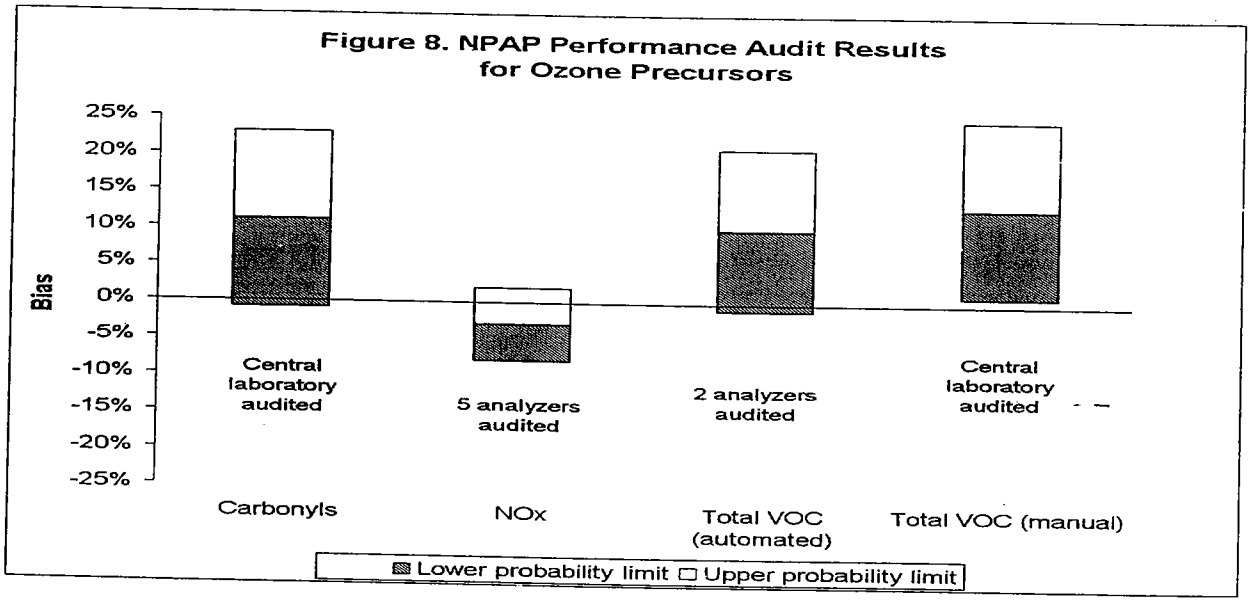


Figure 8 shows the results of the external performance audits performed with the National Performance Audit Program (NPAP) which is administered by the U.S. EPA.



System Audits

Systems audits were performed at two sites during calendar year 2000. These audits evaluated areas such as siting criteria, analyzer and sampler operation and maintenance, operator training, recordkeeping, and serve as a general review of site operations. In general both sites were performing well except for the following:

- The Townsix site had vegetation which had grown too close to the analyzer inlet probes. The vegetation was removed within one week, with assistance from the County Parks and Recreation Department.

A systems audit was also performed at the central analytical laboratory. Results were good with only minor items noted for improvements.

AIR TOXICS

The Acme Reporting Organization monitors the ambient concentrations of air toxic compounds. Three different methods are used, depending on the class of air toxic compound. Volatile organic compounds (VOCs), excluding carbonyls, are measured by continuous analyzers (on-line gas chromatographs) at selected sites. The remaining sites use automated samplers to collect VOC cannister samplers which are then transported to the laboratory for analysis. Carbonyls are collected with adsorbent sampling tubes, which are transported to the laboratory for analysis. Inorganic compounds are collected on $PM_{2.5}$ filters (as part of particulate criteria pollutant monitoring) and analyzed (after weighing for $PM_{2.5}$ mass) by inductively coupled plasma mass spectrometry (ICP MS). This monitoring is conducted as part of the Air Toxics monitoring network.

PROGRAM UPDATE

At the beginning of 2000, the Acme Reporting Organization operated five ambient air monitoring stations that measured ambient air toxics. On March 1, 2000, a station was opened at Townone to monitor air toxics.

QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the Acme Reporting Organization's ambient air monitoring of ambient air toxics are shown in Table 12, below.

Table 12. Quality Objectives for Air Toxics

Data Quality Indicator	Objective
Precision	±25%
Bias	±25%
Completeness	75%
Promptness	100%

DATA QUALITY ASSESSMENT

Summary

Assessment of the data quality for ambient air toxics showed that all instruments met goals for accuracy, precision, completeness, and promptness. System audits showed siting problems at two sites, both of these were corrected promptly.

Promptness and Completeness

At least 75 percent of scheduled monitoring data must be reported. All data must be submitted within six months after the end of the reporting quarter. Table 13 summarizes promptness and completeness for ambient air toxics monitoring data.

Table 13. Data Quality Assessment for Promptness and Completeness

Pollutant	Promptness	Completeness
Carbonyls	100%	78%
Volatile organic compounds	100%	84%
Inorganic compounds	100%	87%

Precision

At least once every two weeks, precision for automated VOC analysis is determined by sampling a gas of known concentration. Precision for manual VOC sampling, carbonyl sampling, and inorganic sampling is obtained by analysis of duplicate samples. Duplicates are taken at a frequency of one duplicate for every 10 samples. Table 14 summarizes the precision check results for 2000.

Table 14. Data Quality Assessment for Precision

Pollutant	Precision checks completed	Precision checks within limits
Carbonyls	91%	90%
Volatile organic compounds	98%	97%
Inorganic compounds	90%	91%

Bias

The results of the annual performance audits conducted by ARO personnel are shown in Figure 9, below. For the automated VOC analyzers, the center line represents the average bias across all sites (i.e., with all sites weighted equally). For the carbonyl, manual VOC, and inorganic analyses, the center line represents the average of all audit samples for the central analytical laboratory. The lower and upper probability limits represent the boundaries within which 95 percent of the individual bias values are expected to be distributed. All measurements represent the average of all audit species.

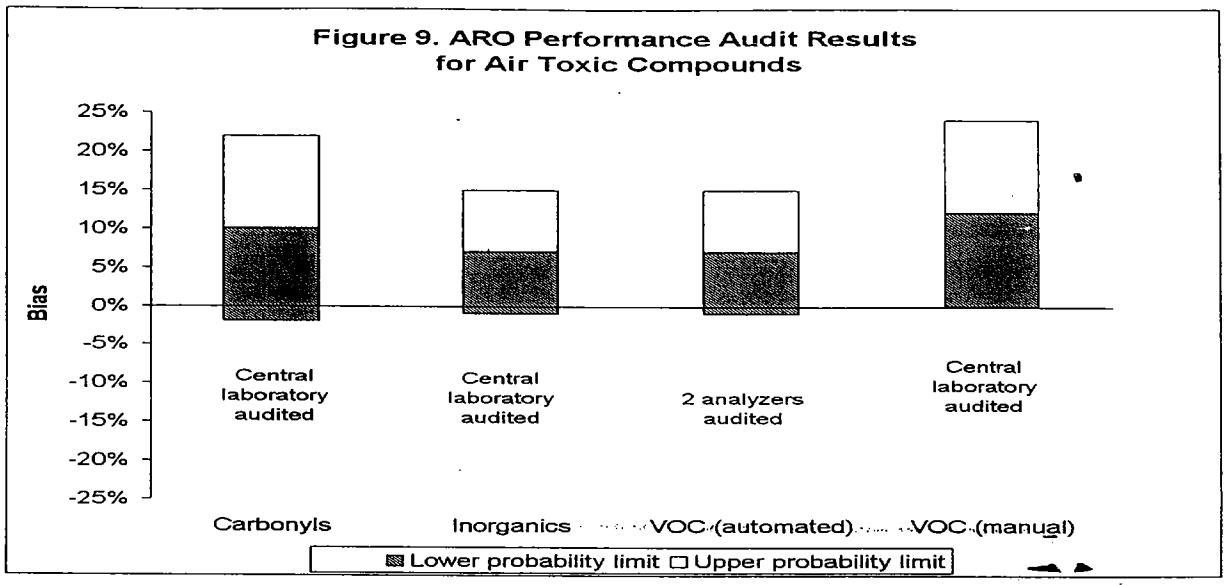
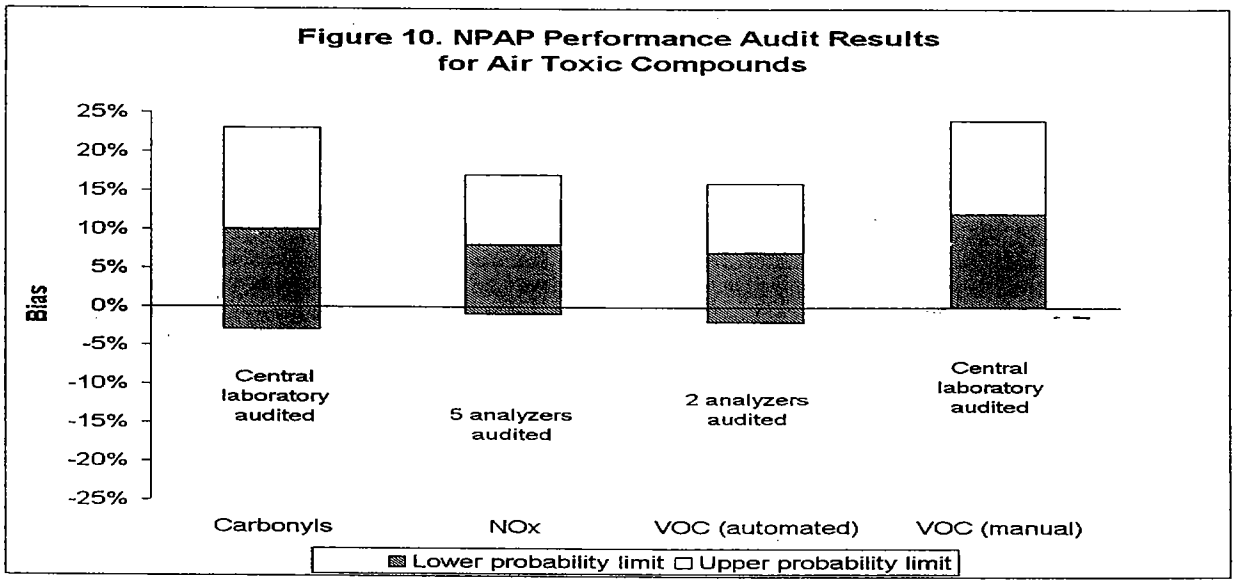


Figure 10 shows the results of the external performance audits performed with the National Performance Audit Program (NPAP) which is administered by the U.S. EPA.



System Audits

Systems audits were performed at two sites during the calendar year 2000. These audits evaluated areas such as siting criteria, analyzer and sampler operation and maintenance, operator training, recordkeeping, and serve as a general review of site operations. No significant problems were found, except for the following:

- The Townsix site had vegetation which had grown too close to the analyzer inlet probes. The vegetation was removed within one week, with assistance from the County Parks and Recreation Department.

A systems audit was also performed at the central analytical laboratory. No significant problems were found.

Example of Corrective Action Form

A corrective action request should be made whenever anyone in the reporting organization notes a problem that demands either immediate or long-term action to correct a safety defect, a operational problem, or a failure to comply with procedures. A typical corrective action request form, with example information entered, is shown below. A separate form should be used for each problem identified.

The corrective action report form is designed as a closed-loop system. First it identifies the originator, that person who reports and identifies the problem, states the problem, and may suggest a solution. The form then directs the request to a specific person (or persons), i.e., the recipient, who would be best qualified to "fix" the problem. Finally, the form closes the loop by requiring that the recipient state how the problem was resolved and the effectiveness of the solution. The form is signed and a copy is returned to the originator and other copies are sent to the supervisor and the applicable files for the record.

ARO - Corrective Action Request

Part A - To be completed by requestor

To: *John S. Visor*

Organization Responsible for Action *ARO Ambient Air Monitoring Section*

Urgency:

☐ Emergency (failure to take action immediately may result in injury or property damage)

☐ Immediate (4 hours) ☒ Urgent (24 hours) ☐ Routine (7 days)

☐ As resources allow ☐ For information only

From: *William Operator* phone: *(000) 555 - 1000*

fax: *(000) 555 - 1001* e-mail: *billo@localhost*

Copies to:

(Always send a copy to the ARO Site Coordinator at 115 Generic Office Building, Townone XX, 00001)

Problem Identification

Site(Location): *Townsix site*

System: *sample inlet*

Date problem identified: *Aug. 1, 2000*

Nature of problem: *Glass sample inlet and dropout trap broken during removal of weeds from site*

Recommended Action: *Replace broken parts*

Signature: *William Operator* Date: *Aug. 1, 2000*

Part B - to be completed by responsible organization

Problem Resolution

Date corrective action taken: *August 4, 2000*

Summary of Corrective Action: *Replacement parts were ordered and received. The new parts were installed within three days of the request. Data from the days with a cracked sample inlet will be flagged as questionable.*

Effectiveness of corrective action: *Sample inlet restored to new condition.*

Signature: *John Visor* Date: *Aug. 4, 2000*

Phone: *(000) 555 - 2000* Fax: *(000) 555 - 2001*

e-mail: *jsv@localhost*

Send copies of the completed form to the requestor and the ARO Site Coordinator at 115 Generic Office Building, Townone XX, 00001)

ARO form CAR-1 , May 1, 1999

TECHNICAL REPORT DATA

(Please read Instructions on reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT-

The Handbook provides additional information and guidance on the material covered in the Code of Federal Regulations pertaining to the Ambient Air Quality Surveillance Program and establishes a set of consistent QA practices that will improve the quality of the nation's ambient air data and ensure data comparability among sites across the nation. The document is written for technical personnel at State and local monitoring agencies to assist them to develop and implement a quality system for the Ambient Air Quality Surveillance Program.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
QA Handbook Vol II	Air Pollution control	

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