EPA United States Environmental Protection Agency

Quality Assurance Handbook for Air Pollution Measurement Systems

Volume II

Ambient Air Quality Monitoring Program

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Quality Assurance Handbook for Air Pollution Measurement Systems

Volume II

Ambient Air Quality Monitoring Program

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
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RTP, NC 27711

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Acknowledgments

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Acronyms and Abbreviations

AAMG	Ambient Air Monitoring Group
APTI	Air Pollution Training Institute
ADQ	audit of data quality
AMNP	Annual monitoring network plan
AMTIC	Ambient Monitoring Technical Information Center
ANSI	American National Standards Institute
AQAD	Air Quality Assessment Division
AQI	Air Quality Index
AQS	Air Quality System
ARM	approved regional method
ASTM	American Society for Testing and Materials
ASQ	American Society for Quality
AWMA	Air and Waste Management Association
CAA	Clean Air Act
CFR	*Code of Federal Regulations*
CL	confidence limit
CBSA	core-based statistical area
CMSA	combined metropolitan statistical area
COC	chain of custody
CPU	central processing unit
CSA	combined statistical area
CSN	PM2.5 Chemical Speciation Network
CRM	certified reference material
CV	coefficient of variation
DAS	data acquisition system
DASC	Data Assessment Statistical Calculator
DC	direct current
DQA	data quality assessment
DOP	digital aerosol photometer
DQI	data quality indicators
DQOs	data quality objectives
EDO	environmental data operation
EDERF	energy dispersive x-ray flouresence
EPA	Environmental Protection Agency
FEM	federal equivalent method
FR	flow rate
FRM	federal reference method
FTIR	fourier transform infrared (spectroscopy)
GC/MS	gas chromatography mass spectrometry
GIS	geographical information systems
GLP	good laboratory practice
GMIS	gas manufactures internal standards
HAP	hazardous air pollutants
HC	hydrocarbon
HPLC	high performance liquid chromatography
HVAC	heating, ventilating and air conditioning
ICP	inductively coupled plasma
IMPROVE	Interagency Monitoring of Protected Visual Environments
IT	information technology
LDL	lower detectable limit
LIMS`	laboratory information management systems
MDL	method detection limit
MFC	mass flow control

Acronyms and Abbreviations (Continued)

MPA	monitoring planning area
MQAG	Monitoring and Quality Assurance Group
MQOs	measurement quality objectives
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NACAA	National Association of Clean Air Agencies
NATTS	National Air Toxics Trends Sites
NECTA	New England city and town area
NEIC	National Enforcement Investigations Center
NTAA	National Tribal Air Association
NTEC	National Tribal Environmental Council
NCore	National Core Network
NERL	National Exposure Research Laboratory
NIST	National Institute of Standards and Technology
NF	National Formulary
NPS	National Park Service
NPAP	National Performance Audit Program
NPEP	National Performance Evaluation Program
NOAA	National Oceanic Atmospheric Administration
NTRM	NIST traceable reference material
OAQPS	Office of Air Quality Planning and Standards
OMB	Office of Management and Budget
ORD	Office of Research and Development
ORIA	Office of Radiation and Indoor Air
P&A	precision and accuracy
PAMS	Photochemical Assessment Monitoring Stations
PDFID	Cryogenic Preconcentration and Direct Flame Ionization Detection
PC	personal computer
PE	performance evaluation
PEP	$PM_{2.5}$ Performance Evaluation Program
PBMS	performance based measurement system
ppb	part per billion
ppm	part per million
PSD	Prevention of Significant Deterioration
PQAO	primary quality assurance organization
PT	proficiency test
PWD	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
RPO	regional planning organization
RSD	relative standard deviation
SD	standard deviation
SIPS	State Implementation Plans
SLAMS	state and local monitoring stations
SOP	standard operating procedure
SPMS	special purpose monitoring stations
SRM	standard reference material
SRP	standard reference photometer

Acronyms and Abbreviations (Continued)

TAD	technical assistance document
TEOM	tapered element oscillating microbalance
TIP	tribal implementation plan
TSA	technical system audit
TSP	total suspended particulate
TTL	transistor-transistor logic
USB	universal serial bus
USGS	U.S. Geological Survey
UTM	universal transverse Mercator
USP	US Pharmacopeial
VAC	volts of alternating current
VOC	volatile organic carbon

0. Introduction

0.1 Intent of the Handbook

This document is Volume II of a five-volume quality assurance (QA) handbook series dedicated to air pollution measurement systems. Volume II is dedicated to the Ambient Air Quality Surveillance Program and the data collection activities inherent to that program. This guidance is part of a quality management system designed to ensure that the Ambient Air Quality Surveillance Program: (1) provides data of sufficient quality to meet the program's objectives, and (2) is implemented consistently across the Nation.

The purpose of the Handbook is twofold. First, it provides additional information and guidance on the material covered in the Code of Federal Regulations (CFR) pertaining to the Ambient Air Quality Surveillance Program. Second, the document is intended to assist technical personnel at tribal, state and local monitoring organizations[1] in developing and implementing a *quality system* for the Ambient Air Quality Surveillance Program. A quality management system (QMS), as defined by *The American National Standard-Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs (ANSI/ASQ E4),*[2] is:

> "a structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring the quality in its work processes, products, and services. The QMS provides the framework for planning, implementing, and assessing the work performed by the organization and for carrying out required quality assurance (QA) and quality control (QC) activities".

A monitoring organization's QMS for the Ambient Air Quality Surveillance Program is described in its quality assurance project plan (QAPP). Therefore, the Handbook 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)*[3]. Environmental data operations (EDO) refer to the work performed to obtain, use, or report information pertaining to natural surroundings and conditions. The information in this Handbook can be used as guidance in the development of detailed monitoring organization QAPPs.

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). In 2006, the term "NAMS" was discontinued and a new national monitoring concept-the National Ambient Air Monitoring Strategy- was adopted. Although the focus will remain on the criteria pollutants, this edition is expanded to cover quality assurance guidance for:

- Photochemical Assessment Monitoring Stations (PAMS) (https://www3.epa.gov/ttn/amtic/pamsmain.html);
- Open path monitoring (https://www3.epa.gov/ttn/amtic/longpath.html);

[1] Monitoring organization will be used throughout the handbook to identify any tribal, state or local organization that is implementing an ambient air monitoring program, especially if they are using the data for comparison to the National Ambient Air Quality Standards (NAAQS).
[2] http://asq.org/quality-press/display-item/index.html?item=T977E
[3] http://www.epa.gov/quality1/qa_docs.html

- $PM_{2.5}$ Chemical Speciation Network (https://www3.epa.gov/ttn/amtic/speciepg.html);
- National Air Toxics Trends Network (NATTS) (https://www3.epa.gov/ttn/amtic/airtoxpg.html);
- NCore Network (https://www3.epa.gov/ttn/amtic/ncore.html).

Due to the dynamic nature of the monitoring networks, this Handbook does not supplant the detailed guidance provided by the programs listed above but provides general information and pointers, in the form of hyperlinks, where one can go for more detailed information.

0.2 Use of the Terms Shall, Must, Should and May

The intent of this handbook is to provide additional guidance on the ambient air monitoring requirements found in the Clean Air Act and 40 CFR Parts 50, 53 and 58. In order to distinguish requirements from guidance, the following terms will be used with consistency.

- *shall, must-* when the element is a requirement in 40 CFR and the Clean Air Act
- *should-* when the element is recommended. This term is used when extensive experience in monitoring provides a recommended procedure that would help establish or improve the quality of data or a procedure. The process that includes the term is not required but if not followed, an alternate procedure should be developed that meets the intent of the guidance.
- *may-* when the element is optional or discretionary. The term also indicates that what is suggested may improve data quality, that it is important to consider, but it is not as important as those that have been suggested using the term "should".

NOTE: The material in the Handbook can only reflect the regulation and guidance up to the date the Handbook was published. Regulations that change after Handbook publication cannot be reflected in this document. Therefore, the reader is cautioned to review current regulations and technical notes when using any guidance in this document.

0.3 Use of Footnotes

This document will make extensive use of internet links that will provide the user with access to more detailed information on a particular subject. Due to the limitations of Adobe, full URL addresses must be provided in order for the links to work. Rather than clutter the body of the document with long URL addresses, footnotes will be used to direct the interested reader to the correct link.

0.4 Handbook Review and Distribution

The information in this Handbook was revised and/or developed by many of the organizations responsible for implementing the Ambient Air Quality Surveillance Program (see Acknowledgments). It has been peer-reviewed and accepted by these organizations and serves to promote 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: **https://www3.epa.gov/ttn/amtic/qalist.html**

Recommendations for modifications or revisions are always welcome. Comments should be sent to the appropriate Regional Office Ambient Air Monitoring QA Contact. The QA Handbook Revision Workgroup will meet twice a year to discuss any pertinent issues and proposed changes.

1.0 Program Background

1.1 Ambient Air Quality Monitoring Network

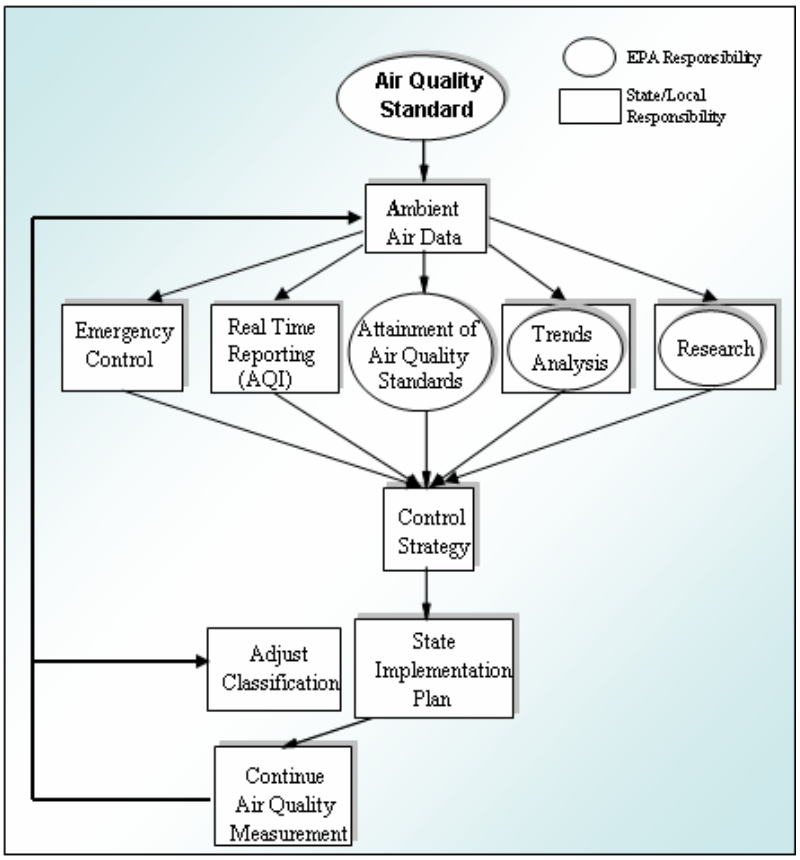

Figure 1.1 Ambient air quality monitoring process

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 Clean Air Act (CAA)[1], 40 CFR Parts 50, 53 and 58[2], and their references.

Between the years 1900 and 1970, the concentrations 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 provide the framework for all pertinent organizations to protect air quality.

40 CFR Part 58, Appendix D requires that monitoring networks for criteria pollutants be designed for three basic monitoring objectives:

- provide air pollution data to the general public in a timely manner;
- support compliance with ambient air quality standards (primary and secondary) and emission strategy development;
- support air pollution research studies.

In addition, these monitoring networks can also be developed to:

- activate emergency control procedures that prevent or alleviate air pollution episodes;
- observe pollution trends throughout the region, including non-urban areas.

To meet these basic needs, the monitoring network may require monitoring sites be located to:

- determine the highest concentration expected to occur in the area covered by the network;

[1] http://epa.gov/air/caa/
[2] http://www.access.gpo.gov/nara/cfr/cfr-table-search.html

- measure typical concentrations in areas of high population density;
- determine the impact of significant sources or source categories on air quality;
- determine background concentration levels;
- determine the extent of regional pollutant transport among populated areas, and in support of secondary standards;
- measure air pollution impacts on visibility, vegetation damage, or welfare-based impacts.

These "site types" will be used during the development of data quality objectives (Section 3). As one reviews the site types, it becomes apparent that it will be rare that individual sites can be located to meet more than two or three types of measurements. Therefore, monitoring organizations need to choose the sites that are most representative of its priority objective(s).

Through the process of implementing the CAA, seven major categories of monitoring stations or networks that measure the air pollutants have been developed. These networks are described below. In addition, a fact sheet on each network (with the exception of SPMs) can be found in Appendix A.

State and Local Air Monitoring Stations (SLAMS) including Tribal Monitoring Stations

The SLAMS consist of a network of monitoring stations whose size and distribution is largely determined by the monitoring requirements for NAAQS comparison and the needs of monitoring organizations to meet their respective tribal/state implementation plan (TIP/SIP) requirements. The TIP/SIPs provide for the implementation, maintenance, and enforcement of the national ambient air quality standards (NAAQS) in each air quality control region within a tribe/state. The Handbook is largely devoted to guidance related to the SLAMS network. SLAMS exclude special purpose monitor (SPM) stations and include NCore, PAMS, Near Road and all other State or locally operated stations that have not been designated as SPM stations.

Special Purpose Monitor Stations (SPMs)[3]

An SPM station means a monitor included in an agency's monitoring network that the agency has designated as a special purpose monitor station in its annual monitoring network plan and in the AQS, and which the agency does not count when showing compliance with the minimum requirements of this subpart (40 CFR Part 58) for the number and siting of monitors of various types. Any SPM operated by an air monitoring agency must be included in the periodic assessments and annual monitoring network plan required by §58.10 and approved by the Regional Administrator. SPMs:

- provide for special studies needed by the monitoring organizations to support TIPs/SIPs and other air program activities;
- are not permanently established and can be adjusted to accommodate changing needs and priorities;
- are used to supplement the fixed monitoring network as circumstances require and resources permit;
- data must meet all QA, siting, and methodology requirements for SLAMS monitoring, if the data from SPMs are to be used for SIP purposes.

Any SPM data collected by an air monitoring agency using a Federal reference method (FRM), Federal equivalent method (FEM), or approved regional method (ARM) must meet these requirements:

[3] 40 CFR Part 58.1 and 40 CFR Part 58.20

- 40 CFR Parts 58.11 and 58.12;
- the QA requirements in 40 CFR Part 58, Appendix A, or an approved alternative to Appendix A to this part;
- requirements of 40 CFR Part 58.16, for submitting the data collected to AQS; and
- submission of an indication to AQS by the monitoring agency that the SPM reporting data to AQS meets the requirements of 40 CFR Part 58, Appendices A and E[4].

40 CFR Part 58.20 provides additional details on the requirements of the SPM and the use of SPM data.

All data from an SPM using an FRM, FEM, or ARM which has operated for more than 24 months is eligible for comparison to the relevant NAAQS, subject to the conditions of §58.30, unless the air monitoring agency demonstrates that the data came from a particular period during which the requirements of 40 CFR Part 58, Appendices A, C, or E were not met in practice.

If an SPM using an FRM, FEM, or ARM is discontinued within 24 months of start-up, the Administrator will not base a NAAQS violation determination for the $PM_{2.5}$ or ozone NAAQS solely on data from the SPM.

If an SPM using an FRM, FEM, or ARM is discontinued within 24 months of start-up, the Administrator will not designate an area as nonattainment for the CO, SO_2, NO_2, or 24-hour PM_{10} NAAQS solely on the basis of data from the SPM. Such data are eligible for use in determinations of whether a nonattainment area has attained one of these NAAQS.

Prior approval from EPA is not required for discontinuance of an SPM.

NO_2 Near-Road Monitoring Network

On February 9, 2010, new minimum monitoring requirements for the nitrogen dioxide (NO_2) monitoring network were promulgated (75 FR 6474) in support of a revised NAAQS for NO_2. The NO_2 NAAQS was revised to include a 1-hour standard with a 98th percentile form and a maximum allowable NO_2 concentration of 100 ppb anywhere in an area, while retaining the annual standard of 53 ppb. In the 2009 NO_2 Risk and Exposure Assessment[5] created during the NAAQS revision process, and as reiterated in the preambles to the Notice of Proposed Rulemaking (NPR for NO_2) (74 FR 34404) and the Notice of Final Rulemaking (NFR for NO_2) (75 FR 6474) on the Primary NAAQS for NO_2, the EPA recognized that roadway-associated exposures account for a majority of ambient exposures to peak NO_2 concentrations.

As part of the NO_2 NAAQS revision, the EPA promulgated requirements for near-road NO_2 monitors in urban areas. The primary objective of the required near-road NO_2 network is to support the Administrator's approach in revising the NO_2 NAAQS by focusing monitoring resources on near-road locations where peak, ambient NO_2 concentrations are expected to occur as a result of on-road mobile source emissions. As such, the NO_2 monitoring is part of the SLAMS Network. Monitoring at such a location or locations within a particular urban area will provide data that can be compared to the NAAQS and used to assess exposures for those who live, work, play, go to school, or commute within the near-roadway environment.

The near-road NO_2 data will provide a clear means to determine whether the NAAQS is being met within the near-road environment throughout a particular urban area. Near-road NO_2 monitoring sites are to be

[4] AQS supports this via the MI – Monitor Regulatory Compliance transaction. It is also available on the Maintain Monitor form in the web app.
[5] http://www.epa.gov/ttn/naaqs/standards/nox/s_nox_cr_rea.html

placed at locations with expected peak NO_2 concentrations in the near-road environment, although the target mobile sources and the roads they travel upon are ubiquitous throughout urban areas. Because of these two factors, these monitoring data may be said to represent the relative worst-case population exposures that may be occurring in the near-road environment throughout an urban area over the averaging times of interest.

Prevention of Significant Deterioration (PSD) Monitoring[6]

Prevention of Significant Deterioration (PSD) applies to new major sources or major modifications at existing sources for pollutants where the area the source is located is in attainment or unclassifiable with the National Ambient Air Quality Standards (NAAQS). It requires the following:

1. installation of the Best Achievable Control Technology (BACT);
2. an air quality analysis;
3. an additional impacts analysis; and
4. public involvement.

Class I areas are areas of special national or regional natural, scenic, recreational, or historic value for which the PSD regulations provide special protection.

The main purpose of the air quality analysis is to demonstrate that new emissions emitted from a proposed major stationary source or major modification, in conjunction with other applicable emissions increases and decreases from existing sources, will not cause or contribute to a violation of any applicable NAAQS or PSD increment.

Generally, the analysis will involve (1) an assessment of existing air quality, which may include ambient monitoring data and air quality dispersion modeling results, and (2) predictions, using dispersion modeling, of ambient concentrations that will result from the applicant's proposed project and future growth associated with the project. In some cases, it may also require ambient air monitoring.

The QA requirements for monitoring criteria pollutants at PSD sites are very similar to the QA requirements for monitoring sites used for NAAQS compliance and can be found in 40 CFR Part 58 Appendix B.

This Handbook is not intended to provide any overall guidance on the PSD program. However, as information is relayed on the ambient air CFR QA requirements, the Handbook will distinguish any differences in the QA requirements between the PSD and ambient air programs. In addition, in 2013 EPA developed some additional guidance related to the PSD quality system[7]

$PM_{2.5}$ Chemical Speciation Network (CSN)[8]

In 1997, the $PM_{2.5}$ NAAQS review led to the establishment of the Chemical Speciation Network (CSN). The initial monitoring network began with 13 pilot sites in 2000 and the size of the network has fluctuated over the years. Currently, the CSN consists of approximately 150 ambient air monitoring sites. These sites collect aerosol samples over 24 hours on filters analyzed for trace elements, major ions, and

[6] https://www.epa.gov/nsr/prevention-significant-deterioration-basic-information
[7] https://www3.epa.gov/ttn/amtic/files/policy/PSD_Q&A.pdf
[8] https://www3.epa.gov/ttn/amtic/speciepg.html

organic and elemental carbon. The primary objectives of the CSN are to support $PM_{2.5}$ regulatory implementation activities, support health effects and exposure research studies, and to provide nationally consistent data for the assessment of trends and a long-term record of the chemical composition of $PM_{2.5}$.

Photochemical Assessment Monitoring Stations (PAMS)[9]

On February 12, 1993, the U.S. Environmental Protection Agency (EPA) revised ambient air quality surveillance regulations in Title 40 Part 58 of the Code of Federal Regulations (40 CFR Part 58) to include provisions for enhanced monitoring of ozone (O_3), oxides of nitrogen (NO_x), volatile organic compounds (VOCs), and selected carbonyl compounds, as well as monitoring of meteorological parameters. On October 1, 2015, EPA made significant changes to the PAMS monitoring requirements and applicability (40 CFR part 58 Appendix D, section 5.0) to better serve both national and local objectives. The EPA finalized a two-part network design. The first part of the design includes a network of fixed sites ("required PAMS sites") intended to support O_3 model development and evaluation and the tracking of trends of important O_3 precursor concentrations. These required PAMS sites are to be located at NCore sites located in CBSAs with a population of one million or more. The second part of the network design requires states with moderate O_3 non-attainment areas to develop and implement Enhanced Monitoring Plans (EMPs) which were intended to allow monitoring agencies the needed flexibility to implement additional monitoring capabilities to suit the needs of their area.

> **NOTE:** As of the publication date of this Handbook, the PAMS Program was undergoing revisions to the implementation of the program. Those interested in more current guidance on the PAMS program should visit the AMTIC website for more up-to-date information.

National Air Toxic Trends Stations (NATTS)[10]

There are currently 188 hazardous air pollutants (HAPs) or Air Toxics (AT) regulated under the CAA. These pollutants have been associated with a wide variety of adverse health and ecosystem effects. In 1999, EPA finalized the Urban Air Toxics Strategy (UATS)[11]. The UATS states that emissions data are needed to quantify the sources of air toxics and their impacts and aid in the development of control strategies, while ambient monitoring data are needed to understand the behavior of air toxics in the atmosphere after they are emitted. Part of this strategy included the need for toxics monitoring. This monitoring includes:

The Urban Air Toxics Monitoring Program[12] (UATMP) - a program designed to characterize the magnitude and composition of potentially toxic air pollution in, or near, urban locations. The UATMP was initiated by EPA in 1988 as an extension of the existing Nonmethane Organic Compounds Program (NMOC) to meet the increasing need for information on air toxics. Over the years, the program has grown in both participation levels and pollutants targeted (EPA, 2009a). The program has allowed for the identification of compounds that are prevalent in ambient air and for participating agencies to screen air samples for concentrations of air toxics that could potentially result in adverse human health effects.

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[9] https://www3.epa.gov/ttn/amtic/pamsmain.html
[10] https://www3.epa.gov/ttn/amtic/airtoxpg.html
[11] https://www3.epa.gov/ttn/atw/area/arearules.html
[12] https://www3.epa.gov/ttnamti1/uatm.html

The National Air Toxics Trends Stations (NATTS) - a program designed to generate long-term ambient air toxics concentration data in order to evaluate trends. The NATTS network was created to generate long-term ambient air toxics concentration data at specific fixed sites across the country. The NATTS Pilot program was developed and implemented during 2001 and 2002, leading to the development and initial implementation of the NATTS network during 2003 and 2004. The goal of the program is to estimate the concentrations of air toxics on a national level at fixed sites that remain active over an extended period of time. Specifically, it is anticipated that the NATTS data will be used for:

- tracking trends in ambient levels to evaluate progress toward emission and risk reduction goals;
- directly evaluating public exposure & environmental impacts in the vicinity of monitors;
- providing quality assured data for risk characterization;
- assessing the effectiveness of specific emission reduction activities; and
- evaluating and subsequently improving air toxics emission inventories and model performance.

National Core Monitoring Network (NCore)[13]

The NCore multi-pollutant stations are part of an overall strategy to integrate multiple monitoring networks and measurements. Each state (i.e., the fifty states, District of Columbia, Puerto Rico, and the Virgin Islands) is required to operate at least one NCore site. Monitors at NCore multi-pollutant sites will measure a number of pollutants. Due to the continued development of NCore, consult the NCore website for a complete listing of the pollutants to be measured at the NCore sites.

The objective is to locate sites in broadly representative urban and rural locations throughout the country to help characterize regional and urban patterns of air pollution. In many cases, monitoring organizations will collocate these new stations with existing CSN sites measuring speciated $PM_{2.5}$ components, PAMS sites already measuring O_3 precursors, and/or NATTS sites measuring air toxics. By combining these monitoring programs at a single location, EPA and its partners will maximize the multi-pollutant information available. This greatly enhances the foundation for future health studies, NAAQS revisions, validation of air quality models, assessment of emission reduction programs, and studies of ecosystem impacts of air pollution.

1.2 The EPA Quality System Requirements

A quality system is the "blueprint" or framework by which an organization applies sufficient quality control (QC) and quality assurance (QA) practices to ensure that the results of its environmental programs meet or exceed expectations. It is based upon the model of planning the work, implementing what is planned, assessing the results against the performance criteria, reporting on data quality and making improvements if necessary. Figure 1.2 provides an illustration of the pertinent regulations and policy that drive the development of a quality system. Some important aspects of this figure are explained below.

1.2.1 Policy and Regulations

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

[13] https://www3.epa.gov/ttn/amtic/ncore.html

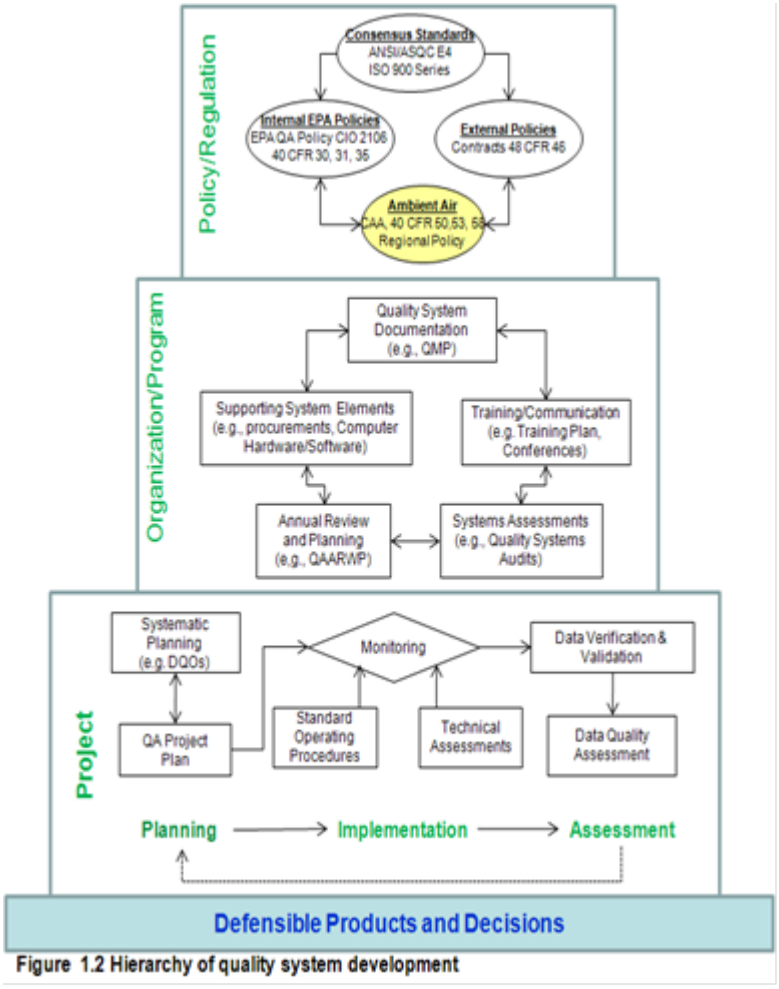


Figure 1.2 Hierarchy of quality system development

- **Consensus Standards ANSI/ASQ E4** – EPA's quality system is based on the document *American National Standard- Quality Management Systems for Environmental Information and Technology Programs-Requirements with Guidance for Use (ANSI/ASQ E4-2014)*[14]. 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. EPA has adopted the ANSI/ASQ E4 as its quality system consensus standard.

- **Internal Policies**- are those policies developed specifically by EPA. The EPA QA Policy CIO 2106.0[15] expresses the EPA policy in regards to the quality system development for all EPA organizations and non-EPA organizations performing work on behalf of EPA through extramural agreements. The EPA QA Policy adheres to E4 under the authority of the Office of Management and Budget. Section 1.2.5 below provides more specifics on this Order. In addition, QA policies fall under Titles 2 and 40 of the Code of Federal Regulations (CFR). Those most important to the monitoring community are 2 CFR Part 1500 and 40 CFR Part 35, but these are not specific to ambient air monitoring.

- **External Policies** - Refers to the Code of Federal Regulation that may have QA requirements that are related to policies other than EPA. For example, 48 CFR refers to federal acquisition requirements (contracting, etc.) which have some specific QA requirements. The references to the external regulations are those that apply to the quality system requirements for external funding.

- **Ambient Air** -The consensus standards (E4) and internal and external requirements then funnel to the Headquarters and Regional programs (yellow circle) where additional QA requirements, specific to a particular monitoring program, are included. Ambient air requirements include

[14] http://webstore.ansi.org/
[15] http://www.epa.gov/quality1/.

documents like the Clean Air Act (CAA) and 40 CFR Parts 50, 53 and 58 which are specific to ambient air monitoring.

1.2.2 Organization/Program

This area in Figure 1.2 refers to the monitoring organization and is used to describe its overall quality system, usually in the form of a **quality management plan (QMP)**[16]. Many monitoring organizations perform a multitude of data collection activities for different media (e.g., air, water, solid waste) where ambient air monitoring might be only one branch in a large organization. The QMP explains the organizations approach to a quality system across all media. It is the responsibility of each organization to have a QMP that demonstrates an acceptable quality system. QMPs are approved by the EPA Regions and reported and tracked in AQS.

1.2.3 Project

The term "project" in Figure 1.2 refers to the specific environmental data operation (EDO) that occurs at the monitoring organization. An EDO refers to the work performed to obtain, use, or report information pertaining to environmental processes and conditions. The ambient air program would be considered a specific project; in fact, monitoring for a specific pollutant could also be considered a project. This Handbook provides the majority of the guidance necessary for the monitoring organizations to develop QA project plans (QAPPs) specific to its 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 B. It is anticipated that the majority of these documents will be available on the AMTIC bulletin board.

1.2.4 Quality System Requirements for EPA Funded Programs

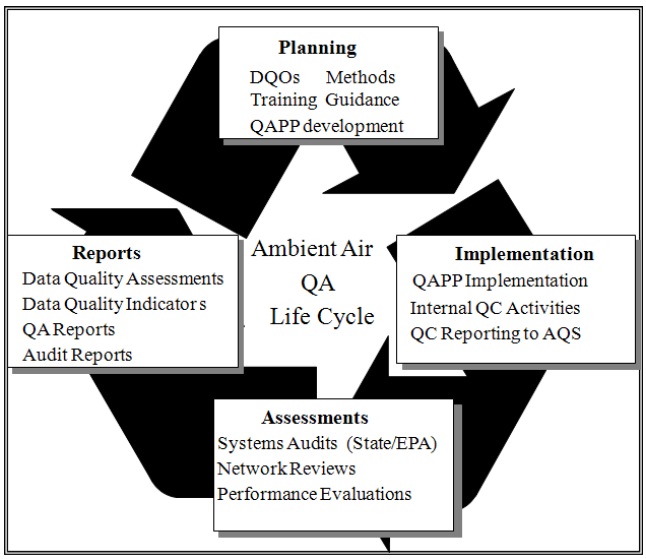


Figure 1.3 Ambient Air Monitoring Quality Monitoring QA Program

EPA's national quality system requirements can be found in EPA QA Policy CIO 2106.0 [17]. Any organization using EPA funds for the collection of environmental data are covered under CIO 2106.0 and must develop, implement, and maintain a quality system that demonstrates conformance to the minimum specifications of ANSI/ASQC E4.

1.3 The Ambient Air Monitoring Program Quality System

Figure 1.3 represents the stages of the Ambient Air Quality Monitoring QA Program. OAQPS modified EPA CIO 2106.0 as appropriate in order to provide data of the quality needed to meet the Ambient Air Monitoring Program

[16] https://www.epa.gov/quality/agency-wide-quality-system-documents
[17] https://www.epa.gov/quality/quality-program-policy-agency-products-and-services

objectives. The planning, implementation, assessment, and reporting tools will be briefly discussed below.

1.3.1 Planning

Planning activities include:

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. Section 3 will provide more information on the DQO Process.

Methods- Reference methods and measurement principles have been written for each criteria pollutant. A method can refer to an instrument, a laboratory analytical method or a combination of both. For monitoring for comparison to the NAAQS, monitoring organizations must use methods that are designated as Federal Reference (FRM) Federal Equivalent (FEM)[18] or approved regional monitor (ARM)[19] for $PM_{2.5}$. ORD NERL implements the FRM/FEM designation program and provides technical assistance in the $PM_{2.5}$ ARM process. Approved FRM/FEM methods refer to individual monitoring instruments that either provide a pollutant concentration or provide a sample for further laboratory analysis and must be operated as required in 40 CFR Part 50. Since these methods do not address all the specifications of a monitoring, sampling or analytical operation, they are used to provide the necessary requirements for the development of detailed standard operating procedures that would be developed by monitoring organizations as part of an acceptable QAPP.

Training - Training is an essential 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. Many of the monitoring networks listed above have developed technical assistance documents and generic QAPPs to help guide personnel in the important aspects of these programs. A list of these documents is included in Appendix B.

QMP/QAPP Development - Each state, local, and tribal organization must develop a QMP and QAPP.

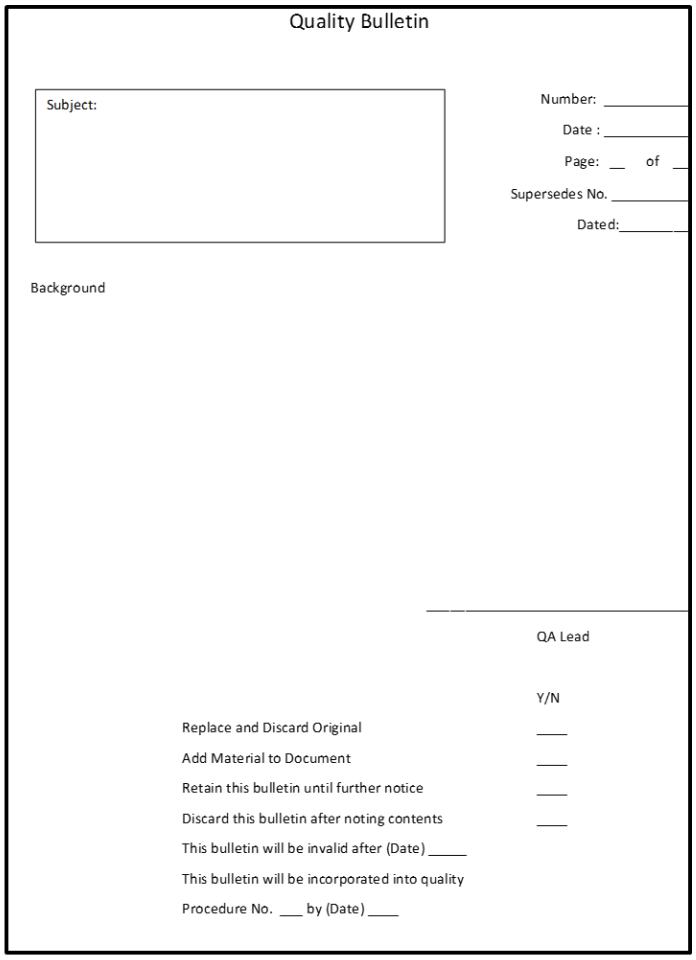
- **QMP** - describes the quality system in terms of the organizational structure, functional responsibilities of management and staff, lines of authority, and required interfaces for those planning, implementing, and assessing activities involving environmental data collection. The QMP is not specific to any particular project, but related to how the monitoring organization implements its quality system. QMPs submission and approval shall be reported to AQS by the EPA Regions. QMPs should be revised every 5 years. If major changes occur in the monitoring organizations quality management structure, it should be reported to the appropriate EPA Region as soon as possible.

[18] http://www.epa.gov/ttn/amtic/criteria.html
[19] 40 CFR Part 58 Appendix C Section 2.4

- **QAPP**- is a formal document describing, in comprehensive detail, the necessary QA/QC and other technical activities that must be implemented to ensure that the results of work performed will satisfy the stated performance criteria, which may be in the form of a data quality objective (DQO). The QAPP is specific to a particular monitoring project. Standard operating procedures (SOPs) are part of the QAPP development process and are vital to the quality of any monitoring program. Although they are part of the QAPP, SOPs can be incorporated by reference. The QAPP must 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/operators, lab staff, and data reviewers and information management. The QAPP facilitates communication among clients, data users, project staff, management, and external reviewers. QAPPs must meet all regulatory requirements described in 40 CFR parts 50, 53 and 58. In addition, they should attempt to conform to the suggestions in this Handbook unless an alternative is proposed that provides data of acceptable quality as described in the regulation and this Handbook. QAPP submission and approval dates are required to be reported to AQS. Monitoring organizations and EPA will have joint responsibility for this reporting. In addition, some monitoring organizations have been delegated authority to approve their QAPPs. Where a PQAO or monitoring organization has been delegated authority to review and approve their QAPP, an electronic copy must be submitted to the EPA region at the time it is submitted to the PQAO/monitoring organization's QAPP approving authority. QAPPs should be kept up to date annually. This does not mean that a QAPP must be revised every year but that it is reviewed and if any edits are necessary, a form of notification be provided to monitoring organizations staff and EPA that an update/revision has been made a documented in a manner that ensures the updated/revision has been implemented. Figure 1.4[20] provides an example of a quality bulletin that can be used to document a change or update to a QAPP or SOP. A formal revision of the QAPP should be made every 5 years and resubmitted to EPA.

Guidance for the development of both QMPs and QAPPs can be found on the EPA Quality Staff's website[21]. In addition, EPA has provided flexibility on how EPA organizations implement this policy, allowing for use of a graded approach. Since EPA funds the collection and use of data for a number of monitoring objectives and for organizations with a broad range of capabilities, flexibility in the QMP and QAPP requirements is necessary. For example, data collection for the purpose of comparison to the National Ambient Air Quality Standards (NAAQS) will require more stringent requirements, while monitoring programs for special purposes may not require the same level of quality assurance. The level of detail of QMPs and QAPPs, as explained by the EPA Quality Staff in the EPA Quality Manual, "should be based on a common sense, graded approach that establishes the QA and QC requirements commensurate with the importance of the work, available resources, and the unique needs of the organization." The ambient air program has developed a graded approach that will help tribes and smaller monitoring organizations develop both a QMP and QAPPs. Appendix C provides information on this approach.

[20] From the document Manual of Quality Assurance Procedures and Forms 1992
[21] http://www.epa.gov/quality1/


Quality Bulletin

Subject:

Number: _____
Date : _____
Page: __ of __
Supersedes No. _____
Dated:_____

Background

_____
QA Lead

Y/N

Replace and Discard Original ____
Add Material to Document ____
Retain this bulletin until further notice ____
Discard this bulletin after noting contents ____
This bulletin will be invalid after (Date) _____
This bulletin will be incorporated into quality
Procedure No. ___ by (Date) ____

Figure 1.4 Example quality bulletin

1.3.2 Implementation

Implementation activities include:

QAPP Implementation - Once the QAPP is written and approved, it is expected to be implemented. This is the major implementation activity in the quality system and is used by EPA during technical systems audits (TSAs).

Internal QC Activities - The quality control (QC) system is used to fulfill requirements for quality. It is the overall system of technical activities that measure 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. 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. Section 10 provides discussions of the ambient air monitoring quality control activities.

QC Reporting - 40 CFR Part 58 Appendix A identifies the quality control samples that must be reported to AQS. This data can be used to judge achievement of data quality objectives and measurement quality objectives described in Section 3.

1.3.3 Assessments

Assessments, as defined in *ANSI/ASQC-E4* and EPA's document, *Guidance on Technical Audits and Related Assessments for Environmental Data Operations (QA/G-7)*[22], are evaluation processes used to measure the performance or effectiveness of a system and its elements. Assessment 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, which are discussed in more detail in Section 15, include:

Technical Systems Audits (TSA) - A TSA is an on-site review and inspection of a monitoring organizations ambient air monitoring program to assess its compliance with established regulations governing the collection, analysis, validation, and reporting of ambient air quality data. While 40 CFR Part 58 Appendix A section 2.5 describe TSAs performed by the EPA Regional Offices, EPA and monitoring organizations perform TSAs.

[22] https://www.epa.gov/quality/agency-wide-quality-system-documents

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).

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:

- **Monitoring Organization Performance Evaluations (Audits)** - These performance evaluation audits are used to provide an independent assessment of the measurement operations of each instrument being audited. This is accomplished by comparing performance samples or devices of "known" concentrations or values to the values measured by the instruments being audited.

- **National Performance Evaluation Program (NPEP) –** These performance evaluation audits are implemented at the federal level although some programs may be implemented by the monitoring organizations if certain requirements are met.

1.3.4 Reports

All concentration data should be assessed in order to evaluate the attainment of the DQOs or the monitoring objectives. These assessments can be documented using the following types of reports:

- **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. Sections 17 and 18 will discuss the data quality assessment in more detail. Data quality assessments of precision, bias, and accuracy can be aggregated at the following three levels.
    - **Monitor**- monitor/method designation
    - **PQAO** - monitors in a method designation, all monitors
    - **National** - monitors in a method designation, all monitors

- **Data Quality Indicator Reports** have been programmed in AQS which can be used to assess data quality. In particular, the AMP256 and AMP600 reports can be used to assess the criteria pollutants for conformance to 40 CFR Part 58 Appendix A criteria for completeness, precision, and bias. EPA also developed an annual box and whisker report of the gaseous criteria pollutants that is posted on AirData[23]. It provides assessments similar to the AMP256, but it also provides a visual display of data quality that can help identify sites that may be in need of corrective action.
- **QA Reports** provide an evaluation of QA/QC data for a given time period to determine whether the data quality objectives are met. Discussions of QA reports can be found in Sections 16 and 18.
- **Audit Report**s provide the formal documentation of internal and external audits including any findings that require corrective action. Details of the reports are described in Section 15.

[23] https://www.epa.gov/outdoor-air-quality-data/single-point-precision-and-bias-report

2.0 Program Organization

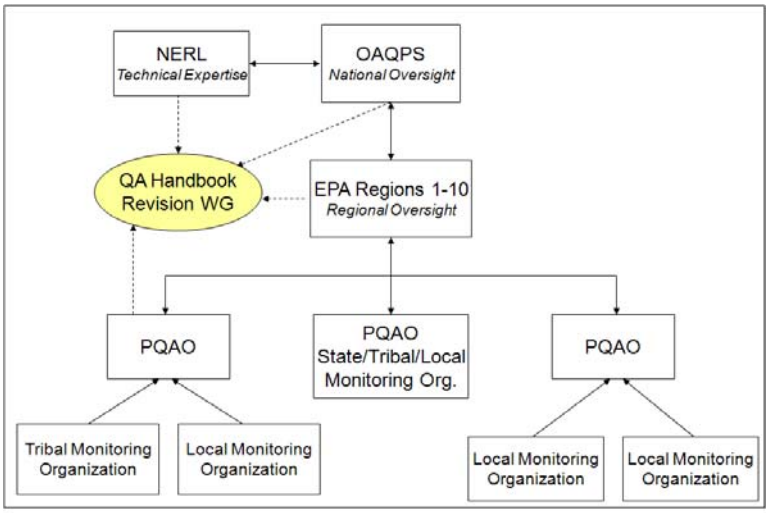


Figure 2.1 Program organization and lines of communication

Federal, state, tribal, and local monitoring organizations all have important roles in developing and implementing air monitoring programs. Figure 2.1 identifies the major entities involved in the Ambient Air Quality Monitoring Program, the organizational structure, and the lines of communication. The responsibilities of each organization follow. In general, most formal QA communication occurs in the pathway illustrated in the Figure 2.1. Primary quality assurance organizations (PQAOs) are identified because each EPA Region consists of many PQAO's and each PQAO may consist of one state, tribal or local monitoring organization or be a consolidation of a number of monitoring organizations. See Section 2.1.4 for additional information on PQAOs. In addition, the QA Handbook Revision Workgroup is highlighted because this entity is informal but provides a venue to communicate at all levels in order to discuss technical issues and improve the Handbook at appropriate time frames.

2.1 Organization Responsibilities

2.1.1 EPA Office of Air Quality Planning and Standards (OAQPS)

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 through national standards and strategies to control air emissions from sources; and ensuring that sources of toxic air pollutants are well controlled.

OAQPS[1] is the organization charged under the authority of the CAA to protect and enhance the quality of the nation's air resources. OAQPS evaluates the need to regulate potential air pollutants and develops national standards; works with monitoring organizations 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 Air Quality Assessment Division, the Ambient Air Monitoring Group (AAMG) is responsible for the oversight of the Ambient Air Quality Monitoring Network and its quality assurance program. AAMG, relative to quality assurance, has the responsibility to:

[1] https://www3.epa.gov/airquality/

- develop a satisfactory quality management system for the Ambient Air Quality Monitoring Network;
- ensure that the methods and procedures used in making air pollution measurements are adequate to meet the program's objectives and that the resulting data are of appropriate quality;
- manage the National Performance Evaluation Program (NPEP);
- perform data quality assessments of organizations making air pollution measurements of importance to the regulatory process;
- ensure that guidance pertaining to the quality assurance aspects of the Ambient Air Quality Program are written and revised as necessary; and
- render technical assistance to the EPA Regional Offices and the air pollution monitoring community.

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

- coordinating the Handbook Revision Workgroup responsible for continued improvement of the Handbook;
- seeking resolution on Handbook issues;
- incorporating agreed upon revisions into the Handbook; and
- reviewing and revising the Handbook (Vol II) as necessary and minimally every five years.

2.1.2 EPA Regional Offices

EPA Regional Offices[2] play a critical role in addressing environmental issues related to the monitoring organizations within their jurisdiction and administering and overseeing regulatory and congressionally mandated programs. In addition, one Region serves a rotating two-year term as Lead Region for monitoring and serves to coordinate and communicate monitoring issues to and from Headquarters and the other Regions.

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 monitoring organizations. This role requires that the Regional Offices:

- distribute and explain technical and quality assurance information to the monitoring organizations;
- identify quality assurance needs of the monitoring organization to EPA Headquarters that are "national" in scope;
- provide personnel and the infrastructure to implement NPEP programs;
- provide personnel with knowledge of QA regulations and with adequate technical expertise to address ambient air monitoring and QA issues;
- ensure monitoring organizations have approved quality management plans (QMPs) and quality assurance project plans (QAPPs) prior to routine monitoring, that they conform to the ambient air regulations, and that the submission and approval dates are reported to AQS;
- perform technical systems audit (TSAs) of PQAOs every three years and monitoring organizations within PQAOs every 6 years and report TSAs to AQS;
- evaluate the capabilities of monitoring organizations to measure the criteria air pollutants by implementing network reviews;
- assess data quality of monitoring organizations within its region; and

[2] https://www.epa.gov/aboutepa#pane-4

- assist monitoring organizations in defining primary quality assurance organizations within their jurisdiction and in assigning sites to a primary quality assurance organization.

Specific responsibilities as they relate to the Handbook include:

- serving as a liaison to the monitoring organizations for their particular Region;
- serving on the Handbook Revision Workgroup;
- fielding questions related to the Handbook and ambient air monitoring programs;
- reporting issues that would require Handbook Revision Workgroup attention; and
- serving as a reviewer of the Handbook and participating in its revision.

2.1.3 Monitoring Agency/Monitoring Organizations

40 CFR Part 58[3] defines a monitoring agency as "a state, local or tribal agency responsible for meeting the requirements of this part" (Part 58), and defines a monitoring organization as a "a monitoring agency responsible for operating a monitoring site for which the quality assurance regulations apply".

The major responsibility of the monitoring organization[4] is the implementation of a satisfactory monitoring program, which would naturally include the implementation of an appropriate quality assurance program. Implementation of an appropriate quality assurance program includes the development and implementation of a QMP and QAPPs for the Ambient Air Quality Monitoring Program. It is the responsibility of monitoring organizations to implement quality assurance programs in all phases of the data collection process, including the field, its own laboratories, and in any consulting and contractor laboratories which it may use to obtain data.

Monitoring organizations may be identified for reasons such as:

- distinguishing geographic regions (e.g. CA Districts);
- distinguishing different entities or sources of funds (e.g., tribal funds versus state/local funds);
- identifying organizations receiving funds directly from EPA;
- identifying organizations that have different methods or objectives for monitoring.

Therefore, if the monitoring organization accepts federal funds for monitoring, it will be identified as a monitoring organization that will be required to submit a requisite QMP and QAPPs to cover its monitoring activities. This does not eliminate it from consolidating to a PQAO with other organizations that it shares common factors, as described in the next section.

Specific responsibilities of monitoring organizations as they relate to the Handbook include:

- serving as a representative (if interested) for the monitoring organization on the Handbook Revision Workgroup;
- assisting in the development of QA guidance for various sections; and
- reporting issues and comments to Regional Contacts.

[3] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl
[4] http://www.4cleanair.org/agencies

2.1.4 Primary Quality Assurance Organizations (PQAOs)

A PQAO is a monitoring organization or a group of monitoring organizations that share a number of common "QA Factors". Below is an excerpt on PQAOs from 40 CFR Part 58, Appendix A:

> 1.2.1 Each PQAO shall be defined such that measurement uncertainty among all stations in the organization can be expected to be reasonably homogeneous as a result of common factors. Common factors that should be considered in defining PQAOs include:
>
> (a) Operation by a common team of field operators according to a common set of procedures;
> (b) Use of a common quality assurance project plan (QAPP) or standard operating procedures;
> (c) Common calibration facilities and standards;
> (d) Oversight by a common quality assurance organization; and
> (e) Support by a common management organization (i.e., state agency) or laboratory.
>
> Since data quality assessments are made and data certified at the PQAO level, the monitoring organization identified as the PQAO will be responsible for the oversight of the quality of data of all monitoring organizations within the PQAO.

The number and type monitors and sites in a PQAO has very important implications to quality assurance activities. For some pollutants, the number of monitoring sites in a PQAO may be used to determine the number and frequency of quality control checks, including the number of collocated monitors and the audit frequencies for the National Performance Audit Program (NPAP) and the $PM_{2.5}$ and Pb Performance Evaluation Program (PEP). Data assessments for completeness, precision and bias are aggregated at the PQAO level. The 5 common factors previously listed (a through e) are the key criteria to be used when an agency decides the sites to be considered for aggregation to a PQAO. There are cases where state, local and tribal monitoring organizations have consolidated to one PQAO. The requirement does not intend that all 5 factors have to be fulfilled but that these factors are considered. However, common procedures and a common QAPP should be considered key to making decisions to consolidate sites into a PQAO. However, the QAPP(s) of the monitoring organizations must refer to the PQAO that the monitoring organization is affiliated with. EPA Regions will need to be aware of monitoring organizations consolidating to a PQAO and have documentation on file to this effect. It is strongly suggested that when an opportunity for QAPP revisions arise that monitoring organizations that have consolidated develop one overarching QAPP that cover all monitoring organizations within the PQAO. Figure 2.2 shows the relationship of pollutants monitored at unique sites and how these unique sites are then related to monitoring organizations and PQAOs. In the case of PQAO #1, a tribal monitoring organization and local monitoring organization have common factors that allow for consolidation.

Since a PQAO is identified at the pollutant (monitor) level, two monitoring organizations may consolidate to a single PQAO for one pollutant due to similar methods and QA procedures, but not consolidate for another pollutant where they may have different quality requirements. Each PQAO should have some coordination entity to schedule/coordinate audits, TSAs, etc. In many cases this will be the state agency with local districts within the PQAO. In other cases, it could be a board that coordinates activities within a PQAO comprised of small agencies (e.g., tribes). This coordination entity needs to be documented in a manner (i.e., QAPP) that informs all monitoring organizations under the PQAO and the appropriate EPA Region.

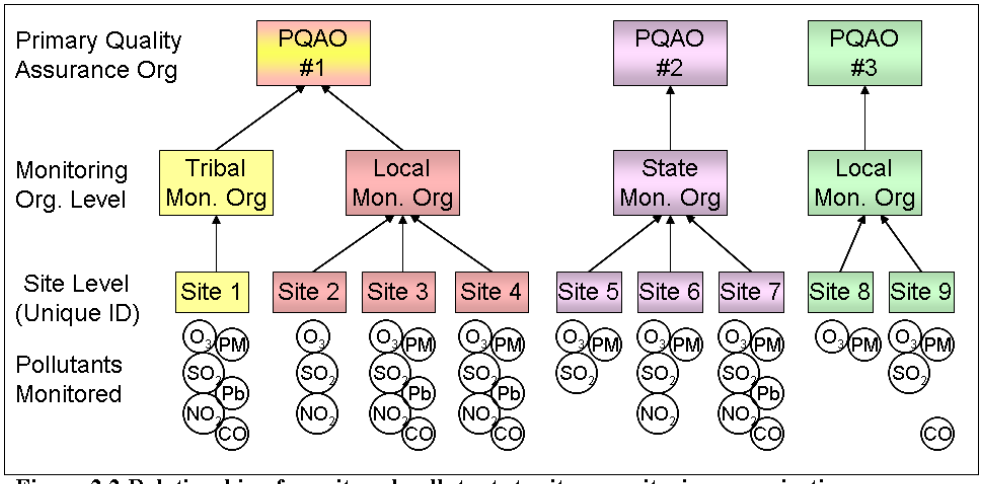


Figure 2.2 Relationship of monitored pollutants to sites, monitoring organizations and primary quality assurance organizations

2.1.5 EPA Office of Research and Development (ORD) National Exposure Research Laboratory (NERL)[5]

NERL conducts research and development that leads to improved methods, measurements and models to assess and predict exposures of humans and ecosystems to harmful pollutants and other conditions in air, water, soil, and food. The NERL provides the following activities relative to the Ambient Air Quality Monitoring networks:

- 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 assess 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 candidate sampling methods conform to accepted reference method specifications and are capable of providing data of acceptable quality and completeness for determining compliance with applicable National Ambient Air Quality Standards;
- 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; and
- provides an independent audit and review function on data collected by other appropriate clients.

NERL will continue to assist in the Handbook by:

- providing overall guidance;
- participating in the Handbook review process;
- developing new methods including the appropriate QA/QC; and
- conducting laboratory and field evaluations of sampling and analysis methods to resolve ad hoc technical issues.

[5] http://www.epa.gov/nerl/

2.2 Lines of Communication

In order to maintain a successful Ambient Air Quality Monitoring Program, effective communication is essential. 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. In most circumstances, the monitoring organizations first line of contact is the EPA Region. Any issues that require a decision, especially in relation to the quality of data, or the quality system, should be addressed to the EPA Region. A monitoring organization should, in only rare circumstances, contact OAQPS with an issue if it has not initially contacted the EPA Region. If this does occur, OAQPS normally tries to include the pertinent EPA Region in the conversation, or at a minimum, briefs the EPA Region about the issue(s) discussed. 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.

There are many other routes of communication available in the monitoring community. Three that occur with some frequency and should be used to identify important monitoring and QA issues are:

National Association of Clean Air Agencies (NACAA)[6]- represents air pollution control agencies in 53 states and territories and over 165 major metropolitan areas across the United States. It formed in the 1970s to improve their effectiveness as managers of air quality programs. The association serves to encourage the exchange of information among air pollution control officials, to enhance communication and cooperation among federal, state, and local regulatory agencies, and to promote good management of our air resources. Specifically for the Ambient Air Monitoring Program, it facilitates a monthly conference call and has organized a Steering Committee, made up of monitoring organization representatives and EPA, that meet twice a year to discuss issues related to ambient air monitoring.

National Tribal Air Association (NTAA)[7]- is an autonomous organization affiliated with the National Tribal Environmental Council (NTEC). The NTAA's mission is to advance air quality management policies and programs, consistent with the needs, interests, and unique legal status of American Indian Tribes, Alaska Natives, and Native Hawaiians. This organization has many similarities to NACCA. It also facilitates a monthly conference call with EPA and holds a national annual meeting.

Association of Air Pollution Control Agencies (AAPCA)[9] – created in 2012, AAPCA is a consensus-driven organization focused on assisting air quality agencies and personnel with implementation and technical issues associated with the federal Clean Air Act. APPCA is interested in creating a technical forum where ideas, information, and best practices can be shared when meeting the common goal of improving air quality and ensuring environmental protection. APPCA members work collaboratively on behalf of states and the communities they protect to act as a conduit for and provide feedback to federal regulators on air quality rules that have significant impacts across the entire nation.

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[6] http://www.4cleanair.org/
[7] http://www.ntaatribalair.org/
[9] http://www.csg.org/aapca_site/

EPA Headquarters Regional Monitoring and QA Calls – These calls between EPA Headquarters and the EPA Regional Offices occur monthly and are devoted to relevant monitoring and QA topics. Through these routine calls, EPA tries to develop consistent approaches to relevant monitoring issues.

Besides the three communication mechanisms described above, there are many others, such as the Regional Planning Organization (RPOs)[10] conference calls/meetings and EPA Regional conference calls/meetings, that also serve to communicate the needs and issues of the ambient air monitoring community.

The Handbook Revision Workgroup- The Workgroup is made up of representatives from the 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 expertise in the reference and equivalent methods program and QA activities.
- **Monitoring Organizations** - A minimum of 10 representatives of the monitoring organizations.

The mission of the workgroup is the continued clarification and addition of quality assurance procedures as related to ambient air monitoring and the networks. The Workgroup provides experiences and insights in the ambient air monitoring field that will assist OAQPS with the task of the continuous improvement of the quality system. This ensures data integrity and provides valid quality indicators for decision makers faced with attainment/nonattainment issues, as well as provides quality data to health professionals, academia, and environmental professionals.

The Handbook Revision Workgroup will meet twice a year to discuss, generally, the "condition" of the Handbook and what changes may be necessary. A running list of these changes will be recorded and, if important, technical guidance developed. A thorough review of the Handbook will occur every five years for the purpose of reviewing and revising the Handbook or sections as needed. Issues may surface from comments made by monitoring organizations' liaisons or the development/revision of regulations.

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[10] https://www.epa.gov/visibility/visibility-regional-planning-organizations

3.0 Data Quality Objectives

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 qualitative and quantitative statements derived from the DQO Planning Process that clarify the purpose of the study, define the most appropriate type of information to collect, determine the most appropriate conditions from which to collect that information, and specify tolerable levels of potential decision errors. 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 (or other objective), developing a quality system, or evaluating the data (e.g., NAAQS comparison). The DQO will be based on the data requirements of the decision maker who needs 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" (Fig. 3.1 a false rejection of the baseline condition) or "attainment" when actually the area is in "nonattainment" (Fig. 3.2 false acceptance of the baseline condition)[1]. Figures 3.1 and 3.2 illustrate how false rejection and acceptance errors can affect a NAAQS decision based on an annual mean concentration value of 15 and the baseline condition (null hypothesis) that the area is in attainment. In the figures the probability density is a statistical measure that defines a probability distribution for a random variable. There are serious 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 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 environmental data operation (EDO) and can be illustrated as follows:

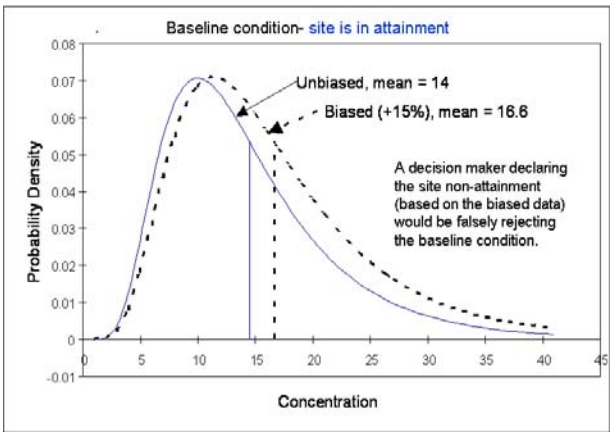


Figure 3.1 Effect of positive bias on the annual average estimate, resulting in a false rejection error.

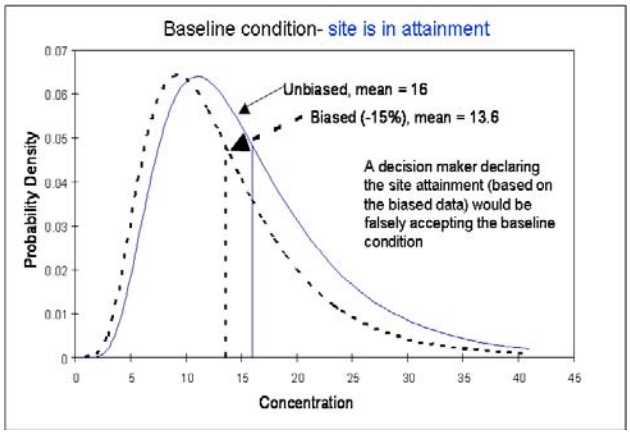


Figure 3.2 Effect of negative bias on the annual average resulting in a false acceptance error.

$$S_o^2 = S_p^2 + S_m^2 \qquad \textit{Equation 3-1}$$

where:

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

[1] "Guidance on Systematic Planning Using the Data Quality Objectives Process," EPA QA/G-4 U.S. Environmental Protection Agency, QAD, February 2006. http://www.epa.gov/quality1/qs-docs/g4-final.pdf

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

Population uncertainties are related to the uncertainty in air concentrations related to spatial and temporal variability. The most important data quality indicator of any ambient air monitoring network is representativeness. This term refers to the degree to which data accurately and precisely represent the frequency distribution of a specific variable in the population (e.g., concentration of air for the spatial scale of interest). Population uncertainty, the spatial and temporal components of error, can affect representativeness. These uncertainties can be controlled through the selection of appropriate boundary conditions (the monitoring area and the sampling time period/frequency of sampling) to which the decision will apply, and the development of a proper statistical sampling design (see Section 6). The Quality Staff's document titled *Guidance for Choosing a Sampling Design for Environmental Data Collection for Use in Developing Quality Assurance Project Plans (EPA/G-5S)*[2] 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;
- identifying and documenting the constraints on the sampling sites that are imposed by meteorology, local topography, emission sources, land access and the physical constraints; and
- selecting sampling schedules and frequencies that are consistent with the monitoring objectives.

Measurement uncertainties are the errors associated with the EDO, including errors associated with the preparation, sample transport, field, 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 and 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 (e.g., field, laboratory) of the measurement system. For example, the collocated $PM_{2.5}$ monitors provide the best estimate of overall measurement precision since it captures both measurement uncertainty in the field and the laboratory.

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

- **Precision** - a measure of agreement among repeated measurements of the same property under identical, or substantially similar, conditions. This is the random component of error. Precision is estimated by various statistical techniques typically 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.

- **Detection Limit** - The lowest concentration or amount of the target analyte that can be determined to be different from zero by a single measurement at a stated level of probability. Due to the fact the NCore sites will require instruments to quantify at lower concentrations, detection limits are becoming more important. Some of the more recent guidance documents suggest that

[2] http://www.epa.gov/quality1/qa_docs.html

monitoring organizations develop method detection limits (MDLs) for continuous instruments and or analytical methods. Many monitoring organizations use the default MDL listed in AQS for a particular method. These default MDLs come from instrument vendor advertisements and/or method manuals. Monitoring organizations should not rely on the instrument vendor's documentation on detection limits but determine the detection limits that are being achieved in the field during routine operations. Use of MDLs are described in the NCore Precursor Gas Technical Assistance Document (TAD)[3].

Accuracy is a measure of the overall agreement of a measurement to a known value and includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations. This term has been used throughout the CFR and in some sections of this document. Whenever possible, it is recommended that an attempt be made to distinguish measurement uncertainties into precision and bias components. In cases where such a distinction is not possible, the term accuracy can be used.

Other indicators that are considered during the DQO process include **completeness** and **comparability**. Completeness describes the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions. For example, a $PM_{2.5}$ monitor that is designated to sample every sixth day would be expected to have an overall sampling frequency of one out of every six days. If, in a thirty-day period, the sampler misses one sample, the completeness would be recorded as four out of five, or 80 percent. Data completeness requirements are included in the reference methods or NAAQS (40 CFR Part 50). Comparability is a measure of the confidence with which one data set or method can be compared to another, considering the units of measurement and applicability to standard statistical techniques. Comparability of datasets is critical to evaluating their measurement uncertainty and usefulness. Criteria pollutant quality indicator summary reports[4] can help to assess data comparability among monitoring sites in a PQAO. The various National Performance Evaluation Programs (NPEP) implemented in the Ambient Air Monitoring Program help EPA evaluate data comparability among PQAOs. Section 15 provides more details of the performance evaluation programs.

3.1 The DQO 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 that will optimize data collection plans; and
- 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:

- **State the problem:** Define the problem that necessitates the study or monitoring; identify the planning team, examine the budget and the schedule.

[3] https://www3.epa.gov/ttn/amtic/ncoreguidance.html
[4] https://www3.epa.gov/ttn/amtic/qareport.html

- **Identify the goal:** State how environmental data will be used in meeting objectives and solving the problem, identify study questions, define alternative outcomes.
- **Identify information inputs:** Identify data and information needed to answer study questions.
- **Define boundaries:** Specify the target population and characteristics of interest, define spatial and temporal limits, scale of inference.
- **Develop the analytical approach:** Define the parameter of interest, specify the type of inference, and develop the logic for drawing conclusions from findings.
- **Specify performance or acceptance criteria:**
    - *Decision making (hypothesis testing):* Specify probability limits for false rejection and false acceptance decision errors.
    - *Estimation approaches:* Develop performance criteria for new data being collected or acceptable criteria for existing data being considered for use.
- **Develop the plan for obtaining data:** Select the resource-effective sampling and analysis plan that meets the performance criteria.

The DQO process is fully discussed in the document titled *Guidance on Systematic Planning using the Data Quality Objectives Process (EPA QA/G-4)*, and is available on the EPA's Quality System for Environmental Data and Technology website[5]. For an illustration of how the DQO process was applied to a particular ambient air monitoring problem, refer to the EPA document titled *Systematic Planning: A Case Study of Particulate Matter Ambient Air Monitoring*[6].

3.2 Ambient Air Quality DQOs

As indicated above, the first steps in the DQO process are to identify the problems that need to be resolved and the objectives to be met. As described in Section 2, the ambient air monitoring networks are designed to collect data to meet three basic objectives:

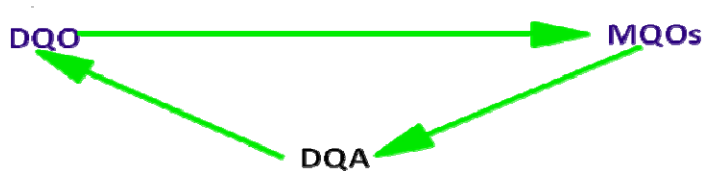
1. provide air pollution data to the general public in a timely manner;
2. support compliance with air quality standards and emission strategy development; and
3. support air pollution research.

These different objectives could potentially require different DQOs, making the development of DQOs complex and unique for each objective. For the criteria pollutants, the priority objective is to ensure that decision makers can make comparisons to the NAAQS within a specified degree of certainty. With the data quality needed for NAAQS evaluation, one can support both timely data reporting and research goals to a certain extent.

OAQPS has established formal DQOs for $PM_{2.5,}$ Ozone, Pb, SO_2, NO_2, NCore, CSN[7], and NATTS[8]. As the NAAQS for the other criteria pollutants come up for review, EPA will develop DQOs for these pollutants.

[5] http://www.epa.gov/quality1/qa_docs.html
[6] http://www.epa.gov/quality1/qs-docs/casestudy2-final.pdf
[7] http://www3.epa.gov/ttn/amtic/specguid.html
[8] http://www3.epa.gov/ttn/amtic/airtoxqa.html

3.3 Measurement Quality Objectives



The DQO process functions to identify the allowable population and measurement uncertainty for a given objective. The monitoring program is then developed and quality control samples are identified and implemented to evaluate data quality [through data quality assessments (DQA)] to ensure that it is maintained within the established acceptance criteria. Measurement Quality Objectives (MQOs) are designed to evaluate and control various phases (e.g., sampling, transportation, preparation, and 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, bias, representativeness, detection limit, completeness and comparability as described in Section 3.0.

MQOs can be established to evaluate overall measurement uncertainty, as well as for an individual phase of a measurement process. As an example, the precision DQO for $PM_{2.5}$ is 10% and it is based on 3 years of collocated precision data collected at a PQAO level. Since only 15% of the sites are collocated, the data cannot be used to control the quality from each site or each sampler (although it could be used for the specific site where the collocated sample was collected). Since the collocated results can be affected by both field and laboratory processes, one cannot pinpoint a specific phase of the measurement system when a precision result is higher than the 10% precision goal. Therefore, individual precision values greater than 10% may be tolerated as long as the overall 3-year DQO is achieved. In contrast, the flow rate audit, which is specific to the appropriate functioning of $PM_{2.5}$ samplers, have an MQO of $\pm$ 4% of the audit standard and $\pm$ 5% of the design value. This MQO must be met each time or the instrument is recalibrated. In summary, since uncertainty is usually additive, there is much less tolerance for uncertainty for individual phases of a measurement system (e.g., flow rate) since each phase contributes to overall measurement. As monitoring organizations develop measurement specific MQOs they should think about being more stringent for individual phases of the measurement process since it will help to keep overall measurement uncertainty within acceptable levels.

For each of these data quality indicators, acceptance criteria can be developed for various phases of the EDO. Various parts of 40 CFR Parts 50 and 58 have identified acceptance criteria for some of these indicators. In theory, if these MQOs are met, measurement uncertainty should be controlled to the levels required by the DQO. MQO tables for the criteria pollutants can be found on AMTIC and have been revised into what is known as a validation template. Three tables of validation criteria have been developed:

Critical Criteria- deemed critical to maintaining the integrity of a sample (or ambient air concentration value) or group of samples. Observations that do not meet each and every criterion on the critical table should be invalidated unless there are compelling reason and justification for not doing so. Basically, the sample or group of samples for which one or more of these criteria are not met is invalid until proven otherwise. In most cases the requirement, the implementation frequency of the criteria, and the acceptance criteria are found in CFR and are therefore regulatory in nature. The sample or group of samples for which one or more of these criteria are not met is invalid until proven otherwise. In many cases, precedent has been set on invalidating data that do not meet CFR criteria.

Operational Criteria Table- important for maintaining and evaluating the quality of the data collection system. Violation of a criterion or a number of criteria may be cause for invalidation. The decision maker should consider other quality control information that may or may not indicate the data are

acceptable for the parameter being controlled. Therefore, the sample or group of samples for which one or more of these criteria are not met is suspect unless other quality control information demonstrates otherwise and is documented. The reason for not meeting the criteria should be investigated, mitigated or justified.

Systematic Criteria Table- include those criteria which are important for the correct interpretation of the data but do not usually impact the validity of a sample or group of samples. For example, the data quality objectives are included in this table. If the data quality objectives are not met, this does not invalidate any of the samples but it may impact the error rate associated with the attainment/non-attainment decision.

More information about data validation and the use of the validation templates can be found in Section 17.

> **NOTE: Please note the designation of quality control checks as Operational or Systematic do not imply that these quality control checks need not be performed.** Not performing an operational or systematic quality control check that is required by regulation (in CFR) can be a basis for invalidation of all associated data. Any time a CFR requirement is identified in the Requirement, Frequency or Acceptance Criteria column it will be identified by ***bold*** and ***italics*** font. Many monitoring organization/PQAOs are using the validation templates and have included them in QAPPs. However, it must be mentioned that diligence must be paid to its use. Data quality findings through data reviews and technical systems audits have identified multiple and concurrent non-compliance with operational criteria that monitoring organization considered valid without any documentation to prove the data validity. The validation templates were meant to be applied to small data sets (single values or a few weeks of information) and should not be construed to allow a criterion to be in non-conformance simple because it is operational or systematic.

Performance Based and Method Based Measurement System Concept: Consistency vs. Comparability

The NATTS Program uses the performance-based measurement system (PBMS) concept. In simple terms, this means that as long as the quality of data that the program requires (DQOs) are defined, the data quality indicators are identified, and the appropriate measurement quality objectives (MQOs) that quantify that the data quality objectives are met, any sampling/analytical method that meets these data quality requirements are appropriate to use in the program. The idea behind PBMS is that if the methods meet the data quality acceptance criteria the data are "comparable" and can be used in the program. Previous discussions in this document allude to the need for "nationally consistent data", "utilization of standard monitoring methods" and "consistency in laboratory methods". Comparability is a data quality indicator because one can quantify a number of data quality indicators (precision, bias, detectability) and determine whether two methods are comparable. Consistency is not a data quality indicator and requiring that a particular method be used for the sake of consistency does not assure that the data collected from different monitoring organizations and analyzed by different laboratories will yield data of similar (comparable) quality. Therefore, the quality system will continue to strive for the development of data quality indicators and measurement quality objectives that will allow one to judge data quality and comparability and allow program managers to determine whether or not to require the use of a particular method (assuming this method meets the data quality needs). However, PBMS puts a premium on up-front planning and a commitment from monitoring organizations to adhere to implementing quality control requirements.

With our NAAQS pollutants we use a combination of PBMS (since we do develop DQOs that provide some flexibility on achieving those DQOS) and method-defined monitoring. The data quality indicator

comparability must be evaluated in light of a pollutant that is considered a **method-defined parameter**. The analytical result of a pollutant measurement of a method-defined parameter has a high dependence on the process used to make the measurement (e.g., $PM_{2.5}$). Most analytical measurements are determinations of a definitive amount of a specific molecule or mixture of molecules. An example of this would be the concentration of carbon monoxide in ambient air. However, other measurements are dependent on the process used to make the measurement. Method-defined parameters include measurements of physical parameters such as temperature and solar radiation which are dependent on the collection height and the design of the instrumentation used. Measurements of particulate mass, especially fine particulate, are also method-defined parameters because they are not "true" measures of particulate mass, being dependent on criteria such as: size cut-points which are geometrically defined; level of volatilization of particulates during sampling; and analytical methods that control the level of moisture associated with particulates at a concentration that may not represent actual conditions. This should not be interpreted to mean that using a method-defined measurement of particulate is inferior, rather when selecting methods or comparing data sets for method-defined parameters it is important to consider that there is no “correct” measurement, only a “defined” method. However as mentioned above in the PBMS discussion, there are certain data quality acceptance limits for “defined” methods that can be used to accept alternative methods.

4.0 Personnel Qualifications and Training

4.1 Personnel Qualifications

Ambient air monitoring personnel may be required to perform a number of functions that are important to the quality of data. Table 4-1 identifies these functions and provides some of the key activities within the functional category. Once the list is completed for a monitoring organization, it can be used in the development of position descriptions for recruitment and training programs.

Not all functions are needed for the entire duration of a project. Monitoring organizations may feel that it can contract some of the functions that are needed. For example, an organization may wish to contract the information technology (IT) function to have the monitoring instruments connected to a data logging system that would transfer data to a local database and eventually to an external data base like AQS. This part of the process might be considered a "one-time" event needing a particular expertise whose function might not require a full time person. However, it is critical that someone within the program understands this IT function to ensure data collection is operating properly on a day-to-day basis and that if changes are needed (e.g., due to regulation/guidance changes) revisions to the system can be made in a timely fashion.

Table 4-1 Monitoring Functions that Need Some Level of Staffing or Expertise

Function	Activities
Procurement	- Purchasing capital equipment and consumables - Developing contracts and maintenance agreements - Applying for EPA grants
Technical	- Setting up a monitoring site, electricity, communications - Developing standard operating procedures - Selecting and installing monitoring equipment - Calibrating equipment, performing quality control - Shelter and equipment maintenance
Data/Statistical Analysis and Interpretation	- Understanding population and measurement uncertainty - Developing sampling designs - Developing networks to achieve objectives - Assessing/interpreting data (data quality assessments)
Quality Assurance	- Developing quality management systems, QMPs/QAPPs - Developing data quality objectives - Certifying and recertifying standards - Implementing technical systems audits, performance evaluations - Ensuring corrective actions occur - Validating data - QA reporting
Information Technology	- Selecting information technology (data loggers and local data base) - Developing analyzer outputs to data loggers and data transfer to local data base - Transfering data from local data base to external data repositories (AQS, etc.) - Ensuring security of data

Personnel assigned to ambient air monitoring activities are expected to have the educational, work experience, responsibility, personal attributes, and training requirements for their positions. In some cases, certain positions may require certification and/or recertification. An example would be certifying auditors on instruments to be audited. These requirements should be outlined in the position

advertisement and in personal position descriptions. Records on personnel qualifications and training should be maintained and accessible for review during audit activities (unless the records are maintained as part of confidential personnel records). 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. It is recommended that monitoring organizations maintain some requirements for air personnel qualifications (combination of education and experience). Training is aimed at increasing the effectiveness of employees and their organization. As part of a quality assurance program, EPA QA/G-10, *Guidance for Developing a Training Program for Quality Systems*[1], suggests 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, web-based courses, teleconferences, vendor-provided and on-the-job training. Training should also include appropriate reading materials, such as the CFR, EPA guidance documents, and the monitoring organization's QAPPs and SOPs, to name a few. EPA encourages monitoring organizations to maintain documentation that details the training provided to all monitoring staff, along with documentation that illustrates the successful completion of the training requirements.

Along with suggested training, there are some EPA programs that require mandatory training and/or certifications. These programs include, but are not limited to, the National Performance Audit Program (NPAP) and the Performance Evaluation Program (PEP). All personnel performing audits in these projects or programs are required to possess mandatory training or a current certification issued by the EPA Office responsible for the monitoring program.

EPA encourages regional planning organizations and monitoring organizations to develop training programs that require some level of certification.

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/apti/
- Air & Waste Management Association (AWMA) http://www.awma.org/
- American Society for Quality (ASQ) http://www.asq.org/
- EPA Quality Staff (QS) http://www.epa.gov/quality1/
- EPA Regional Offices https://www.epa.gov/aboutepa
- EPA Ambient Monitoring Technology Information Center (AMTIC) Technology Transfer Network (http://www.epa.gov/ttn/amtic/training.html)

[1] http://www.epa.gov/quality1/qs-docs/g10-final.pdf

In addition, OAQPS uses contractors and academic institutions to develop and provide training for data collection activities that support regulatory efforts throughout EPA and monitoring organizations. In addition, instrument and data management manufacturers may provide training on the equipment they sell. Monitoring organizations should consider adding manufacturer-provided training to the equipment purchase cost.

Table 4-2 provides a suggested sequence of core QA-related ambient air monitoring courses for ambient air monitoring staff by job position. The suggested course sequences assume little or no experience in QA/QC or air monitoring, but some courses may have pre-requisites. 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 4-2 Suggested Sequence of Core QA-related Ambient Air Training Courses for Ambient Air Monitoring and QA Personnel

Source-Sequence	Course Title (SI = self-instructional)	Field	Lab	QC-Supv..	Data Mgt.	Mon Supv..	QA*	QA Mgt.
APTI- SI:422	Air Pollution Control Orientation Course	X	X	X		X	X	X
APTI 452	Principles and Practices of Air Pollution Control	X		X		X	X	X
APTI -SI:100	Mathematics Review for Air Pollution Control	X	X					
QS**- QA1	Orientation to Quality Assurance Management					X	X	X
APTI-SI:434	Introduction to Ambient Air Monitoring	X	X	X	X	X	X	X
APTI -SI:471	General Quality Assurance Considerations for Ambient Air Monitoring	X	X	X	X	X	X	X
APTI- SI:409	Basic Air Pollution Meteorology	X		X		X	X	X
APTI SI:473A	Beginning Environmental Statistical Techniques (Revised)	X	X	X	X	X	X	X
APTI-470	Quality Assurance for Air Pollution Measurement Systems			X		X	X	X
QS-QA2	Data Quality Objectives Workshop					X	X	X
QS-QA3	Quality Assurance Project Plan			X		X	X	X
APTI-435	Atmospheric Sampling	X	X	X		X	X	
No Source	Basic Electronics	X		X		X		
APTI-SI:433	Network Design and Site Selection for Monitoring $PM_{2.5}$ and PM_{10} in Ambient Air			X		X	X	
APTI-464	Analytical Methods for Air Quality Standards		X	X		X	X	
APTI	Chain Of Custody	X	X	X	X	X	X	X
APTI- SI:436	Site Selection for Monitoring SO_2	X		X		X	X	
OAQPS	AQS Training (annual AQS conference)				X	X	X	
QS- QA4	Data Quality Assessment					X	X	X
QS- QA5	Assessing Quality Systems					X	X	X
APTI-	Introduction to Environmental Statistics				X	X	X	X
AWMA QA6	Quality Audits for Improved Performance						X	X
ASQC-STAT1	Statistics for Effective Decision Making			X	X	X	X	X

*- Personnel performing technical system audits (TSAs) would fit into this category
** QS- Refers to Quality Staff http://www.epa.gov/quality1/

5.0 Documentation and Records

Organizations that perform environmental data operations (EDO) and management activities must establish and maintain procedures for the timely preparation, review, approval, issuance, use, control, revision and maintenance of documents and records. Each organization should have a documented records management policy with the following elements addressed:

1. A list of files considered the official records and their media type (e.g., paper, electronic)
2. Schedule for retention and disposition of records
3. Storage and retrieval system of records
4. Person(s) responsible at each level of storage and retrieval of records
5. Assignment of appropriate levels of security

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 Annual Monitoring Network Plans (AMNP) 5-Year Network Assessment Site characterization file Site maps/pictures
Environmental Data Operations	QA Project Plans (QAPPs) 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 and strip charts Data quality assessments QA reports System audits Network reviews

This information should be included in a monitoring organization's quality assurance project plan. Please refer to Section 14 for further information and the EPA records website[1]

A document, from a records management perspective, is a volume that contains information that 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

[1] http://www.epa.gov/records/

value of data in them....". This section will provide guidance of documentation and records for the Ambient Air Quality Monitoring Program.

Table 5-1 represents the categories and types of records and documents that are applicable for document control. Information on key documents in each category follows. 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.

Electronic Records

As monitoring technologies advance it is becoming more likely that data will be generated and retained electronically. The majority of the documentation referred to in this section can be saved as an electronic record. Retention of electronic records[2] is included in the above definition. It is recommended that electronic as well as paper records be stored in a logical order for ease of access. This is discussed more in-depth in Section 14 and Appendix J provides EPA guidance on use of electronic logbooks (e-logbooks).

Statute of Limitations

Retention requirements for records are codified in 2 CFR 200.333. 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 all litigation, claim, or audit findings involving the records have been resolved and final action taken. Title 2 Part 1500.6(a) further states that, in the EPA, some programs require longer retention requirements for records by statute. Therefore, where there is a difference between the retention requirements for records defined in 2 CFR 200.333 and the applicable statute, the non-federal entity will follow the retention requirements for records in the statute (see 2 CFR 1500.6(b)). For clarification purposes, the retention of samples produced as a result of required monitoring may differ depending on the program and/or purpose collected. For retention of samples for a specific program please refer to the appropriate reference in CFR for the individual program.

All original documents an records be kept for the statute of limitation. If documents and records want to be kept for some time after the statute of limitations has expired, scanning this material into an electronic form may be a viable option

5.1 Management and Organization

Most of the record types in this category in Table 5-1 can be found in a single document, the quality management plan. The quality management plan is a blueprint for how an organization's quality management objectives will be attained. It includes the QA and QC activities used to ensure that the results of technical work are of the type and quality needed for their intended use. The EPA Quality Staff provide requirements for quality management plans[3] that monitoring organizations may find helpful.

[2] http://www.epa.gov/records/tools/erks.htm
[3] EPA Requirements for Quality Management Plans (QA/R-2) https://www.epa.gov/quality/agency-wide-quality-system-documents

5.2 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. This information should be kept to characterize the site through time. Because monitoring organizations are required to file an Annual Monitoring Network Plan (AMNP) and perform network assessments at a minimum of every five years (40 CFR Part 58.10), this information should be retained and updated periodically by both the agency responsible for the site and the office responsible for reviewing the site information for the network assessment process. The AMNPs, the 5-Year Network Assessments, and the Air Quality System (AQS) Site Files are good areas to record, capture, and retain site information. Another source where site information is provided is the QAPP. At a minimum, the QAPP should identify the sites for which the QAPP applies either by listing the sites or with a definitive reference. If sites are included or discontinued in a given year, an addendum to the QAPP by way of a technical memo can be included in the QAPP file and sent to the EPA Region to describe the changes to the sites. This information could also be incorporated by reference to Annual Network Plans.

Most ambient air agencies retain site records in paper and/or electronic file format. Included in a site information file are maps and pictures of an individual site. Typically, the kinds of information found in a site identification record should include:

1. The AQS site identification number
2. Station type (SLAMS, NCore, CSN, etc.)
3. Instrumentation, sampling and analysis methods for each parameter (manufacturer's model number, pollutant measurement technique, AQS Method Code and Pollutant Code etc.)
4. The location, including street address and geographical coordinates
5. Purpose of measurements (monitoring to determine compliance with air quality standards)
6. The operating schedule for each monitor
7. The monitoring objective and spatial scale of representativeness for each monitor as defined in 40 CFR Part 58 Appendix D
8. The MSA, CBSA, CSA or other area represented by the monitor
9. The designation of any Pb monitors as either source-oriented or non-source-oriented, according to 40 CFR Part 58 Appendix D
10. Any monitors for which a waiver has been requested or granted by the EPA Regional Administrator
11. Influential pollutant sources (point and area sources, proximity, pollutant density, etc.)
12. Topography (hills, valleys, bodies of water, trees; type and size, proximity, orientation, etc., picture of a 360-degree view from the probe of the monitoring site)
13. Atmospheric exposure (unrestricted, interferences, etc.)
14. Site diagram (measurement flow diagram, service lines, equipment configuration, etc.)
15. Site audits

5.3 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. Integrity[4] is defined as "the representational faithfulness of information to the true state of the object that the information represents,

[4] From Boritz, J. Efrim. IS Practioners' Views on Core Concepts of Information Integrity. *International Journal of Accounting Information Systems*. Elsevier.

where representational faithfulness is composed of four essential qualities or core attributes: completeness, currency/timeliness, accuracy/correctness and validity/authorization". Ambient air monitoring results, and in certain types of measurements - the sample itself, may be essential elements in proving the validity of the data or the decisions made using the data. Data cannot be admitted as evidence unless it can be shown that they are representative of the conditions that existed at the time that the data (or sample) was collected. Therefore, each step in the sampling 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 measurement preparation and identification of the sample, sample location and sample time. It also includes the conditions during the measurements in the form of data sheets, logbooks, strip charts, and raw data.
2. Sample and/or measurement result handling[5] - includes evidence that the sample and data were protected from contamination and tampering during transfer between people, from the sampling site to the laboratory and during analysis, transmittal, and storage. This process is documented in chain of custody forms.
3. Analysis - includes evidence that samples and data were properly stored prior to and after analysis, interpretation and reporting.
4. Preparation and filing of measurement report(s) - 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. Documentation for environmental data operations include:

- **QA Project Plans** - Documents how environmental data operations are planned, implemented, and assessed during the life cycle of a program, project, or task (see below).
- **Standard operating procedures (SOPs) -** Written documents that give detailed instruction on how a monitoring organization will perform daily tasks: field, laboratory and administrative. SOPs are a required element of a QAPP and therefore any EDO must include these (see below).
- **Field and laboratory notebooks -** Any documentation that may provide additional information about the environmental data operation (e.g., calibration notebooks, strip charts, temperature records, site notes, maintenance records etc.) (See below.)
- **Sample handling and/or custody records -** Records tracing sample and data handling from the site through analysis, including transportation to facilities, sample storage, and handling between individuals within facilities. (Section 8 provides more information on this activity).

Quality Assurance Project Plan

As described in 2 CFR 1500.11, quality assurance systems must be established in conjunction with the receipt of federal award dollars, with the written quality assurance system submitted to EPA for review and approval. In addition to these grant requirements, 40 CFR Part 58, Appendix A[6] states that all

[5] Measurement results in this case may be in the form of a paper copy or flash drive downloaded from instrument or data logger that is manually transferred to another IT device. Some of chain of custody for this data should be considered.

[6] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl

PQAOs must develop a quality system that is described and approved in QMPs and QAPPs. PQAOs must develop QAPPs that describe how the organization intends to control measurement uncertainty to an appropriate level in order to achieve the data quality objectives for the EDO. The quality assurance policy of the EPA requires every EDO to have a written and approved QAPP prior to the start of the EDO. It is the responsibility of the PQAO/monitoring organization to adhere to this policy. The QAPP must be suitably documented in accordance with EPA requirements (*EPA Requirements for Quality Assurance Project Plans*[7]) and include standard operating procedures for all EDOs either within the document or by appropriate reference. The QAPP must identify each PQAO operating monitors under the QAPP as well as generally identify the sites and monitors to which it is applicable either within the document or by appropriate reference. The QAPP submission and approval dates must be reported to AQS either by the monitoring organization or the EPA Region. QAPPs should be updated every five years and revised as soon as possible when significant changes occur in a monitoring program.

Standard Operating Procedures

In order to perform EDOs consistently, standard operating procedures (SOPs) must be written as part of the QAPP or incorporated by reference. SOPs are written documents that detail the method for an operation, analysis, or action with thoroughly prescribed techniques and steps, and are officially approved as the method for performing certain routine or repetitive tasks. Although not every activity in the field/laboratory needs to be documented, the activities that could potentially cause measurement uncertainties, or significant variance or bias, should be described in an SOP. Common SOPs maintained by monitoring organizations include those that detail field operation procedures, such as calibration and maintenance regimes for gaseous analyzers and particulate samplers, as well as data handling SOPs that prescribes the procedures by which an agency verifies, validates, and certifies its monitoring data.

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 that may be included in SOPs which are explained in the guidance document *Guidance for the Preparation of Standard Operating Procedures* EPA QA/G-6[8] are:

1. Scope and Applicability
2. Summary of Method
3. Definitions
4. Health and Safety Warnings
5. Cautions
6. Interferences
7. Personnel Qualifications
8. Equipment and Supplies
9. Procedure (section may include all or part of these sections):
    a. Instrument or Method Calibration
    b. Sample Collection
    c. Sample Handling and Preservation

[7] https://www.epa.gov/quality/agency-wide-quality-system-documents
[8] https://www.epa.gov/quality/guidance-preparing-standard-operating-procedures-epa-qag-6-march-2001

   d. Sample Preparation and Analysis
   e. Troubleshooting
   f. Data Acquisition, Calculations & Data Reduction
   g. Computer Hardware & Software (used to manipulate analytical results and report data)
10. Data Management and Records Management Parameters
11. Quality Control/Quality Assurance

Elements that are not needed for a particular procedure may be excluded or listed as "NA" (not applicable).

Personnel implementing SOPs may not be involved in the "larger picture" which includes the use of the data and whether or not DQOs are being achieved. Therefore, it's very important that the SOP covers the objectives of the monitoring program and the importance of following each step in an SOP in order to achieve quality results.

> **NOTE:** There may be some incentive to rely on vendor developed methods manuals or to reference analytical methods on internet sites (e.g., TO-15 for NATTS VOCs) as a monitoring organization's SOP without revision. Although the majority of information in these documents may be appropriate, many times the methods provide more than one option for method implementation and are not specific to the organization implementing the method. Therefore, organizations are encouraged to utilize these methods, but edit them to make them specific to the organization.

Many of these operational procedures described 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. Regulatory requirements for the method described in CFR must be followed unless a waiver is applied for and approved by EPA or a technical memo has been developed by EPA and posted on AMTIC. EPA approval of a QAPP or SOP that has modifications to regulatory requirements does not constitute approval of the modifications. Monitoring organizations must formally submit a waiver.

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 should be stated that the method is followed exactly or an addendum that explains changes to the method should be included in the QAPP (see NOTE above). 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 occurs during the approval of the QAPP. Individuals with appropriate training and experience with the particular SOPs in the QAPP need to review the SOPs.

SOPs should have some level of documented approval by the monitoring organization and be reviewed/approved at some frequency. There should be some level of document control on SOPs so that personnel can quickly determine whether or not they are using the most current method. The document control information on the pages of this Handbook provide a good example. It is suggested that the monitoring organization create a "master" list of the current SOPs it uses and include some document control information to allow users to identify the appropriate SOPs.

Field and Laboratory Notebooks

Recording field and laboratory data is necessary for ambient air monitoring. Section 11 provides information on the types of notebooks as well as the activities that can be recorded in these notebooks. A standardized format should be utilized to ensure that all necessary information is obtained. The format should be designed to clearly identify the parameters during the measurements, the date and time, location of the measurement station, and operating personnel. This information may determine the credibility of the data and should not be erased or altered. Document everything thoroughly from data collection through data use, to include conversations with QA/QC personnel and EPA officials concerning the data. The motto is "write it down!". Nothing enhances the credibility of a data collection program more than thoroughly detailed documentation. Data usability, for the future as well as the present applications, depends on how well all of these details are documented.

If a manual record is kept, any error should be crossed out with a single line, and the correct value recorded above the crossed-out entry and dated. It is recommended that manual documentation always use indelible black or blue ink when recording or correcting data entries, that corrections be made as specified above, and that all forms be completed with the signatures and dates required on the forms. Since these records may be subpoenaed, it is important that all field notes be legible. Corrections should be initialed and dated as to who made the change and when. Comments at the bottom of the form can provide clarification as to why a change was made when others review the document.

Electronic recording and storage of data is widely used. Electronic recording of the data allows for flagging and retention of additional information that is pertinent to day to day operations that could otherwise be lost with conventional systems. The same information as listed in the above paragraph should be recorded during routine quality checks. Some monitoring organizations like to electronically produce strip charts of data and/or supporting information. This data can be used to enhance and support the validity of the data.

Developing a consistent technique for documenting information in a logbook and archiving this information is very important. Below is a list of resources that may be helpful in developing field and laboratory logbooks.

- Basic Requirements of an Electronic Recordkeeping System at EPA http://www.epa.gov/records/tools/erks.htm
- Keeping a Log Book http://www.aerogel.org/?p=814
- Keeping A Scientific Notebook Or Log http://raider.mountunion.edu/Organizations/scienceday/pdf/Scientific%20log.pdf
- Implementing and Auditing Electronic Recordkeeping Systems Used in Scientific Research and Development http://www.tandfonline.com/doi/full/10.1080/10529410590924577
- "A Laboratory Quality Handbook of Best Practices" By Donald Singer. Chapter 5, Laboratory Documentation and Data, pg. 27-37
- 2003 NELAC Standard Section 5.5.5.5 http://www.nelac-institute.org/docs/2003nelacstandard.pdf
- NEIC Procedures Manual for the Evidence Audit of Enforcement Investigations by Contractor Evidence Audit: Page IV-8 http://nepis.epa.gov/Adobe/PDF/9100LLFC.PDF

Use of electronic logbooks are becoming more prevalent but they must be developed in a manner that preserves the integrity of data found in hardcopy logbooks. An e-logbook system should meet National Archives and Records Administration[9] (NARA) requirements that pertain to e-logbooks. The e-logbook system should and be able to: 1) collect, organize, and categorize, and 2) facilitate the preservation, retrieval, use, and disposition of records. Although not all of the regulation pertains to e-logbooks, many of the requirements described are applicable to e-logbooks. EPA acknowledges that monitoring organizations may also have local records policies, and they will need to ensure their system meets the need of both EPA & their own policies.

Appendix J contains the information that will be reviewed by EPA when approving the use of e-logbooks. Much of the information in Appendix J comes from the website: Basic Requirements of an Electronic Recordkeeping System at EPA[10] and are the features that must be addressed when developing or evaluating an e-logbook system for data defensibility. This information needs to either be included or referenced in the monitoring organizations QMP or QAPP in order for the EPA approving authority to be able to review and approve the e-logbook process as adequate.

Do not discard original field records; copies of them 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.

5.4 Raw Data

Raw data includes any original factual information from a measurement activity or study recorded in laboratory work sheets, records, memoranda, notes, computer (electronic) files or exact copies thereof and that are necessary for the reconstruction and evaluation of a concentration, an assessment, a report or a decision. Raw data may include photographs, 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 then reduced to data that are 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.

5.5 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 are generally 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 measurement and analysis. Thus, the field operator, all persons having custody of the samples and data, and the analyst would be required to lay the foundation for the introduction of the measurement as evidence. This evidence can and should be recorded in the form of initials and notes/forms written in indelible ink at the time of data collection on paper that is kept on file (or in e-logbook systems). Examples of this include strip charts dated and initialed by operator when visiting the site for routine quality checks and initials on routine paperwork

[9] 36 CFR 1236
[10] https://www.epa.gov/records

and in logbooks when events are recorded. Electronic records should also allow for a recording of initials and be traceable to the operator performing the work.

To ensure compliance with legal rules, all measurement 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 or other data (chain of custody, field data sheets, etc.) should also be filed.

The original of a document is the best evidence; a copy is not normally admissible as evidence. Snap-out carbon copies, and similar contemporary business methods of producing copies are acceptable in many jurisdictions if the unavailability of the original is adequately explained and if the copy was made in the ordinary course of business. Although copies may be problematic, they are better than no information if for some reason original versions are lost or destroyed. It is suggested that original copies are scanned and stored electronically for back-up.

In summary, although all original calculations and measurement data need not be included in the final report, they should be kept in the agency's files; either in hardcopy or electronically if acceptable electronic recording systems have been approved. 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.

5.6 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 14.

5.7 Quality Assurance

Quality assurance information is necessary to document the quality of data. A monitoring organization's plan for all quality assurance activities must be documented in its QAPP. This information should be retained in a manner that it can be associated with the routine data that it represents. QA information includes:

- **Control charts** – A control chart is a graph used to study how a process changes over time. Use of control charts are explained in Section 10.5.
- **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. More discussion on DQAs can be found in Section 18.
- **QA Reports -** Reports pertaining to the quality of data are discussed in Sections 1 and 16.
- **Evaluation/Audits** - Assessments of various phases of the environmental data operation are discussed in Section 15.

6.0 Monitoring Network Design

The development of a monitoring network of sites for a specific pollutant requires:

1. Understanding the monitoring objective(s).
2. Identifying the spatial scale most appropriate for the monitoring objective(s).
3. Identifying the general locations where the monitoring site(s) should be placed in order to collect a representative pollutant measurement.
4. Identifying specific monitoring sites.

This section describes the general concepts for establishing the SLAMS, NCore, CSN, PAMS, and open path monitoring. Additional details can be found in 40 CFR Part 58, Appendix D [1] and the guidance information for the various monitor networks that can be found on AMTIC[2].

As described in Section 1, air quality monitoring data are generally collected for one or more of the following objectives:

- To provide air pollution data to the general public in a timely manner
- To support compliance with ambient air quality standards and emissions strategy development
- To support for air pollution research studies

Network information related to these purposes are discussed below.

Timely Air Quality Public Reporting- AirNow

The U.S. EPA, NOAA, NPS, tribal, state, and local agencies developed AirNow[3] to provide the public with easy access to national air quality information. The AirNow site offers daily Air Quality Index (AQI):

Conditions- Nationwide and regional real-time ozone and $PM_{2.5}$ air quality maps covering 46 US States and parts of Canada. These maps are updated daily every hour. A click of a mouse brings up the U.S. map and a second click can bring up the AQI details of a region, state or local area within a state.

Forecasts - Nationwide daily air quality forecasts for over 300 major cities and areas in the U.S.

In addition, this information is also found in local/national newspapers/television, on local and tribal web pages and more recently on smart phone applications.

Federal requirements in 40 CFR Part 58.50 state that Metropolitan Statistical Areas (MSAs) with a population of more than 350,000 are required to report the AQI daily to the general public. The U.S. Office of Management and Budget defines MSAs according to the most recent census. However, many monitoring organizations who are not subject to the 58.50 AQI requirements participate in AirNow. Guidance for reporting is included in the *Technical Assistance Document for the Reporting of Daily Air Quality-The Air Quality Index (AQI)*[4]

[1] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl
[2] http://www3.epa.gov/ttn/amtic/
[3] http://airnow.gov/
[4] https://www3.epa.gov/airnow/aqi-technical-assistance-document-dec2013.pdf

The air quality data used in AirNow maps and forecasts are collected using either federal reference or equivalent monitoring methods (FRM/FEM), or approved regional methods (ARM). Since the information needed to make maps must be as "real-time" as possible, the data are displayed as soon as practical after the end of each hour. Although some preliminary data quality assessments are performed, the data as such are not fully verified and validated through the quality assurance procedures monitoring organizations use to officially submit and certify data on the EPA AQS. Therefore, data are used on the AirNow Web site only for the purpose of reporting the AQI. Information on the AirNow web site is not used to formulate or support regulation, guidance or any other Agency decision or position.

Compliance Monitoring

Since the focus of this Handbook is on criteria pollutants, compliance monitoring, in most cases, is associated with attaining the NAAQS. The information required for selecting the number of samplers[5] 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 expected to occur in the area/region[6] covered by the network; one or more stations should 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 compliance monitoring is the 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 strategies; and
- some information of air quality should be available to represent all portions of the region of concern.

Some stations will be capable of fulfilling more than one of the guideline described above. 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.

Research Monitoring

There are a number of activities that could be described under research monitoring. A few are considered in this section

[5] A “sampler” in this context refers to both continuous instruments that provide an ambient air concentration without additional preparation or analytical techniques as well as instruments that provide a sample needing additional analysis.

[6] Most compliance monitoring is associated with a particular monitoring boundary like a CBSA or CSA (see section 6.1.1). The term area or region refers to these boundaries.

Environmental and Human Health Effects Research --

Air monitoring networks related to environmental and human health effects are composed of integrating samplers both for determining pollutant concentrations for ≤24 hours and for developing long term (≥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.

Some considerations for aerometric monitoring in support of health studies follow:

- 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; and
- the monitoring system should be flexible and responsive to emergency conditions with data available on short notice.

Attention must still be paid to QA/QC activities since environmental or human health research activities can lead to policy decisions and potentially compliance-related monitoring. The uncertainty of this research data should be known and quantified.

Atmospheric and/or Methods Research --

Some research will be accomplished either for studying a particular atmospheric phenomenon or for determining if a particular sampler or analytical method is appropriate for ambient air monitoring. In this regard many of the points described above for health research are applicable and include:

- Ensuring the data are representative (spatially and temporally) of the population (or atmospheric conditions) under study
- Enough data are collected (including quality assurance data) to make definitive statements or decisions
- Ensuring that (method research) testing covers the extremes of temperature, pressure, humidity and other environmental conditions for which the method will be exposed
- Testing whether the method can be operated with little maintenance
- That the precision and bias of the method is comparable to the standard

Additional Types of Monitoring

In addition to the three basic monitoring objectives, the following also occur with the Ambient Air Monitoring Program.

Trends Monitoring --

Trends monitoring can be used to determine the extent and nature of air pollution and to determine the variations in the measured levels of the atmospheric contaminants in respect to geographical, socio-economic, climatological, and other factors. The data are useful in planning epidemiological investigations and in providing the background against which more intensive regional and community

studies of air pollution can be conducted. 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 NCore, NATTS, and CSN networks meet the objectives of trends monitoring.

At times trends monitoring may classify/evaluate certain areas separately. An example would be monitoring urban and non-urban areas. 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 of 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.

Emergency Episode Monitoring --

For episode avoidance purposes, data are needed quickly – in 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 reporting, the norm is the use of automated monitoring/reporting networks that can report data back to central information management systems on an hourly basis (see Section 14). 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.

The control actions for emergencies must be based on real-time measurements that are correlated with the various decisions (e.g., evacuation) that need to be made using this information. Therefore, it is necessary to use continuous air samplers because of the short durations of episodes. Based on episode alert criteria and mechanisms now in use, 1-hour averaging times are adequate for surveillance of episode conditions. Shorter averaging times provide information on data 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. EPA has developed a document entitled *EPA Emergency Response Air Monitoring Guidance Tables*[7] that can be helpful in the selection of the right type of monitoring equipment based on the pollution and its severity.

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 qualified for emergency episode monitoring should typically be located in areas where human health and welfare are most threatened such as:

[7] http://www.uscg.mil/hq/nsfweb/foscr/ASTFOSCRSeminar/Presentations/RemovalandResponseTech/AirMonGuidanceTables09Ed2.pdf

- in densely populated areas;
- near large stationary sources of pollution;
- near hospitals or schools;
- near high density traffic areas; and
- near homes for the elderly.

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. Portability of monitoring equipment and "footprint" can be key. Solar, satellite, and low-power technology can make the difference in response time and reporting. 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. Use of new sensor technologies may be considered as long as one has a thorough knowledge of the limitations of this technology and FRM/FEMs are not required.

6.1 Monitoring Objectives and Spatial Scales

The monitoring network can include monitoring sites located to meet the following objective(s):

1. Determine the highest concentrations expected to occur in the area covered by the network.
2. Measure typical concentrations in areas of high population density.
3. Determine the impact of significant sources or source categories on air quality.
4. Determine general background concentration levels.
5. Determine the extent of regional pollutant transport among populated areas, and in support of secondary standards.
6. Measure air pollution impacts on visibility, vegetation damage, or other welfare-based impacts.

These six objectives indicate the nature of the data that the monitoring network will collect that must be representative of the spatial area being studied. The primary monitoring objectives should be determined before any data is collected.

Monitoring stations that are located in areas where pollutant concentrations are expected to be among the highest and in areas with the highest population densities are often used in health effects research networks and generally use automated equipment to continually sample and analyze pollutant levels. These stations are used to report data to the public through AirNow[8] and the air quality index (AQI) and can be used to alert the public to potential deleterious air pollution episodes.

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. This achieves the goal of the data quality indicator representativeness discussed in Section 3. 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.

[8] http://airnow.gov/

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 basic monitoring objectives and the scales of representativeness that are generally most appropriate for that objective. Appendix E provides more detailed spatial characteristics for each pollutant while Table 6-2 provides a summary for a number of the monitoring programs.

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

Monitoring Objective	Appropriate Siting Scale
Highest Concentration	Micro, middle, neighborhood (sometimes urban/regional for secondarily formed pollutants)
Population	Neighborhood, urban
Source impact	Micro, middle, neighborhood
General/background & 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. 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, NCore, PAMS, and Open Path (OP) Sites

Spatial Scale	SLAMS Sites[1]							$PM_{10-2.5}$	NCore	CSN	NATTs	PAMS	OP
	SO_2	CO	O_3	NO_2	Pb	PM_{10}	$PM_{2.5}$						
Micro	*	*		*	*	*	*	*					
Middle	*	*		*	*	*	*	*					*
Neighborhood	*	*	*	*	*	*	*	*	*	*	*	*	*
Urban	*		*	*			*		*	*	*	*	*
Regional			*				*		*		*		*

[1] SLAMS Site scales based on current listing in 40 CFR Part 58, Appendix D and do not include NCore spatial scale objective.

6.1.1 Monitoring Boundaries

The NAAQS refer to several boundaries that are defined below. These definitions are derived from the U.S. Office of Management and Budget (OMB).

Core-based Statistical Area (CBSA) – is defined by the OMB as a statistical geographic entity consisting of the county or counties associated with at least one urbanized area/urban cluster of a

population at least 10,000, plus adjacent counties having a high degree of social and economic integration.

Metropolitan Statistical Area (MSA) - a category of CBSA with populations greater than 50,000[9].
Micropolitan Statistical Area - are a category of CBSA with populations between 10,000 and 50,000

Combined Statistical Area (CSA) - is defined by the OMB as a geographical area consisting of two or more adjacent CBSAs with employment interchange of at least 15 percent. Combination is automatic if the employment interchange is 25 percent and determined by local opinion if more than 15 but less than 25 percent.

New England city and town areas (NECTAs) - are analogous to CBSAs and are similarly classified as either metropolitan NECTAs (corresponding to MSAs) or micropolitan NECTAs (corresponding to micropolitan statistical areas). The principal difference between a CBSA and a NECTA is that NECTAs use New England towns as building blocks instead of counties. In the New England region, towns are a much more important level of government than counties. Because of this, NECTAs are usually a much closer approximation to metropolitan areas in New England than MSAs

Monitoring Planning Area (MPA) - means a contiguous geographic area with established, well defined boundaries, such as a CBSA, county or State, having a common area that is used for planning monitoring locations for $PM_{2.5}$. An MPA may cross State boundaries, such as the Philadelphia PA–NJ MSA, and be further subdivided into community monitoring zones. MPAs are generally oriented toward CBSAs or CSAs with populations greater than 200,000, but for convenience, those portions of a State that are not associated with CBSAs can be considered as a single MPA.

6.2 Monitoring Site Location

Location of the monitoring site is initially dependent on the monitoring objective. For example, once it is known that there is a requirement to monitor for peak ambient CO at a microscale site, it reduces the monitoring site location to specific areas. Hence, the first task when evaluating a possible site location is to determine the scale for which a candidate location can qualify by considering the following:

1. location and emissions strengths of nearby sources, especially major source;
2. prevailing wind direction in the area;
3. nearby uniformity of land use; and
4. nearby population density.

To select locations according to these criteria, it is necessary to have detailed information on the location of emission sources, 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 require 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.

[9] https://www.census.gov/population/metro/

There has been a trend for multi-pollutant monitoring (e.g., NCore). If possible, monitoring organizations should try to take advantage of combining pollutant monitoring to a smaller network of sites only when it does not conflict with meeting the primary objective for measuring the pollutant.

The sampling site selection process involves considerations of the following factors:

Economics - Site selection economics/expenditures consists of: 1) rental of property, if necessary; 2) installation of power and/or phone lines; 3) excavation of the grounds and installation of concrete pads; 4) installation of fencing or other security; 5) installation of lightning protection; 6) site maintenance (tree/brush cutting) and 7) delivery of trailer/shelter and monitors to the site. Different site selections may entail significantly different costs.

Security - 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, electronic surveillance 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 the spatial and temporal variability of the pollutants and its transport to the monitoring site. 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 dispersion 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 conditions to consider are atmospheric stability and lapse rate (the decrease of an atmospheric variable with height).

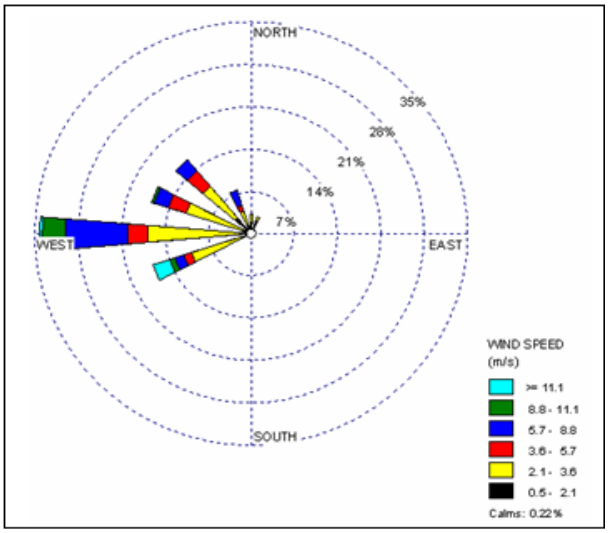


Figure 6.1 Wind rose pattern

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 wind direction. In this particular example, the wind is primarily from the west. More detailed guidance for meteorological considerations is available in *QA Handbook Volume IV Meteorological Measurements*[10]. Relevant weather information, such as stability-wind roses, is usually available from local National Weather Service stations.

Meteorological conditions, particularly those that can affect light transmission, should also be considered in selecting the location for open path analyzers. 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.

Topography - 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.

[10] http://www3.epa.gov/ttn/amtic/met.html

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 may not produce representative 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.

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 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 was implemented to improve ambient monitoring of NOx and VOC emissions in order to obtain a more comprehensive and representative dataset on ozone air pollution. Currently, the network has a two-part design. The first part of the design includes a network of fixed sites ("required PAMS sites") intended to support O_3 model development and evaluation and the tracking of trends of important O_3 precursor concentrations. These required PAMS sites are to be located at NCore sites located in CBSAs with a population of one million or more. The second part of the network design requires states with moderate O_3 non-attainment areas to develop and implement Enhanced Monitoring Plans (EMPs) which were intended to allow monitoring agencies the needed flexibility to implement additional monitoring capabilities to suit the needs of their area."

6.2.2 NCore Site Descriptions

NCore is a multi-pollutant network that integrates several advanced measurement systems for particles, pollutant gases, and meteorology. Most NCore stations have been operating since the formal start of the network on January 1, 2011. The NCore Network addresses the following objectives:

- Timely reporting of data to the public by supporting AirNow, air quality forecasting, and other public reporting mechanisms;
- Support for development of emission strategies through air quality model evaluation and other observational methods;
- Accountability of emission strategy progress through tracking long-term trends of criteria and non-criteria pollutants and their precursors;
- Support for long-term health assessments that contribute to ongoing reviews of the NAAQS;
- Compliance through establishing nonattainment/attainment areas through comparison with the NAAQS;
- Support to scientific studies ranging across technological, health, and atmospheric process disciplines; and
- Support to ecosystem assessments recognizing that national air quality networks benefit ecosystem assessments and, in turn, benefit from data specifically designed to address ecosystem analyses.

For more detailed information on each specific site, click on the "site map" link to connect to each site's Characterization Report.

NCore is both a repackaging and an enhancement of existing networks. The emphasis on the term “Core” reflects a multi-faceted, multi-pollutant national network that can be complemented by more specific efforts, such as intensive field campaigns to understand atmospheric processes, or personal and indoor measurements to assess human exposure and health effects. The NCore network leverages all of the major existing networks to produce an integrated multi-pollutant approach to air monitoring.

Emphasis is placed on a backbone of multi-pollutant sites, continuous monitoring methods, and measurement of important pollutants other than the criteria pollutants (e.g., ammonia and NOy). When complete, NCore will meet a number of important data needs: improved flow and timely reporting of data to the public, including supporting air quality forecasting and information systems such as AirNow; continued determination of NAAQS compliance; improved development of emissions control strategies; enhanced accountability for the effectiveness of emission control programs; and more complete information for scientific, public health, and ecosystem assessments. Specific design criteria for NCore can be found in 40 CFR Part 58, Appendix D.

6.3 Minimum Network Requirements

Rather than place tables for minimum monitoring site requirements in the Handbook (since they have a tendency to change), the reader is directed to 40 CFR Part 58, Appendix D[11] of the most current regulation to find the appropriate minimum monitoring network requirements.

[11] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl

6.4 Operating Schedules

NOTE: The reader should check the most current version of 40 CFR Part 58 to ensure the schedules below have not changed.

For continuous analyzers, consecutive hourly averages must be collected except during:

1. periods of routine maintenance;
2. periods of instrument calibration, quality control checks, or performance evaluation; or
3. periods or monitoring seasons exempted by the Regional Administrator.

For Pb manual methods, at least one 24-hour sample must be collected every 6 days except during periods or seasons exempted by the Regional Administrator.

For PAMS VOC samplers, samples must be collected as specified in 40 CFR Part 58, Appendix D Section 5. Area-specific PAMS operating schedules must be included as part of the PAMS network description and must be approved by the Regional Administrator.

For manual $PM_{2.5}$ samplers (including SPMs using FRM/FEM methods):

1. **Manual $PM_{2.5}$ samplers at SLAMS stations –** a 24-hour sample must be taken from midnight to midnight (local standard time) to ensure national consistency and, other than NCore stations, must operate on at least a 1-in-3 day schedule at sites without a collocated, continuously operating $PM_{2.5}$ monitor. For SLAMS $PM_{2.5}$ sites with both manual and continuous $PM_{2.5}$ monitors operating, the monitoring agency may request approval for a reduction to 1-in-6 day $PM_{2.5}$ sampling or for seasonal sampling from the EPA Regional Administrator. The EPA Regional Administrator may grant sampling frequency reductions after consideration of factors including, but not limited to, the historical $PM_{2.5}$ data quality assessments, the location of current $PM_{2.5}$ design value sites, and their regulatory data needs.

   Required SLAMS stations whose measurements determine the design value for their area and that are within ±10 percent of the annual NAAQS, and all required sites where one or more 24-hour values have exceeded the 24-hour NAAQS each year for a consecutive period of at least 3 years are required to maintain at least a 1-in-3 day sampling frequency until the design value no longer meets these criteria for 3 consecutive years. A continuously operating FEM or ARM $PM_{2.5}$ monitor satisfies this requirement unless it is identified in the monitoring agency's annual monitoring network plan as not appropriate for comparison to the NAAQS and the EPA Regional Administrator has approved that the data from that monitor may be excluded from comparison to the NAAQS.

   Required SLAMS stations whose measurements determine the 24-hour design value for their area and whose data are within ±5 percent of the level of the 24-hour $PM_{2.5}$ NAAQS must have an FRM or FEM operate on a daily schedule if that area's design value for the annual NAAQS is less than the level of the annual $PM_{2.5}$ standard. A continuously operating FEM or ARM $PM_{2.5}$ monitor satisfies this requirement unless it is identified in the monitoring agency's annual monitoring network plan as not appropriate for comparison to the NAAQS and the EPA Regional Administrator has approved that the data from that monitor may be excluded from comparison to the NAAQS. The daily schedule must be maintained until the referenced design value no longer

meets these criteria for 3 consecutive years. The national sampling schedule can be found on AMTIC[12].

1. **Manual $PM_{2.5}$ samplers at NCore stations** and required regional background and regional transport sites must operate on at least a 1-in-3 day sampling frequency.
2. **Manual $PM_{2.5}$ speciation samplers at CSN stations** must operate on a 1-in-3 day sampling frequency.

For PM_{10} samplers, a 24-hour sample must be taken from midnight to midnight (local standard time) to ensure national consistency. The minimum monitoring schedule for the site in the area of expected maximum concentration shall be based on the relative level of that monitoring site concentration with respect to the 24-hour standard as illustrated in Figure 6.2. If the operating agency demonstrates by monitoring data that during certain periods of the year conditions preclude violation of the PM_{10} 24-hour standard, the increased sampling frequency for those periods or seasons may be exempted by the Regional Administrator and permitted to revert back to once in six days. The minimum sampling schedule for all other sites in the area remains once every six days.

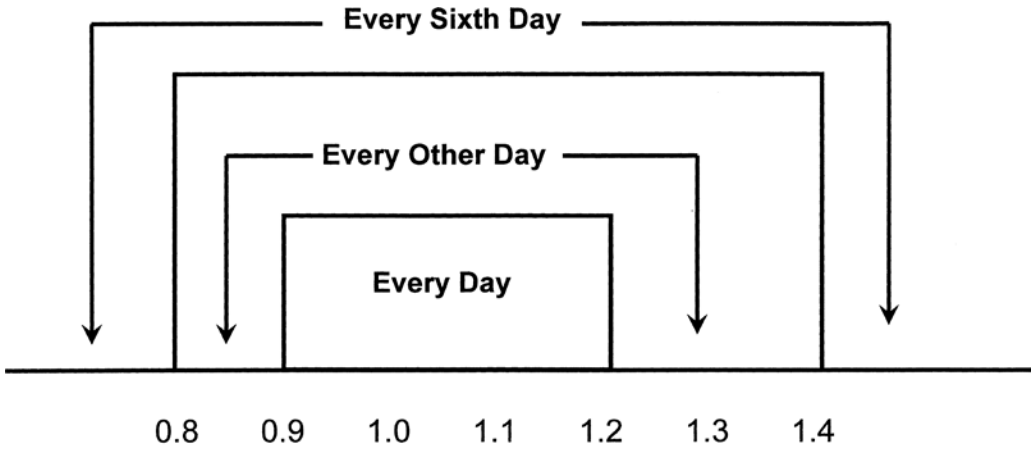


Figure 6.2 Sampling schedule based on ratio to the 24-hour PM_{10} NAAQS

Manual $PM_{10-2.5}$ samplers at NCore stations must operate on at least a 1-in-3 day schedule at sites without a collocated continuously operating federal equivalent $PM_{10-2.5}$ method that has been designated in accordance with 40 CFR Part 53.

For NATTS monitoring, samplers must operate year round and follow the national 1-in-6 day sampling schedule.

6.4.1 Operating Schedule Completeness

Data required for comparison to the NAAQS have specific completeness requirements. These completeness requirements generally start from completeness at hourly and 24-hour concentration values. However, the data used for NAAQS determinations include 3-hour, 8-hour, quarterly, annual, and multi-

[12] http://www.epa.gov/ttn/amtic/calendar.html

year levels of data aggregation. Generally, depending on the calculation of the design value, EPA requires data to be 75% complete. See the appendices of 40 CFR Part 50 for the completeness requirements for the specific criteria pollutants. All continuous measurements come down to what is considered a valid hour and currently all 24-hour estimates based on sampling (manual PM, Pb, TSP) are based on a 24-hour sampling period. Table 6-4 provides the completeness goals for the ambient air monitoring programs. Completeness goals change so check 40 CFR Part 50 for the most current requirements.

The data cells highlighted in Table 6-4 refer to the standards that apply to the specific pollutant. Even though a highlighted cell lists the completeness requirement, CFR provides additional detail, in some cases, on how a design value might be calculated with less data than the stated requirement. Therefore, the information provided in Table 6-4 should be considered the initial completeness goal. Completeness goals that are not highlighted, although not covered in CFR, are very important to the achievement of the CFR completeness goals. So, for example, even though there is only an 8-hour ozone standard, it's important to have complete 1-hour values in order to compare to the 8-hour standard.

Table 6-4 Completeness Goals for Ambient Air Monitoring Data

	Completeness Goals and Associated Standards (highlighted)					
Pollutants	**1-hour**	**3-hour**	**8-hour**	**24-hour**	**Quarterly**	**Annual**
CO	45, 1 min. values		75% of hourly values	75% of hourly values		75% of hourly values per quarter
O_3	45, 1 min. values		75% of hourly values	13 of 17 8-hour periods.		75% of days within season[1]
SO_2	45, 1 min. values	All 3 hours 75% complete		75% of hourly values		75% of hourly values per quarter
NO_2	45, 1 min. values					75% of hourly values per quarter
PM_{10} Cont	45, 1 min. values			18 Hours		
$PM_{2.5}$ Cont.	45, 1 min. values			18 Hours		
PM_{10} Manual				23 Hours**		
$PM_{2.5}$ Manual				23 hours	75% of samples	
Pb				23 Hours	3 mo avg >75% of monthly means	
PAMS				23 Hours		
NATTS				23 Hours		
CSN				23 Hours		

**** not defined in CFR**

1= For ozone the requirements are met for a 3-year period at a site if valid daily maximum 8-hour average O_3 concentrations are available for at least 90% of the days within the O_3 monitoring season, on average, for the 3-year period, with a minimum of at least 75% of the days within the O_3 monitoring season in any one year

For continuous instruments, it is recommended that 45, 1-minute values be considered a valid hour. Therefore, it is expected that 1-minute concentration values would be archived for a period of time (see statute of limitations in Section 5). Since various QC checks (e.g., zero/span/1-point QC) take time to complete, it is suggested that they be implemented in a manner that spans two hours (e.g., at 11:45 PM to 12:15 AM) in order to avoid losing an hour's worth of data.

6.4.2 Monitoring Seasons

Most of the monitoring networks operate year round with the exception of PAMS and ozone monitoring.

PAMS - 40 CFR 58, Appendix D stipulates that PAMS precursor monitoring must be conducted annually throughout the months of June, July and August (at a minimum) when peak O_3 values are expected in each area. Alternate precursor monitoring periods may be submitted for approval to the Administrator as a part of the annual monitoring network plan.

Ozone - Since O_3 levels decrease significantly in the colder parts of the year in many areas, O_3 is required to be monitored at SLAMS monitoring sites only during the ''ozone season'' as designated in the AQS files on a State-by-State basis and described in 40 CFR Part 58, Appendix D[13]. Deviations from the O_3 monitoring season must be approved by the EPA Regional Administrator, documented within the annual monitoring network plan, and updated in AQS. At NCore sites, ozone is required to be monitored year round.

6.5 Network Plan Reporting

The following two types of documents related to the monitoring network are required to be reported to EPA. Additional information on these assessments can be found in 40 CFR Part 58.10 and should be reviewed since the information below may have changed in the regulation.

Annual Monitoring Network Plan

The monitoring organization shall submit to the Regional Administrator an annual monitoring network plan which shall provide for the documentation of the establishment and maintenance of an air quality surveillance system that consists of a network of SLAMS monitoring stations that can include FRM, FEM, and ARM monitors that are part of SLAMS, NCore, CSN, PAMS, and SPM stations. The plan shall include a statement of whether the operation of each monitor meets the requirements of 40 CFR Part 58 appendices A, B, C, D, and E, where applicable. The Regional Administrator may require additional information in support of this statement. The annual monitoring network plan must be made available for public inspection and comment for at least 30 days prior to submission to the EPA and the submitted plan shall include and address, as appropriate, any received comments. These network plans are posted on AMTIC[14].

5-Year Network Assessments

The monitoring organization shall perform and submit to the EPA Regional Administrator an assessment of the air quality surveillance system every 5 years to determine, at a minimum, if the network meets the monitoring objectives defined in 40 CFR Part 58 Appendix D, whether new sites are needed, whether existing sites are no longer needed and can be terminated, and whether new technologies are appropriate for incorporation into the ambient air monitoring network. The network assessment must consider the ability of existing and proposed sites to support air quality characterization for areas with relatively high populations of susceptible individuals (e.g., children with asthma) and, for any sites that are being proposed for discontinuance, the effect on data users other than the agency itself, such as nearby States and Tribes or health effects studies. For $PM_{2.5}$, the assessment also must identify needed changes to population-oriented sites. The State, or where applicable, local agency must submit a copy of this 5-year assessment, along with a revised annual network plan, to the Regional Administrator.

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[13] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl
[14] http://www3.epa.gov/ttn/amtic/plans.html

7.0 The Sampling System

To establish the validity of ambient air monitoring data, it must be shown that:

- the proposed sampling method complies with the appropriate monitoring regulations;
- the equipment is accurately sited;
- the equipment is accurately calibrated using correct and established calibration methods;
- there is enough information from data quality indicators to assess data uncertainty;
- samples are appropriately handled through proper chain of custody procedures; and
- the organization implementing the data collection operation is qualified and competent.

For example, if the only reasonable monitoring 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 QAPP. 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. A sampling system for the ambient air monitoring program will include aspects of:

- siting;
- the establishment of a monitoring station or platform for monitors/samplers;
- outfitting for electricity, HVAC, water, etc.;
- use of appropriate probe and inlet material;
- setting up quality control systems; and
- information management systems.

Information management systems will be described in Section 14.

7.1 Monitor Placement

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.

7.2 Environmental Control

7.2.1 Monitoring Station Design

Monitoring organizations 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, prolongs downtime, and may delay required maintenance (i.e., not cleaning manifolds because they are too hard to get to). The goal is to optimize data collection and quality and it starts with designing the shelter and laboratory around staff needs and requirements.

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 its equipment. 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 effects of temperature, humidity, light, vibration, and chemicals on the instruments. In addition, security can also be an issue if people other than agency staff have access to the equipment. Monitoring organizations should give serious thought to locating 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 for operation, maintenance and repair. In addition, the shelter should be rugged enough to withstand local weather condition extremes. 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 structures should be secured to their foundations and protected from damage during natural disasters. All monitoring shelters should be designed to control excessive vibrations and prevent external light from 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 or audit equipment (e.g., NPAP/PEP). Every attempt should be made to reduce the environmental footprint of shelters to make them as energy efficient as possible. Some possibilities include venting of excess heat of monitoring instruments to the outside in summer months, use of energy efficient fixtures and HVAC systems, and ensuring that the amount of space devoted to the monitors is not excessive (remembering that space is needed at times for additional QA equipment). Figure 7.1 represents one shelter design that has proven adequate. This should not be considered the only acceptable design. It is included because of the features discussed below.

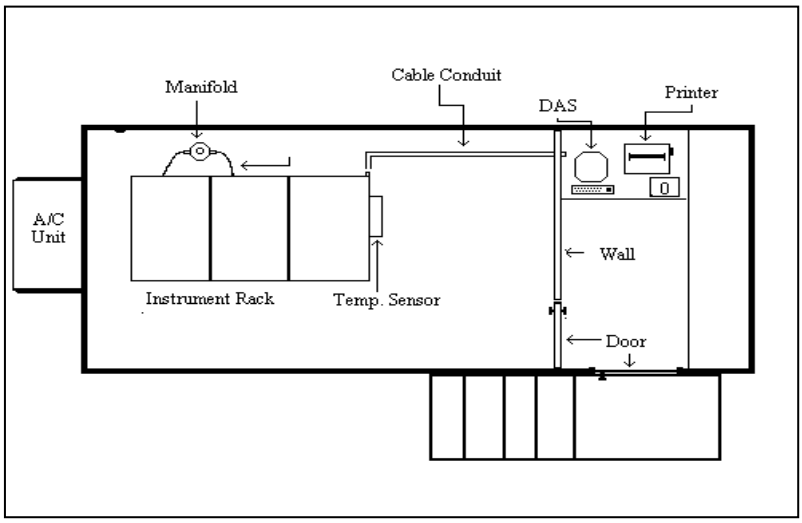

Figure 7.1 Example Design for Shelter

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. In some cases, vibration and noise can be reduced by locating pumps outside the shelter (if appropriate weather conditions exist). 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 which may lead to investigation and corrective action. 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.

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 days and heat on the coldest days of the year. Second HVAC units as back-ups should be considered to reduce the potential for data invalidation due to temperature excursions beyond FRM/FEM temperature operating ranges. 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 allow the site operators access to the instruments without removing them from the racks. Most instrument vendors offer sliding rails as an optional purchase. If several instruments are placed in an instrument rack, the labeling of all power cords, sample and exhaust lines will help to identify where lines and inlets are and it will help when it comes time to trace things back to an instrument.

7.2.2 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. Locate pumps outside if appropriate conditions exist.

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 analyzers designated as FRM or FEM, most analyzers have been tested and qualified over a temperature range of 20°C to 30°C; however, some have been qualified over a wider range. Analyzers must be operated within the range for which they were designated, in order for the data produced by the analyzers to be considered FRM/FEM. When one is outfitting a shelter with monitoring equipment, it is important to recognize and accommodate the instrument with the most sensitive temperature requirement. The 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. Although generally not specified in the analyzer's FRM/FEM designation, EPA suggests that shelters be maintained within a standard deviation (SD) of $\leq +2^{o}$ C over a 24-hour period, in order to provide a stable temperature environment for the analyzer. The SD should be assessed using 1-hour shelter temperature measurements.
Some monitoring sites are established inside buildings (such as schools) where the monitoring organization has no direct control of the interior temperature. In these situations, analyzers may be subject to energy conservation plans that do not continuously maintain their required temperature range. Operators should be alert to situations where environmental temperatures might fall below the FRM/FEM designation of the analyzer, such as during night hours or weekends. To accommodate energy conservation regulations or guidelines specifying lower thermostat settings, EPA will permit designated analyzers located within facilities subject to such restrictions to be operated at temperatures down to 18°C, if an alternate monitoring location, or use of an analyzer designated at a wider temperature range, is not available and the monitoring organization can demonstrate that the analyzer meets data quality requirements at these lower temperatures. In these unique cases, the monitoring organization should converse with its EPA Regional Office to determine the most appropriate course of action, which may include requesting a waiver from the Administrator in order to operate the analyzer outside its designated temperature range[1].

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. Sites that continually have problems maintaining adequate temperatures may necessitate additional temperature control equipment or rejection of the area as a sampling site. When providing cooling to shelters, care should be taken to avoid cool air blowing directly on monitors or sample lines.

In order to detect and correct temperature fluctuations, it is suggested that a 24-hour temperature recorder that collects hourly values (minimally) be located in the shelter. The device should be accurate to within

[1] See 40 CFR Part 58 Appendix C sections 2.8.2 and 2.7

± 2°C and checked every 6 months by a NIST-traceable standard. 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 twofold: 1) through remote interrogation of the DAS, the monitoring organization can tell if values collected by air quality instruments are valid, and 2) the monitoring organization can tell if the shelter temperature is within a safe operating range should the air conditioning/heating system fail.

7.3 Sampling Probes And Manifolds

7.3.1 Design of Probes and Manifolds for Automated Methods

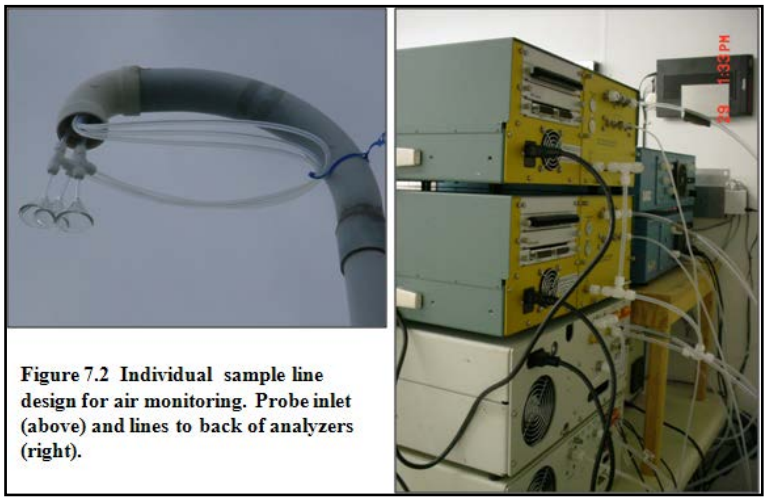

Figure 7.2 Individual sample line design for air monitoring. Probe inlet (above) and lines to back of analyzers (right).

Some important variables affecting the sampling manifold design are the diameter, length, flow rate, pressure drop, and materials of construction. With the development of NCore precursor gas monitoring, various types of probe/manifold designs were reviewed. This information can be found in the *Technical Assistance Document (TAD) for Precursor Gas Measurements in the NCore Multi-pollutant Monitoring Network*[2] and is also included in Appendix F of this Handbook.

Of the probe and manifold material looked at over the years, only Pyrex® glass and Teflon® have been found to be acceptable for use as intake sampling lines for all the reactive gaseous pollutants. Furthermore, the EPA has specified borosilicate glass or FEP Teflon® as the only acceptable probe materials for delivering test atmospheres in the determination of reference or equivalent methods. Therefore, borosilicate glass (which includes Pyrex®), FEP Teflon® or their equivalent must be the only material in the sampling train (from inlet probe to the back of the analyzer) that can be in contact with the ambient air sample for existing and new SLAMS. Questions have been asked about PFA (perfluoroalkoxy co-polymer). It's a newer formulated Teflon than FEP. Like FEP, it is translucent which is also not machined but unlike FEP can be molded into fittings. It has been accepted as equivalent to FEP Teflon®, but there is no real advantage to using PFA.

For volatile organic compound (VOC) monitoring at PAMS, FEP Teflon® is unacceptable as the probe material because of VOC adsorption and desorption reactions on the FEP Teflon®. Borosilicate glass, stainless steel, or its equivalent, are acceptable probe materials for VOC and carbonyl sampling. Care must be taken to ensure that the sample residence time is kept to 20 seconds or less (see below).

[2] http://www.epa.gov/ttn/amtic/files/ambient/monitorstrat/precursor/tadversion4.pdf

When determining how to set up a sampling station with regards to probes, inlets and sampling material, monitoring organization have the option of:

Figure 7.3 Left & top left glass intakes for manifolds; top right long tube manifold; bottom right short tube manifold with water trap.

1) using individual Teflon® sampling lines (Fig7.2) which may access the ambient air through one port (with a number of individual lines) but each line would run directly to an analyzer.

2) using glass manifolds (Fig 7.3) which allow for ambient air to enter from a single inlet, collect in the manifold and then be distributed through manifold outlet ports in individual analyzers.

Either method is appropriate and it may depend on the number of analyzers at the site, how the shelter is configured for access, and what resources are available for maintenance and cleaning.

It is suggested that manifolds be designed so that audit gas can be introduced to the inlet of the probe system. Flow rates should be such that they do not exceed the generation capacity of the audit equipment allowing the system to be audited under normal sampling conditions.

Residence Time Determination

No matter how nonreactive the sampling probe material may be, after a period of use, reactive particulate matter is deposited on the probe walls. Therefore, the time it takes the gas to transfer from the probe inlet to the sampling device is critical. Ozone, in the presence of nitrogen oxide (NO), will show significant losses even in the most inert probe material when the residence time exceeds 20 seconds. Other studies indicate that a 10 second or less residence time is easily achievable.

Residence time is defined as the amount of time that it takes for a sample of air to travel from the opening of the inlet probe (or cane) to the inlet of the instrument and is required to be less than 20 seconds for reactive gas monitors. The residence time of pollutants within the sampling manifold is also critical. It is recommended that the residence time within the manifold and sample lines from the manifold to the instruments be less than 10 seconds (of the total allowable 20 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, cm^3
Mv = Volume of the sample manifold and trap, cm^3
Lv = Volume of the instrument lines, cm^3

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, cm^3
pi = 3.14159
L = Length of the component, cm
d = inside diameter, cm

Once the total volume is determined, divide the volume by the flow rate of all instruments and pumps (additional blower motors or vacuum pumps) used. This will give 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.

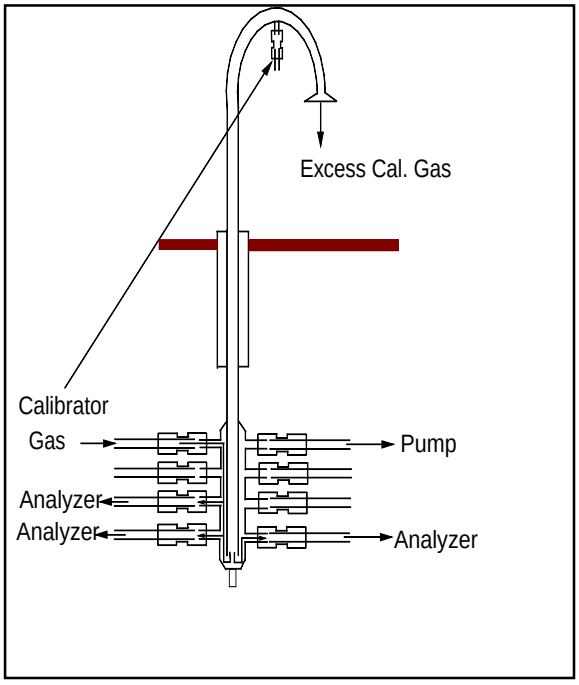

Figure 7.4 Positions of calibration line in sampling manifold

The air flow through the manifold must not be so great as to cause the pressure inside the manifold to be more than one inch of water below ambient. These last two conditions are in opposition to each other, but can be assessed as follows. Construct the manifold. Use a pitot tube to measure the flow of the sample inside the manifold. At the same time, attach a water manometer to a sampling port. Turn on the blower and measure the flow rate and the vacuum. (Remember to allow for the air demand of the instrumentation). Adjust the flow rate to fit between these two parameters. If this is impossible, the diameter of the manifold is too small.

Placement of tubing on the Manifold: If the manifold that is employed at the station has multiple ports then placement of the instrument lines can be crucial. If a manifold similar to Figure 7.4 is used, ambient air flows down the center tube and then travels up on both sides of the manifold to the analyzer ports. It is suggested that instruments requiring lower flows be placed towards the bottom of the manifold. The general rule of thumb states that the placement of the calibration line (if used) should be in a location such

that the calibration gases flow past the instruments before the gas is evacuated out of the manifold. Figure 7.4 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 and should be considered. It can also be used for other types of QC samples.

7.3.2 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
- probes need to be accessible for performance evaluation auditors
- height of the probe above the ground depends on the pollutant being measured
- design of the probe system should be such that both analyzer & calibrator exhaust are vented outside for safety reasons, and that operators should periodically check the outside vent line to ensure it's not clogged or block. The outside vent line should be of minimal length, in order to prevent it getting lost in weeds/dirt under shelter.

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[3]. For PM_{10} and $PM_{2.5}$, Figure 7.5 provides the acceptable areas for micro, middle, neighborhood and urban samplers, with the exception of microscale street canyon sites.

[3] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl All references to CFR in following sections can be found at this site.

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

Pollutant	Scale (maximum monitoring path length, meters)	Height from ground to probe, inlet or 80% of monitoring path [1] (meters)	Horizontal and vertical distance from supporting structures[2] to probe, inlet or 90% of monitoring path[1] (meters)	Distance from trees to probe, inlet or 90% of monitoring path[1] (meters)	Distance from roadways to probe, inlet or monitoring path[1] (meters)
SO_2 [3,4,5,6]	Middle (300 m) Neighborhood Urban, and Regional (1 km).	2–15	> 1	> 10	N/A
CO [4,5,7]	Micro, Middle (300 m), Neighborhood (1 km).	3 ±1/2: 2–15	> 1	> 10	2–10; see Table 7–3 of this section for middle and neighborhood scales.
NO_2, O_3 [3,4,5]	Middle (300 m) Neighborhood, Urban, and Regional (1 km).	2–15	> 1	> 10	See Table 7-3 of this section for all scales.
Ozone precursors (for PAMS) [3,4,5.]	Neighborhood and Urban (1 km)	2–15	> 1	> 10	
PM, Pb [3,4,5,6,8]	Micro: Middle, Neighborhood, Urban and Regional.	2–7 (micro); 2–7 (middle PM10-2.5); 2–15 (all other scales).	> 2 (all scales, horizontal distance only).	> 10 (all scales).	2–10 (micro); see Figure 7.3 of this section for all other scales

N/A—Not applicable.

[1] Monitoring path for open path analyzers is applicable only to middle or neighborhood scale CO monitoring and all applicable scales for monitoring SO_2 ,O_3, O_3 precursors, and NO_2.

[2] When probe is located on a rooftop, this separation distance is in reference to walls, parapets, or penthouses located on roof.

[3] Should be >20 meters from the dripline of tree(s) and must be 10 meters from the dripline when the tree(s) act as an obstruction.

[4] 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 (see text).

[5] Must have unrestricted airflow 270 degrees around the probe or sampler; 180 degrees if the probe is on the side of a building.

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

[7] For microscale CO monitoring sites, the probe must be >10 meters from a street intersection and preferably at a midblock location.

[8] Collocated monitors must be within 4 meters of each other and at least 2 meters apart for flow rates > 200 liters/min and at least 1 meter for flow rates < 200 liters/min .

Table 7-3 Minimum Separation Distance Between Roadways and Sampling Probes or Monitoring Paths at Neighborhood and Urban Scales for O_3 , Oxides of Nitrogen (NO, NO_2, NO_x, NO_y) and CO

Roadway ave. daily traffic vehicles per day	O_3 and Oxides of N Neighborhood & Urban [1](meters)	O_3 and Oxides of N Neighborhood. & Urban [1& 2](meters)	CO Neighborhood (meters)
≤ 1,000	10	10	
10,000	10	20	
≤ 10,000			10
15,000	20	30	25
20,000	30	40	45
30,000			80
40,000	50	60	115
50,000			135
≥ 60,000			150
70,000	100	100	
≥110,000	250	250	

[1] Distance from the edge of the nearest traffic lane. The distance for intermediate traffic counts should be interpolated from the table values based on the actual traffic count.

[2] Applicable for ozone monitors whose placement has not already been approved as of December 18, 2006.

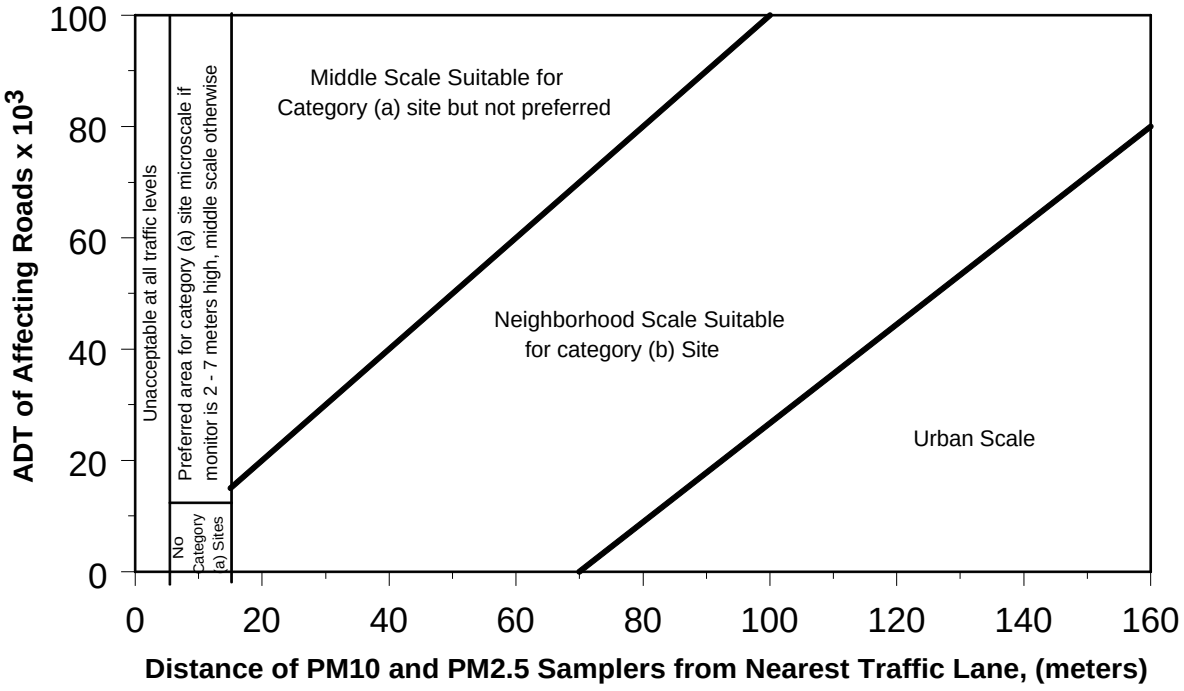

Figure 7.5 Acceptable areas for PM10 and PM2.5 micro, middle, neighborhood, and urban samplers except for microscale street canyon sites.

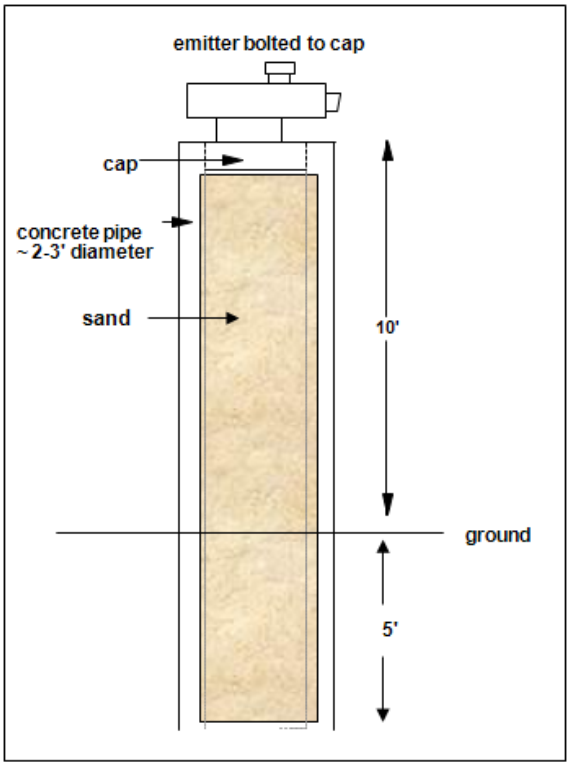

Figure 7.6 Optical mounting platform

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, 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. The 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.

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 7.6. More information on open path monitoring can be found in the following document: *EPA Handbook: Optical Remote Sensing for Measurement and Monitoring of Emissions Flux*[4].

7.3.3 Probe, Tubing and Manifold Maintenance

Figure 7.7 Examples of contaminated tubing and manifolds needing more frequent 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

[4] http://www3.epa.gov/ttn/emc/guidlnd/gd-052.pdf

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. Conduct sample line integrity checks- More and more monitoring organization are performing zero/span/and 1-point QC checks through the probe. This has advantages for testing the integrity of inlet lines and manifolds. This type of testing is encouraged and may help formulate a more efficient cleaning schedule.
3. Establish cleaning/replacement techniques and a schedule. Minimally, an annual cleaning or replacement (i.e., Teflon® lines) is suggested but the monitoring organization needs to gauge whether more frequent cleaning is necessary. 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.
4. Plug the ports on the manifold when sampling lines are detached.
5. 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.
6. Maintain the vacuum in the manifold <0.64 cm water gauge. Keeping the vacuum low will help to prevent the development of leaks.

For monitoring organizations that use individual sampling lines instead of manifolds, one may want to weigh the cost of cleaning lines versus replacing them.

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 air conditioner vents away from analyzers;
- 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 to avoid adsorption and desorption reactions of VOCs 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 that does not increase the sampled air temperature by more than 3-5 degrees C above ambient temperature;
- ensuring the manifold has a moisture trap and that it is emptied often (water traps in sample lines from the manifold to the instruments should be avoided); and
- using water-resistant particulate filters in-line with the instrument.

NOTE: Sample probes or manifolds which capture moisture, dirt, or debris may result in biased data collection, as well as pose a risk to the analyzer, should contaminates enter the instrument. Operators should inspect the condition of sample lines and manifolds to ensure they are clean and condensation-free during each site visit. In some locations, and/or in certain seasons, monitoring agencies may need to increase their cleaning frequencies (see Figure 7.7)

7.4 Reference/Equivalent Methods and Approved Regional Methods

For monitoring in a SLAMS network, either reference or equivalent methods are usually required. This requirement, and any exceptions, are specified in 40 CFR Part 58, Appendix C. 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. 40 CFR Part 58, Appendix A requires 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. 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 particulates and Pb, the reference method for each is a unique manual method that is completely specified in 40 CFR Part 50; all other approved methods for particulates and Pb qualify as equivalent methods. SO_2, has a reference method and a measurement principle. For CO, NO_2, and O_3, Part 50 provides only a measurement principle and calibration procedure applicable to reference methods for these 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. 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 SO_2, CO, NO_2, and O_3. Further information on this subject is in the preamble to 40 CFR Part 53.

Except for the unique reference methods for SO_2, particulates, and Pb specified in 40 CFR Part 50, all reference and equivalent methods must be officially designated as such by EPA under the provisions of 40 CFR Part 53. Notice of each designated method is published in the *Federal Register* at the time of designation. 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 AMTIC[5]. 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 as promulgated in 40 CFR Part 53.9. Monitoring organizations should be aware of the vendor condition.

[5] http://www3.epa.gov/ttn/amtic/criteria.html

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;
- the suitability for the weather and/or geographic conditions at the site;
- analyzer sensitivity and available operating ranges suitable for the site;
- susceptibility to interferences that may be present at the monitoring site;
- requirements for support gases or other equipment;
- reliability;
- past performance and reliability of vendor servicing and equipment replacement
- maintenance requirements;
- initial as well as operating costs;
- features such as internal or fully automatic zero and span checking;
- compatibility to your current and future network, i.e. software and connections (RS 232, Ethernet); and
- manual or automated methods.

Specify the EPA method designation when ordering a new reference or equivalent analyzer.

The required performance specifications, terms of the warranty, time limits for delivery and acceptance testing, and what happens in the event that the analyzer falls short of performance requirements should be documented. Aside from occasional malfunctions, consistent or repeated noncompliance with any of these conditions should be reported to EPA. 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.

FRM/FEM Designated Operating Ranges and the Affect of Span Checks

Although all FRM/FEMs are required to meet the range specified in Table 7-4[6], many instruments are designated for ranges narrower and or broader than the requirement. Table 7-4 are performance specifications for vendors attempting to receive FRM/FEM approvals and should not be confused with QC acceptance criteria for ambient air monitoring discussed in Section 10. During the equipment purchase/selection phase, monitoring organizations should select an instrument with ranges most appropriate to the concentration at the site where the instrument will be established and then use the range that is most appropriate for the monitoring situation. Earlier versions of this Handbook suggested that the concentration of the span checks be 70 – 90% of the analyzers measurement range. Using this guidance and the designated ranges of some of the FRM/FEM method being used, a span check might be selected at a concentration that is never found in the ambient air at the site for which the monitor is operating. The span check concentration should be selected that is more beneficial to the quality control of the routine data at the site and EPA suggests: 1) the selection of an appropriate measurement range, and 2) selecting a

[6] performance specifications can be found in 40 CFR Part 53.23 Table B-1

span that at a minimum is above 120% of the highest NAAQS (for sites used for designation purposes) and above 99% of the routine data over a 3-year period. The multi-point verification/calibrations that are performed annually can be used to challenge the instrument and confirm linearity and calibration slope of the selected calibration scale. Section 10 provides more information on selection of concentrations for span checks as well as other QC checks.

Table 7-4 Performance Specifications for Automated Methods

TABLE B-1 TO SUBPART B OF PART 53—PERFORMANCE LIMIT SPECIFICATIONS FOR AUTOMATED METHODS

Performance parameter	Units[1]	SO_2		O_3	CO		NO_2	Definitions and test procedures
		Std. range[3]	Lower range[2,3]	(Std. range)	Std. range[3]	Lower range[2,3]	(Std. range)	
1. Range	ppm	0-0.5	<0.5	0-0.5	0-50	<50	0-0.5	Sec. 53.23(a).
2. Noise	ppm	0.001	0.0005	0.005	0.2	0.1	0.005	Sec. 53.23(b).
3. Lower detectable limit	ppm	0.002	0.001	0.010	0.4	0.2	0.010	Sec. 53.23(c).
4. Interference equivalent								
Each interferent	ppm	±0.005	[4]±0.005	±0.02	±1.0	±0.5	±0.02	Sec. 53.23(d).
Total, all interferents	ppm	---	---	0.06	---		0.04	Sec. 53.23(d).
5. Zero drift, 12 and 24 hour	ppm	±0.004	±0.002	±0.02	±0.5	±0.3	±0.02	Sec. 53.23(e).
6. Span drift, 24 hour								
20% of upper range limit	Percent	---	---	±20.0	---	---	±20.0	Sec. 53.23(e)
80% of upper range limit	Percent	±3.0	±3.0	±5.0	±2.0	±2.0	±5.0	Sec. 53.23(e).
7. Lag time	Minutes	2	2	20	2.0	2.0	20	Sec. 53.23(e).
8. Rise time	Minutes	2	2	15	2.0	2.0	15	Sec. 53.23(e).
9. Fall time	Minutes	2	2	15	2.0	2.0	15	Sec. 53.23(e).
10. Precision								
20 % of upper range limit	ppm	---	---	0.010	---	---	0.020	Sec. 53.23(e).
	Percent	2	2	---	1.0	1.0	---	Sec. 53.23(e).
80 % of upper range limit	ppm	---	---	0.010	---	---	0.030	Sec. 53.23(e).
	Percent	2	2	---	1.0	1.0	---	Sec. 53.23(e).

1. To convert from parts per million (ppm) to $\mu g/m^3$ at 25 °C and 760 mm Hg, multiply by M/0.02447, where M is the molecular weight of the gas. Percent means percent of the upper measurement range limit.
2. Tests for interference equivalent and lag time do not need to be repeated for any lower range provided the test for the standard range shows that the lower range specification (if applicable) is met for each of these test parameters.
3. For candidate analyzers having automatic or adaptive time constants or smoothing filters, describe their functional nature, and describe and conduct suitable tests to demonstrate their function aspects and verify that performances for calibration, noise, lag, rise, fall times, and precision are within specifications under all applicable conditions. For candidate analyzers with operator-selectable time constants or smoothing filters, conduct calibration, noise, lag, rise, fall times, and precision tests at the highest and lowest settings that are to be included in the FRM or FEM designation.
4. For nitric oxide interference for the SO_2 UVF method, interference equivalent is ±0.0003 ppm for the lower range.

$PM_{2.5}$ 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 40 CFR Part 50, Appendix L. 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) or a multiple filter capability (sequential) 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 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. To minimize the difficulty of meeting equivalent method designation requirements, three classes of equivalent methods have been established in the 40 CFR Part 53 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.

Approved Regional Methods (ARM)

There are some continuous $PM_{2.5}$ methods that currently may not be able to meet the national FRM and FEM designation criteria. However, these methods may operate at acceptable levels of data quality in certain regions of the country or under certain conditions. The EPA has expanded the use of alternative $PM_{2.5}$ measurement methods through ARMs. A method for $PM_{2.5}$ that has not been designated as an FRM or FEM as defined in 40 CFR Part 50.1 may be approved as an ARM. If a monitoring organization feels that a particular method may be suitable for use in its network, it can apply for the method to be designated as an ARM. The following provides a summary of the ARM requirements.

$PM_{2.5}$ ARM Criteria Summary

1. Must meet Class III Equivalency Criteria
    - Precision
    - Correlation
    - Additive and multiplicative bias
2. Tested at site(s) where it will be used
    - 1 site in each MSA/CMSA up to the first 2 highest pop MSA/CMSA
    - 1 site in rural area or Micropolitan Statistical Area
    - Total of 3

If the ARM has been approved by another agency then:

- 1 site in MSA/CMSA and 1 site in rural area or Micropolitan Statistical Area
- Total of 2

3. 1 year of testing, all seasons covered
    - 90 valid sample pairs per site with at least 20 valid sample pairs per season.
    - Values < 3 ug/m^3 may be excluded in bias estimates but this does not affect completeness criteria.
4. Collocation to establish precision not required
    - Peer-reviewed published literature or data in AQS that can be presented is enough
5. ARM must be operated on an hourly sampling frequency providing for aggregation into 24-hour average measurements.
6. Must use approved inlet and separation devices (Part 50 Appendix L or FEM Part 53)
    - Exception –methods that by their inherent measurement principle may not need an inlet or separation device.
7. Must be capable of providing for flow audits
    - Exception –methods that by their inherent measurement principle measured flow is not required.
8. Monitoring agency must develop and implement appropriate procedures for assessing and reporting precision and bias.

Routine Monitoring Implementation

9. Collocation of ARM and FRM/FEM at 30% of SLAMS network or at least 1/network
    - 1-in-6 day sampling frequency
    - Located at design value site among the largest MSA/CMSA
    - Collocated FRM/FEM can be substituted for ARM, if ARM is invalidated
10. Collocation ARM with ARM
    - 7.5% of sites or at least 1 site
11. Bias assessment (PEP)
    - Same frequency as Appendix A

ARM Approval

1. New ARM- EPA NERL, RTP, NC
2. ARM that has been approved by another agency- EPA Regional Administrator

8.0 Sample Handling and Custody

A critical activity within any data collection phase involving physical samples is the handling of sample media prior to sampling, during preparation, handling/transporting sample media to the field, handling samples in the field at the time of collection, storage of samples (in the field or other locations), transport of samples from the field site, and the analysis of the samples. Documentation ensuring that proper handling has occurred throughout these activities is part of the custody record. This documentation initially comes in the form of a written sample handling and custody procedure and then in the development, use, and archiving of field and laboratory notebooks and chain of custody forms and electronic media (e.g., barcode data or e-logbooks).

Chain of Custody is a legal term that refers to the ability to guarantee the identity and integrity of the sample (or data) from collection through final reporting of results. Custody records document this "chain"-- providing the necessary record of the date and person(s) responsible for the various sample handling steps associated with each sample, as well as the information that acknowledges that sample integrity remained intact. Custody records also provide a reviewable trail for quality assurance purposes and can be used as evidence in legal proceedings.

Prior to the start of an EDO, the various types of samples should be identified and the following questions asked:

- Does the sample need to be analyzed within a specified time period?
- What modes of sample transport are necessary and how secure should they be?
- What happens if a sample is collected on Friday? Is the sample shipped for a weekend delivery, or stored at the field office (awaiting weekday delivery)? What are the appropriate custody procedures under these scenarios?
- Can the sample's integrity be affected by outside influences (e.g. temperature, pressure, humidity, jostling/dropping during shipment), and do these need to be monitored (e.g., max/min thermometers, pressure sensors)?
- How critical is it that sample integrity be known (e.g., is evidence tape necessary)?
- How can it be documented that sample integrity was maintained from the collection to reporting?
- What are the procedures when sample integrity is compromised (e.g., flag, don't analyze)?

These are some of the questions that should be answered and documented in the monitoring organization's QAPP and chain of custody procedures.

This section specifically addresses the handling and custody of physical environmental samples (e.g., exposed filters for particulate matter or lead (PM or Pb) determinations and canisters containing whole air samples) that are collected at a field location and transported to a laboratory for analysis. For specific details of sample handling and custody (i.e., PAMS, NATTS, CSN etc), the monitoring organization should consult the appropriate technical assistance documents located in the National Program summaries in Appendix A of this Handbook.

In addition to physical samples, some types of field data collected in hard copy (e.g., strip charts, sampler flow data, etc.) or electronic (e.g., data downloaded from a data logger with limited storage space or barcodes) format are irreplaceable and represent primary information about physical samples or on-site measurements that are needed to report a final result. When such hard copy or electronic data are transported and/or change custody, it is advised that the same chain of custody practices described in this

section for physical samples be employed to ensure that irreplaceable data can be tracked and are not altered or tampered with.

For additional information, an EPA on-line self-instructional course, "*Chain-of-Custody Procedures for Samples and Data (APTI SI:303)*[1]" is available for review.

Laboratory Information Management Systems

A laboratory information management system (LIMS) is a computer system used in the laboratory for the management and tracking of samples, instruments, standards and other laboratory functions such as data reductions, data transfer and reporting. The goal is to create an EDO where:

- Instruments used are integrated in the lab network; receive instructions and worklists from the LIMS and return finished results, including raw data, back to a central repository where the LIMS can update relevant information to external systems (i.e., AIRNow or AQS).
- Lab personnel will review/check calculations, documentation, and results using online information from connected instruments, reference databases, and other resources using electronic lab notebooks connected to the LIMS.
- Management can supervise the lab process, react to bottlenecks in workflow, and ensure regulatory demands are met.
- External participants can review results and print out analysis certificates and other documentation (QA Reports, quality control charts, outlier reports, etc.).

For monitoring programs that are fairly stable, such as criteria pollutant monitoring, development of a LIMS system may be very cost effective and should be considered. There is an upfront cost in the development of these systems, but monitoring organizations that have devoted resources to their development have seen pay offs in improved data quality, sample tracking, and data reporting.

8.1 Sample Handling

In the Ambient Air Quality Monitoring Program, discrete samples from manual methods associated with SLAMS, PAMS, NATTS, and other networks, are physically handled prior to analysis. One must pay particular attention to the handling of filters for particulate matter and lead since it has been suggested that the process of filter handling may be the largest source of measurement error (especially low-volume methods). 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 that should be documented in a QAPP and SOP include:

- sample preparation, labeling, and identification;
- sample collection;
- transportation;
- sample analysis; and
- storage (at all stages of use) and archival.

[1] http://www.apti-learn.net/LMS/register/EPALearning.aspx?t=0

8.1.1 Sample Preparation, Labeling and Identification

Sample containers should be cleaned and filters prepared (e.g., pre-weighing of filters), before being used to collect samples. SOPs should indicate the proper care and handling of the containers/filters to ensure their integrity. Proper lab documentation that tracks the disposition of containers/filters through preparation is just as important as the documentation after sampling. Care must be taken to properly mark all samples to ensure positive, unambiguous identification throughout sample collection, handling, and analysis procedures. Figure 8.1 shows a standardized identification sticker that may be used to label physical samples. Additional information may be added as required, depending on the particular monitoring program. 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. Any information that can be used to assess sample integrity, such as the pressure of canisters or cooler temperature, should be recorded at the time of sample collection. Canister pressure or cooler temperature can then be reviewed at another stage in the analytical process to confirm sample integrity.

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 (e.g., bar coding), if they provide a positive means of identification and do not impair the capacity of the filter to function.

(Name of Sampling Organization)

Sample ID No: _____ Storage Conditions: _____

Sample Type:_____ Site Name:_____

Date/Time Collected: _____ Site Address:_____

Sampler:_____

Figure 8.1 Example Sample Label.

8.1.2 Sample Collection

The sample collection phase includes transporting the sampling material (e.g., sample filters, canisters) to the sampling site, setting up the samplers to run, and then collecting the samples for transport to the laboratory. This section does not cover proper installation of sampling media in a sampler/monitor; although very important, such information is specific to individual sampler types and should, therefore, be covered in detail in applicable SOPs. Custody procedures may start prior to sampling if there are specific timeframes when the sampling media must be used (e.g.,30-day filter use for $PM_{2.5}$ filters). Therefore, custody forms may start from the laboratory that prepared the sample media and care must be taken to review and ensure the sample media is viable for use.

Sometimes the specific sample media (e.g., specific filter ID) has been identified to a particular sampler at the office or laboratory rather than at the sampling site. If the site operator is setting up a number of samplers at one site or at a number of sites, it is very important the sample media and the chain of custody data are carefully checked to ensure: 1) the chain of custody matches the sample media ID, and 2) the sample media is used at the correct site and in the correct sampler.

To reduce the possibility of invalidating the results, all collected samples must be carefully removed from the monitoring device, placed in labeled, nonreactive containers, and sealed. Use of tamper-evident custody seals are suggested and may be required in certain cases. The sample label must adhere firmly to the container to ensure that it cannot be accidentally removed. Custody seals on sample containers serve two purposes: to prevent accidental opening of the sample container and to provide visual evidence should the container be opened or tampered with. The best type of custody seal depends on the sample container: often, a piece of tape placed across the seal and signed by the operating technician is sufficient; for other containers, wire locks or tie wraps may be the best choice. In some cases, the opening of sample containers by unauthorized personnel, such as Transportation Security Administration officers, cannot be avoided. The proper use of custody seals minimizes the loss of samples and provides direct evidence whether sample containers have been opened and possibly compromised. Samples whose integrity is questioned should be qualified (flagged).

8.1.3 Sample Transportation

Samples should be delivered to the laboratory for analysis as soon as possible following sample collection. 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 transport containers (e.g., carrying case, cooler, shipping box, etc.) for protection from breakage, contamination, and loss and in an appropriate controlled-temperature device (i.e., refrigerator or freezer), if the samples have specific temperature requirements. Each transport container should have unique identification, such as sampling location, date, and transport container number (e.g., number 2 of 5) to avoid interchange and aid in tracking the complete shipment. The number of the transport containers should be subsequently recorded on the chain of custody (COC) form (described in Section 8.2) along with the sample identification numbers of the samples included within each transport container. It is advised that the container be sealed using an appropriate tamper-evident method, such as with custody tape or a wire lock.

In transporting samples, it is important that precautions be taken to eliminate the possibility of tampering, accidental destruction, and/or physical and chemical action on the sample. The integrity of samples can be affected by 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 organization's QAPP and site specific SOPs.

The person who has custody of the samples 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 with restricted access.

8.1.4 Sample Analysis

SOPs, if properly developed, have detailed information on the handling of samples at the analysis phase. Similar to the preparation step, if the sample undergoes a number of steps (preparation, equilibration, extraction, dilution, analysis, etc.), and these steps are performed by different individuals, there should be a mechanism in place to track the sample through the steps to ensure SOPs are followed and the integrity of the sample maintained. Laboratories should make extensive use of laboratory notebooks at the various steps (stations) of the analytical process to record the sample handling process and maintain sample integrity.

8.1.5 Storage and Archival

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, whenever samples are not under the direct control of the sample custodian, they should be kept in a secured location. This may be a locked vehicle, locked refrigerator, or locked laboratory with limited access. 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 on the COC form or in a laboratory notebook, indicating the storage location and conditions. Any samples not destroyed during the analysis process (e.g., exposed filters for PM) should be archived as directed by the method requirements or applicable QAPP. 40 CFR Part 58.16 requires PM_{10}, $PM_{10-2.5}$ and $PM_{2.5}$ filters from SLAMS manual low-volume samplers (i.e., samplers having flow rates less than 200 liters/minute) to be archived for 5 years from collection and archived the first year in cold conditions (i.e., at 0-4° C). It is also suggested that non-destructive lead analysis and CSN samples follow this guidance.

8.2 Chain of Custody (COC)

Chain of custody is the unbroken trail of accountability that verifies the physical security of environmental samples and documented information[2]. In order to use the results of a sampling program as evidence, a written record must be available listing the location of the samples at all times. This is also an important component of good laboratory practices[3]. The COC record is necessary to legally demonstrate that the integrity of samples have been maintained. Without it, one cannot be sure that the samples and sampling data analyzed were the same as the samples and data reported to have been taken at a particular time. Procedures may vary, but an actual COC record sheet with the names and signatures of the relinquishers/receivers works well for tracking physical samples. The samples should be handled only by persons associated in some way with the monitoring 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 must be able to state from whom and when the item was received and to whom and when it was delivered. A COC form should be used to track the handling of the samples through various stages of storage, processing, and analysis at the laboratory. It is recommended practice to have each person who relinquishes or receives samples sign the COC form for the samples. An example of a form that may be used to establish the COC for samples generated in the field is shown in Figure 8.2. This form should accompany the samples at all times from the field to the laboratory. All persons who handle the samples should sign the form. Some organization may want to use the forms to provide additional information about sample load or collection dates. Although this not the primary intent of the COC forms, they can serve more than one purpose and so the forms can be developed to accommodate multiple needs. Figure 8.3 is an example of a laboratory COC form. COC forms should be retained and archived as described in Section 5 (Documents and Records).

When using professional services to transport physical samples, only reliable services that provide a tracking number should be used. Information describing the enclosed samples should be placed on the bill of lading. A copy of the shipping receipt and tracking number should be kept as a record. The package

[2] ASQ/ANSI E4:2014
[3] http://www.epa.gov/compliance/good-laboratory-practices-standards-compliance-monitoring-program

should be addressed to the specific person authorized to receive the package, although it is recognized that staff not typically part of the COC may receive the samples and deliver them to the authorized addressee. A procedure must be in place to ensure that samples are delivered to the appropriate person without being opened or damaged. In this circumstance, the sample is considered still in transport until received by the authorized addressee. It may be necessary to ship and/or receive samples outside of normal business hours. A procedure should be developed in advance that considers staff availability, secure storage locations, and appropriate storage conditions (temperature-controlled, e.g.).

8.2.1 Sample Inspection and Acceptance

Once the samples arrive at their destination, and at every custody change, the samples should first be checked to ensure that their integrity is intact. The contents of the shipment should be checked against the COC form to ensure that all samples listed were included in the shipment. If max/min thermometers are used to monitor the temperature of the shipping containers, this information should be recorded to document that temperatures were adequately maintained. When using passivated stainless steel canisters, the canister pressure, upon receipt, should be recorded and later compared to the final sample collection pressure in order to determine any canister leakage and/or sample loss. It is recommended that this comparison be made using a certified gauge that is calibrated annually. Any samples whose integrity or identity may be questionable should be brought to the attention of the person/persons that are in the custody chain and subsequently flagged. All flags should be "carried" along with the samples until the validity of the samples can be proven. This information can be included in the remark section of the COC form.

Chain of Custody Record					
Project No.		**Project Title**			
					Organization
Shipping Container No.					**Contact**
Field Technician: *print*		*signature*			**Address**
Date	**Time**	**Site/Location**	**Sample Type**	**Sample ID**	**Remarks**
Relinquished by (*print and signature*):			Received by (*print and signature*):		**Comments**

Figure 8.2 Example Field COC Form.

Chain of Custody Record					
Project No.		**Project Title**			**Organization**
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 COC Form.

9.0 Analytical Methods

The choice of methods used for any environmental data operation should be based upon the program's data quality objectives (DQOs). Outputs from the DQO process can help determine acceptable measurement uncertainty and assist in the selection of methods capable of meeting the data quality acceptance limits. 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 in the various technical assistance documents for the other national ambient air programs, this section will discuss the general concepts of standard operating procedures and good laboratory practices as they relate to the reference and equivalent methods. A more detailed discussion on the attributes of SOPs can be found in Section 5.

Many ambient air methods utilize continuous instruments and therefore do not involve laboratory analysis. However, particulate matter methods involve both continuous and manual methods, and some of the other major monitoring programs involve sampling which requires the use of laboratory analysis. Table 9-1 provides a summary of the pollutants measured and the analytical methods for these programs. For the SLAMS Network pollutants, the methods listed are considered the reference methods and are not the only methods available for use. Federal equivalent methods are available and posted, once approved, on AMTIC and are considered an acceptable alternative to the reference method. Information on reference and equivalent methods can be found on the AMTIC website, as well as the current list of designated Federal Reference and Equivalent Methods[1]. CSN[2] and NATTS[3] SOPs are also on AMTIC.

Table 9-1 Acceptable Analytical Methods

Network	Pollutant	Acceptable Method	Reference
SLAMS	PM_{10} – Hi-Vol	Gravimetric	40 CFR Part 50 App J
SLAMS	PM_{10}- dichot	Gravimetric	40 CFR Part 50 App J
SLAMS	PM_{10} – Low-Vol	Gravimetric	40 CFR Part 50 App O
SLAMS	$PM_{2.5}$	Gravimetric	40 CFR Part 50 App L
SLAMS	$PM_{10-2.5}$	Gravimetric- difference	40 CFR Part 50 App O
SLAMS	Pb from TSP	Inductively Coupled Plasma /Mass Spectrometry (ICP/MS)	40 CFR Part 50 App G
SLAMS	Pb from PM10	Energy Dispersive X-Ray Fluorescence (EDXRF)	40 CFR Part 50 App Q
PAMS	VOCs	Gas Chromatography/Mass Spectrometry (GC/MS)	TO-15
PAMS	Carbonyl compounds	High Performance Liquid Chromatography (HPLC)	TO11-A
PAMS	Non-methane organic compounds	Cryogenic Preconcentration and Direct Flame Ionization Detection (PDFID)	TO-12
NATTS	Metals	Inductively Coupled Plasma (ICP)	IO 3.5
NATTS	Aldehydes	High Performance Liquid Chromatography	TO11-A
NATTS	VOCs	Gas Chromatography/Mass Spectrometry (GC/MS)	TO-15
CSN	$PM_{2.5}$	Gravimetric	40 CFR Part 50 App L
CSN	Elements	Energy Dispersive X-Ray Fluorescence (EDXRF)	CSN QAPP and SOPs
CSN	Anions	Ion Chromatography	CSN QAPP and SOPs
CSN	Cations	Ion Chromatography	CSN QAPP and SOPs
CSN	Organic, Elemental, Carbonate, Total Carbon	Thermal Optical Reflectance (IMPROVE_A)	CSN QAPP and SOPs
CSN	Semi-volatile Organic Compounds	Gas Chromatography/Mass Spectrometry (GC/MS)	CSN QAPP and SOPs

[1] http://www3.epa.gov/ttn/amtic/criteria.html
[2] http://www3.epa.gov/ttn/amtic/specsop.html
[3] http://www3.epa.gov/ttn/amtic/airtox.html

The SLAMS network provides more rigorous quality control requirements for the analytical methods. These methods are found in 40 CFR Part 50, as described in the Table 9-1 references. Monitoring organizations need to ensure that the instruments are operated in a manner consistent with the Part 50 methods including any technical memo on AMTIC that might provide an alternative to the current CFR method. In addition, the method identified for Pb is the reference method. There are a number of equivalent analytical methods that are available for the Pb[4]. Some of the NATTS methods are derived from the Toxics Organic Method Compendium[5]. Others, like the CSN Network[6] may be developed specifically for the program, based on the national laboratory currently performing the analysis. The PAMS, NATTS, and CSN networks follow the performance-based measurement process paradigm. These networks' QA project plans or technical assistance documents suggest a method, but also allow some flexibility to use other methods that meet the network's measurement quality objectives. Various, independent proficiency test samples and technical systems audits are performed to ensure that the data quality within these networks remain acceptable.

AQS Parameter and Method Codes --

Most monitoring information is reported to the Air Quality System (AQS). The pollutant measured is called a "parameter" and the specific method used is designated as the "method code". AQS provides a website that can assist in identifying the correct method code for data reporting[7]. Any approved reference or equivalent method listed on the AMTIC website has a reference or equivalent method number. An example of an approved reference sampler is the BGI sampler listed below. This sampler can be used by the Parameter Code "88101" ($PM_{2.5}$ local conditions) and is associated with the method code "116". The method code is usually the last three digits of the designated reference (listed as RFPS) or equivalent method (listed as EQPM).

> ***BGI Inc. Models PQ200 or PQ200A $PM_{2.5}$ Ambient Fine Particle Sampler***
> **Manual Reference Method: RFPS-0498-116**
> "BGI Incorporated Models PQ200 and PQ200A $PM_{2.5}$ Ambient Fine Particle Sampler," operated with firmware version 3.88 or 3.89R, for 24-hour continuous sample periods, in accordance with the Model PQ200/PQ200A Instruction Manual and with the requirements and sample collection filters specified in 40 CFR Part 50, Appendix L, and with or without the optional Solar Power Supply or the optional dual-filter cassette (P/N F-21/6) and associated lower impactor housing (P/N B2027), where the upper filter is used for $PM_{2.5}$. The Model PQ200A is described as a portable audit sampler and includes a set of three carrying cases.
> ***Federal Register: Vol. 63, page 18911, 04/16/98***

In 2011, as the NCore network was deploying and with the need for more sensitive equipment for monitoring at lower concentration ranges, instrument manufactures started providing more sensitive trace gas equipment. Methods codes in AQS starting at 500 represent these trace gas monitors. In addition, when reporting NO2 from a NOy analyzer, the first character in the three character AQS method code has changed to "6".

[4] https://www3.epa.gov/ttn/amtic/pb-monitoring.html
[5] https://www3.epa.gov/ttn/amtic/airtox.html
[6] https://www3.epa.gov/ttn/amtic/specsop.html
[7] https://www.epa.gov/aqs/aqs-code-list

9.1 Good Laboratory Practices

Good laboratory practices (GLPs)[8] 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. In many cases, the activities mentioned above may not be formally documented because they are considered common knowledge. However, for consistency in laboratory technique, these activities should have some form of documentation.

9.2 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), properly documented, and received peer and management review.
4. Complete and accurate records must be kept (Section 5).

It is assumed that at some frequency the laboratory would be audited by an independent part of the monitoring organization or external entity (e.g., EPA Regions), and that audit would serve to document that the basic requirements were being met.

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 for lead, particulate matter (PM and CSN), NATTS[9], and PAMS[10] (VOCs). However, many laboratories also prepare reference materials, 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.

[8] https://www.epa.gov/compliance/good-laboratory-practices-standards-compliance-monitoring-program

[9] http://www.epa.gov/ttn/amtic/airtox.html
[10] http://www.epa.gov/ttn/amtic/files/ambient/pams/newtad.pdf

10.0 Quality Control

As described in Section 3, any data collection process that provides an estimate of a concentration contains two types of uncertainty: population (spatial/temporal variability) and measurement uncertainty. DQOs define the data quality needed to make a correct decision an acceptable percentage of the time.

Measurement quality objectives (MQOs) identify the **quality control samples** and the acceptance criteria for those samples that will allow one to quantify the data quality indicators: precision, bias, representativeness, detection limit, completeness, and comparability. The MQOs 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.

Data quality assessment (DQAs) is the scientific and statistical evaluation of environmental data to determine if they meet the planning objectives of the project, and thus are of the right type, quality, and quantity to support their intended use[1]. DQA is built on a fundamental premise: *data quality* is meaningful only when it relates to the *intended use* of the data, which in many cases stem from the DQOs. DQAs can be used to determine whether modifications to the DQOs are necessary, or "tighter" quality control is required.

10.1 The Quality Control Process

Within any phase or step of the data collection process, errors can occur. For example:

- samples and filters can be mislabeled;
- data can be transcribed or reported incorrectly or information management systems can be programmed incorrectly;
- calibration or check standards can be contaminated or certified incorrectly, resulting in faulty calibrations;
- instruments can be set up improperly or over time fail to operate within specifications; and
- SOPs may not be followed.

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[2]. Quality control includes establishing specifications or acceptance criteria for each quality characteristic of the monitoring/analytical process, assessing procedures used in the monitoring/analytical process to determine conformance to these specifications, and taking any necessary corrective actions to bring them into conformance. The EPA's QAPP guidance

[1] https://www.epa.gov/quality/agency-wide-quality-system-documents
[2] American Nation Standard ANSI/ASQ E4-2014 http://www.asq.org/

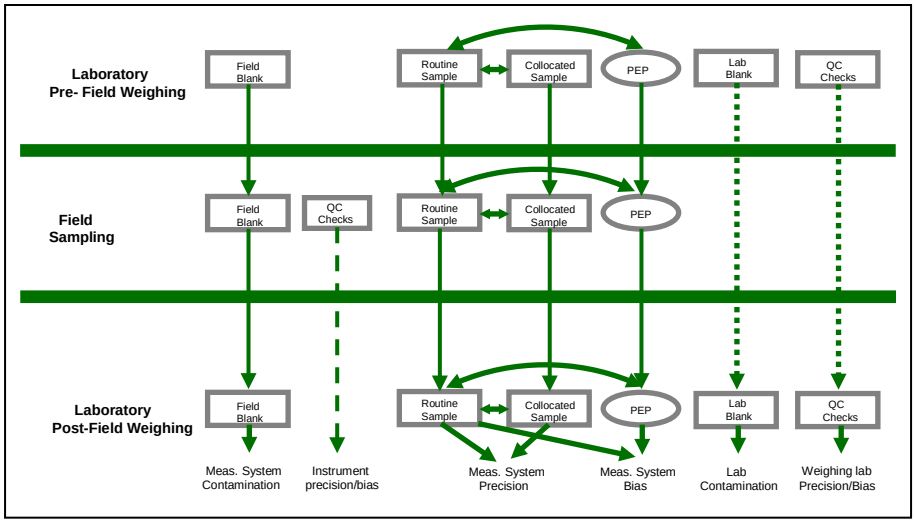

Figure 10.1 QC samples for $PM_{2.5}$ placed at various stages of measurement process

document QA/G5[3] suggests that "QC activities are those technical activities routinely performed, not to eliminate or minimize errors, but to measure their effect". The effect of an error, such as lab contamination leading to high $PM_{2.5}$ values, might lead to incorrectly concluding a site was in non-attainment. Although there is agreement that the measurement or assessment of a QC check does not itself eliminate errors, the QC data can and should be used to take appropriate corrective actions which can minimize error or control data to an acceptable level of quality in the future. So, QC is both proactive and corrective. It establishes techniques to determine if field and lab procedures are producing acceptable data and identifies actions to correct unacceptable performance.

The goal of quality control is to provide a reasonable level of checking at various stages of the data collection process to ensure that data quality is maintained, and if it is found that the quality has not been maintained, that it is discovered with a minimal loss of data (invalidation). Figure 10.1 provides an example of some of the QC samples used in the $PM_{2.5}$ data collection process. The figure also identifies what sources of error are associated with the QC sample. So, in developing a quality control strategy, one must weigh the costs associated with quality control against the risks of data loss.

With the objective to minimize data loss, quality control data are most beneficial when they are assessed as soon as they are collected. Therefore, information management systems can play a very important role in reviewing QC data and flagging or identifying spurious data for further review. These information management procedures can help the technical staff review the QC checks coming from a number of monitoring sites in a consistent and time efficient manner. There are many graphical techniques (e.g., control charts and outlier checks) that can be employed to quickly identify suspect data. More details of information management systems are discussed later in this section. It is the responsibility of the monitoring organization, through the development of its QAPP, policies and procedures, to develop and document the:

- QC techniques;
- frequency of the QC checks and the point in the measurement process that the check is introduced;
- traceability of QC standards;
- matrix of the check sample;
- appropriate test concentrations;
- actions to be taken in the event that a QC check identifies a failed or changed measurement

[3] http://www.epa.gov/quality/qa_docs.html

system (e.g., data invalidation);
- formulae for estimating data quality indicators;
- QC results, including control charts; and
- the means by which the QC data will be used to determine that the measurement performance is acceptable.

10.2 QC Activity Areas

For air monitoring projects, the following three areas must have established QC activities, procedures and criteria:

1. Data collection.
2. Data management and the verification and validation process.
3. Reference materials (check standards).

Data collection includes any process involved in acquiring a concentration or value, including but not limited to: sample preparation, field sampling, sample transportation, field analytical (continuous) methods, and laboratory preparation/analytical processes. Depending on the importance of the data and resources available, monitoring programs can implement QC samples, as illustrated in Figure 10.1, to identify the errors occurring at various phases of monitoring process. Many of the QC samples can identify errors from more than one phase. Table 10-1 provides a list of the majority of the QC samples utilized in the ambient air program and include both their primary (double check √√) and secondary uses (single √) in error identification. Many of these checks are required in CFR; others are strongly suggested in the method guidance. The MQO/validation templates described in Appendix D provide the minimum requirements for the frequency that these checks be implemented, but many monitoring organizations choose more frequent checking in order to reduce the risk of data invalidation. A good example of this increased effort is the zero/span and one-point precision checks for the gaseous criteria pollutants. Although CFR requires the check to be performed once every two weeks, due to the advent of more sophisticated automated monitoring systems, many monitoring organizations perform these checks every 24-hours (for example, every night from 11:45 PM – 12:15 AM). In addition, once the QC checks are developed for a particular monitoring method, it is important to identify the acceptance criteria and what corrective action will be taken once a QC check fails.

The MQO/validation templates in Appendix D can be used to list the QC samples with a column added to include corrective action. Table 10-2 provides an example[4] of a QC Sample Table for $PM_{2.5}$. Such a table, modified by each individual agency to reflect their corrective action and QC review system, can be used as a basis for documenting data review and validation. Although the validation templates provide guidance for when data should be invalidated, it is up to the monitoring organization to provide the specific corrective actions for the failure of a specific QC check item; therefore, Table 10-2 does not identify specific corrective actions.

Data management quality control is discussed in more detail in Section 14 and in the verification/validation process described in Section 17. Automated verification/validation processes require some frequency of checking to ensure that they are performed correctly since errors in programming can cause persistent errors for long periods of time. At times new versions of software can

[4] The table is considered an example because acceptance values in this table may change. The reader should refer to the validation templates on AMTIC for the most current acceptance criteria.

cause programs that worked properly in the past to falter. Providing QC checks to software to ensure they operate properly is strongly suggested. For example, a simple test to challenge the software would be to enter a data set that has known errors of which the software's program(s) would be expected to identify; the success of this challenge/test (or lack thereof) is an indicator of the software's reliability.

Reference materials are the standards against which many of the QC checks are performed. Reference material can be gaseous standards as well as other devices (e.g., flow rate standards). If these standards are not checked and verified as to their certified values, then the quality of data becomes suspect. Reference materials need to be certified and recertified at acceptable frequencies in order to maintain the integrity of the reference material. It is suggested that standards be certified annually. More discussion on standards is included in Section 12.

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 the procedures for QC sample preparation and handling;
- **Sampling Method Requirements -** which include following the QC requirements of the reference methods found in 40 CFR Part 50, and for determining if the collected samples accurately represent the population of interest (representativeness);
- **Sample Handling and Custody Requirements** - which discuss 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 include 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 1-point QC check, performance evaluation or multi-point verification).

10.3 Internal vs. External Quality Control

Quality control can be separated into 2 major categories: internal QC and external QC. Both types of quality control are important in a well implemented quality system.

Internal –Most quality control activities take place internally, meaning the monitoring organization responsible for collecting the data develops and implements the quality control activities, evaluates the data, and takes corrective action when necessary. The internal activities can be used to take immediate action if data appear to be out of acceptance.

External QC – External quality control can be implemented as an audit with external/independent devices or through the submission of samples of two types: "double-blind", meaning the QC sample is not known (looks like a routine sample) and therefore its concentration is unknown; or "single-blind", meaning the sample is known to be a QC sample, but its concentration is unknown to the person or organization performing the measurement. These samples are also called performance evaluation or proficiency test samples and are further explained in Section 15. External QC may identify errors occurring in internal QC activities. For example, an external flow rate audit may identify an internal flow rate verification standard that is out of calibration. Because these checks are performed by external organizations, the results may not always be immediately available and therefore have a diminished capacity to control data quality in "real-time." However, they are useful as an objective test of the

internal QC procedures and may identify errors (i.e., biased or contaminated standards) that might go unnoticed in an internal QC system.

Table 10-1 QC Samples Used in Various Ambient Air Monitoring Programs

Data Quality Indicator	QC Check and QC Sample	Sources of Measurement Error										Purpose
		Sample Collection				Sample Transport	Field (continuous)/Laboratory Analytical Method					To evaluate or determine the source of measurement error arising from:
		Sampling Equipment	Conditions During Sampling	Preservation Technique	Sampling Matrix	Shipment Process	Sample Storage	Sample Preparation Reagents	Sample Preparation	Analytical Methods Reagents/ Standards	Analytical Equipment	
Accuracy/Bias Positive or negative bias primarily due to contamination. (could also be due to operator error)	Lot Blank								✓✓			Filters that have not equilibrated
	Exposure Lot Blanks								✓✓	✓	✓	A batch of filters that have not equilibrated
	Laboratory Blanks						✓✓	✓✓	✓✓	✓✓	✓✓	Ambient contamination arising within laboratory or balance not operating
	Trip Blanks					✓✓	✓	✓	✓	✓	✓	Contamination from shipping and/or lab
	Field Blanks	✓✓	✓✓	✓✓		✓	✓	✓	✓	✓	✓	Ambient contamination from field activities sampling equipment, shipping and/or lab
	Reagent Blank			✓✓				✓	✓	✓	✓	Contamination introduced by reagents used in sample preparation/preservation
	Equipment Blank (Rinsate Blank)	✓✓		✓		✓	✓	✓✓	✓✓	✓✓	✓✓	Carryover contamination resulting from successive use of sampling equipment
Accuracy/Bias Due to sample matrix or sample preparation/ analytical methodology	Matrix Spike				✓✓			✓	✓	✓	✓	Preparation/analytical bias for specific compounds in sample matrices
	Surrogate Spike				✓✓			✓	✓	✓	✓	Preparation/analytical bias for specific sample matrices
	Lab Control Samples							✓✓	✓✓	✓✓	✓✓	Labs ability to accurately identify and quantify target compounds
Accuracy/Bias Due to inadequate temp. control	Cooler Temp Check			✓✓		✓✓	✓✓					High temperatures causing volatilization affecting mass concentration
	Temp Verifications	✓✓					✓✓				✓✓	Sampler, sample storage, or laboratory prep facility problems
Accuracy/Bias Primarily due to equipment malfunction or not properly calibrated and/or operator error	Balance Check										✓✓	Analytical balance precision and stability
	Flow Rate Verifications/Audits										✓✓	Equipment not operating within specific parameters
	Humidity Verifications	✓✓							✓✓		✓✓	Laboratories inability to have an adequate measurement environment
	Pressure Verifications	✓✓										Sampler malfunction
	Leak Checks	✓✓										Sampler malfunction
	Timer Verifications	✓✓										Sampler malfunction
	Zero/Span								✓	✓	✓✓	Analyzer out of calibration or bad standards
Precision/Bias	One-Point QC Check								✓	✓	✓✓	Analyzer out of calibration or bad standards
Precision	Collocated Samples	✓✓	✓	✓	✓✓	✓	✓	✓	✓	✓	✓	Cumulative effects of both field & lab precision to measure overall precision
	Field Duplicates	✓	✓	✓	✓✓	✓	✓	✓	✓	✓	✓	Cumulative effects of both field & lab precision to measure overall precision
	Sample/Analytical Replicate										✓✓	Filters not equilibrating, incorrect weighing procedure or balance problems
	Standard Certifications	✓✓								✓✓	✓✓	Contaminated Reagents/Standards
	Calibrations	✓✓								✓✓	✓✓	Sampling analytical equipment bias or drift
Accuracy/Bias	Round Robins								✓✓	✓✓	✓✓	Overall sampling/analysis process
	Proficiency Tests								✓✓	✓✓	✓✓	Overall sampling/analysis process
Bias	PEP	✓✓		✓		✓	✓		✓✓	✓✓	✓✓	Overall sampling/analysis process
	NPAP									✓✓	✓✓	Overall sampling/analysis process
Sensitivity	MDL Studies							✓✓	✓✓	✓✓	✓✓	

Table 10-2 $PM_{2.5}$ Field and Lab QC Checks. EXAMPLE Since QC can change over time (see Validation Templates)

Requirement	Frequency	Acceptance Criteria	Corrective Action
Field QC Checks			
Calibration Standard Recertifications			
Flow Rate Transfer Std.	1/yr	<±2.1% of NIST-traceable Std.	
Field Thermometer	1/yr	± 0.1° C resolution ± 0.5°C accuracy	
Field Barometer	1/yr	± 1 mm Hg resolution ± 5 mm Hg accuracy	
Verification/ Calibration			
Flow Rate (FR) Calibration	1/yr, or if multi-point failure	<± 4.1% of transfer standard	
One point FR verification	1/mo	<± 4.1% of transfer standard	
External Leak Check	every 5 sampling events	<80.1 mL/min (or equivalent)	
Temperature Calibration	If multi-point failure	<± 2.1°C of standard	
Temp multi-point verification	on installation, then 1/yr	<± 2.1°C of standard	
One- point temp Verification	1/mo	<± 2.1°C of standard	
Pressure Calibration	on installation, then 1/yr	<±10.1 mm Hg	
Pressure Verification	1/mo	<±10.1 mm Hg	
Clock/timer Verification	1/mo	1 min/mo	
Blanks			
Field Blanks	See 2.12 reference	<±30.1 µg	
Precision Checks			
Collocated samples	every 12 days	CV < 10.1%	
Audits (*external assessments*)			
FRM PEP	5 or 8 sites/year	<± 10.1%	
Flow rate audit	1/6mo	<± 4.1% of audit standard	
External Leak Check	1/6mo	< 80.1 mL/min (or equivalent)	
Temperature Audit	1/year	<± 2.1°C	
Pressure Audit	1/ year	<± 10.1 mm Hg	
Laboratory QC Checks			
Blanks			
Lot Blanks	9-lot	<±15.1 µg difference	
Exposure lot blanks	3 per lot	<±15.1 µg difference	
Lab Blanks	10% or 1 per weighing session	<±15.1 µg difference	
Verification/ Calibration			
Balance Calibration	1/yr	Manufacturers spec.	
Lab Temp. Calibration	1/6mo	<± 2.1°C	
Lab Humidity Calibration	1/6mo	<± 2.1%	
Bias			
Balance Audit	1/year	<± 0.003 mg or manufacturers specs, whichever is tighter	
Balance Check	beginning, every 10th samples, end	< ±3.1 µg	
Calibration standards			
Working Mass Stds.	3-6 mo.	25 µg	
Primary Mass Stds.	1/yr	25 µg	
Precision			
Duplicate filter weighings	1 per weighing session	<±15.1 µg difference	

10.4 CFR-Related Quality Control Samples

40 CFR Part 58, Appendix A identifies a number of quality control samples that must be implemented for criteria pollutants that are used in comparison to the NAAQS. In addition, the quality control requirements found in the reference methods and the measurement principles described in 40 CFR Part 50 must be implemented unless there is a technical memo from EPA that provides an alternative procedure or check. Any special purpose monitors that use FRMs or FEMs will also be required to follow these requirements unless granted a waiver by the Regional Administrator (or delegate).

Blanks and Blank Correction

The objective for collecting blanks at various phases of sample collection is to determine whether contamination is occurring at that phase, be it in the field, during sample transport, or at the analytical laboratory, and to try to reduce this contamination if it is greater than acceptance limits. Some level of contamination is acceptable and values below the acceptance limits do not require corrective action or investigation. Values above this level should be investigated in order to reduce this contamination to acceptable levels. EPA does not endorse blank correction of data. In rare cases there may be a laboratory or measurement phase that has a measurable, consistent and documented level of contamination that cannot be eliminated and blank correction may be contemplated to adjust the data for this contamination. In this case, the monitoring agency should contact the EPA Region for advice before blank correction is implemented.

Other Data Correction (Post- Processing)

Other than the discussion about blank correction and the discussion about zero adjustment (see zero point discussion below), EPA does not recommend post-processing of data to "correct" for data failing QC checks. For example, if after failure of a one-point QC check a subsequent verification and calibration found that data was biased high by 15%, the previous routine data up until the last acceptable 1-point QC check is not adjusted down by 15% and reported. Based upon validation criteria, the data is either reported as initially measured or invalidated if it exceeds the acceptance limits.

Operating Ranges, Calibration Scale, Zero, Span, 1-point QC Checks and Performance Evaluations

Due to successes over the years in reducing pollution, ambient air monitoring concentrations are steadily decreasing. Many monitoring organizations are now purchasing trace-gas monitors not only for NCore sites but also for the routine monitoring sites. The ambient air QA regulations have kept up with this trend by lowering concentration levels for one-point QC checks and performance evaluation audit levels and suggesting that the audit levels chosen reflect ambient concentrations measured by the analyzer being evaluated. The intent of the regulatory language is to perform and report quality control data at concentrations more reflective of the routine concentrations.

When the ambient air QA regulations and guidance were initially promulgated, routine concentrations were higher; additionally, there were different reference methods, different and less sensitive monitoring instruments and calibration technologies, and a different quality of gas standards available. All of the technological change in recent years has been for the better and should allow for better precision and bias

at lower concentration ranges. Current guidance suggests the following for each of the QC checks for gaseous pollutants:

Operating Range- This term should be used for the ranges that are promulgated in the approved federal reference method (FRM) or federal equivalent method (FEM) designation. Some instruments have been designated for more than one operating range and one range may need to be selected for operating the instrument. This range needs to be acknowledged when determining calibration concentrations, but only to the extent that one would not operate within one operating range and calibrate with points higher than the selected operating range.

Calibration Scale – The term should be used to indicate the concentration range that the instrument is calibrated over. EPA feels that the monitoring organization should have more flexibility in deciding their calibration scale and, although it needs to be within the selected operating range, it does not necessarily need to be performed at concentration levels not normally measured by the monitor. Figure 10.2 provides an example of some calibrations performed in the past where the 4 calibration points (plus zero point) were spread evenly across the operating range starting at 80% of the operating range. As indicated, the routine data for this site is clustered around the lowest calibration point. It is suggested that monitoring organizations select a calibration scale that provides more calibration points at the lower concentrations to establish a better test of linearity at the routine concentration ranges. The calibration scale minimally should cover the "controlling" NAAQS standard especially if the monitor is used for regulatory purpose (comparison to the NAAQS). Some NAAQS have more than one level (e.g., CO has a 9 ppm 8-hour level and a 35 ppm 1-hour level). The controlling standard is the level that a monitor is more likely to approach. See guidance on selecting appropriate concentration ranges for gaseous QC samples below for more details.

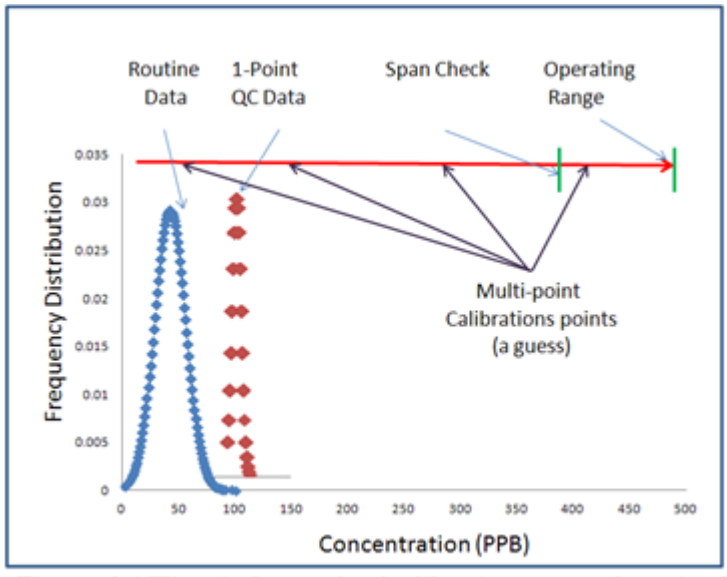

Figure 10-2 Historical example of calibration, span and 1 point QC

Zero Point - the bi-weekly zero point is fairly well defined and a straight forward procedure for using zero air generators or standards to measure a zero point. 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. EPA discourages the use of either adjustment but considers automatic zero adjustments reasonable when: 1) the automatic zero standards pass through the sample inlet and sample conditioning system, 2) the zero point/adjustment is performed daily, and applied to the following 24-hour period, 3) the zero reading is within the 24-hour acceptance criterion, and 4) both the adjusted and unadjusted zero response readings can be obtained from the data recording device. Zero adjustments cannot be used to correct data prior to zero test.

Span Point - the bi-weekly **s**pan points have been traditionally set at 80-90% of the operating range, as indicated in Figure 10-2. The span check concentration should be selected that is more beneficial to the quality control of the routine data at the site and EPA suggests: 1) the selection of an appropriate calibration scale (as described above) and, 2) selecting a span that at a minimum is above 120% of the highest NAAQS (for sites used for designation purposes) and above 99% of the routine data over a 3-year period and within the calibration scale (see Fig 10.3).

One-Point QC – The bi-weekly one-point QC check is required to be reported within the range of 0.005-0.08 ppm for O_3, SO_2 and NO_2 and 0.5- 5 ppm for CO. The QC check gas concentration selected within the prescribed range should be related to the monitoring objectives for the monitor. If monitoring at an NCore site or for trace level monitoring, the QC check concentration should be selected to represent the mean or median concentrations at the site. If the mean or median concentrations at trace gas sites are below the MDL of the instrument the agency can select the lowest concentration in the prescribed range that can be practically achieved. If the mean or median concentrations at trace gas sites are above the prescribed range the agency can select the highest concentration in the prescribed range. An additional QC check point is encouraged for those organizations that may have occasional high values or would like to confirm the monitors' linearity at the higher end of the operational range or around NAAQS concentrations. If monitoring for NAAQS decisions, the QC concentration can be selected at a higher concentration within the prescribed range but should also consider precision points around mean or median monitor concentrations. Due to the audit levels being expanded to allow for lower concentration audits to support NCore and trace-level work, a May 5, 2016, Technical Memo[5] was posted on AMTIC in which EPA suggests the use of "dual" acceptance criteria for one-point QC checks that are performed at lower concentration ranges. The data is evaluated in the AQS AMP256 Report under "One Point Quality Control".

- O3: $\pm$ 1.5 ppb difference or $\pm$ 7 percent difference, whichever is greater (from 5-21.5 ppb, 1.5 is greater than 7%)
- SO2: $\pm$ 1.5 ppb difference or $\pm$ 10 percent difference (from 5-15 ppb, 1.5 is greater than 10%)
- NO2: $\pm$ 1.5 ppb difference or $\pm$ 15 percent difference (from 5-10 ppb, 1.5 is greater than 15%)
- CO- NOTE: since the low end of CO one-point QC checks is 0.500 ppm, the absolute difference acceptance criteria that was developed for the annual PE ($\pm$ 0.03 ppm for concentrations <0.200ppm) will not be in effect.

Annual Performance Evaluations (PE) – the Annual PE includes 10 audit levels for the gaseous pollutants of SO_2, NO_2, O_3, or CO. The evaluation is made by challenging the monitor with audit gas standards of known concentration from at least three audit levels. One point must be within two to three times the method detection limit of the instruments within the PQAOs network, the second point will be less than or equal to the 99th percentile of the data at the site or the network of sites in the PQAO or the next highest audit concentration level. The third point can be around the primary NAAQS or the highest 3-year concentration at the site or the network of sites in the PQAO. An additional 4th level is encouraged for those agencies that would like to confirm the monitors' linearity at the higher end of the operational range. Due to the audit levels being expanded to allow for lower concentration audits to support NCore

[5]Technical Note- Guidance on Statistics for Use of 1-Point QC Checks at Lower Concentrations as described in 40 CFR Part 58 Appendix A Section 3.1.1 https://www3.epa.gov/ttn/amtic/files/policy/Tech_Memo_%20for_%201-pt_QC.pdf

and trace-level work, a February 11, 2011, Technical Memo[6] was posted on AMTIC in which EPA suggests the use of the following acceptance criteria for levels 1 and 2 audit ranges:

- For O_3, SO_2, and NO_2: ± 1.5 ppb difference or ± 15 percent difference, whichever is greater.
- For CO: ± 0.03 ppm difference or ± 15 percent difference, whichever is greater.

For audit levels 3-10, the 15 percent difference acceptance criteria, currently in guidance, is acceptable. The data is evaluated in the AQS AMP256 Report under "Annual Performance Evaluation".

Selecting Appropriate Concentration Ranges for Gaseous QC Samples

The regulations attempt to provide some flexibility on how monitoring organizations choose the QC concentration ranges. The following scenario is an acceptable approach to selecting the QC concentrations. It uses ozone data from a typical routine monitoring site. Figure 10.3 illustrates this process.

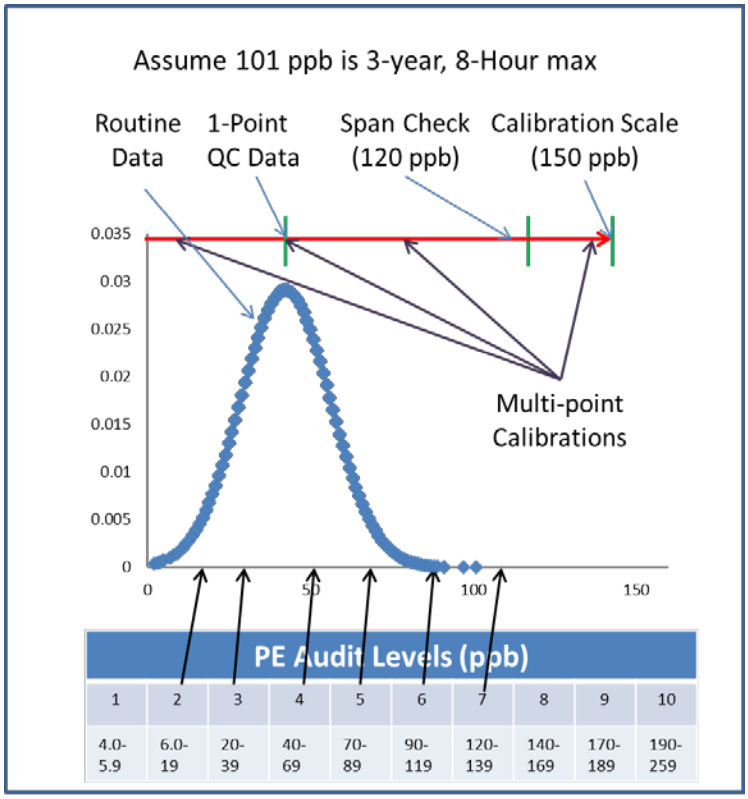

Figure 10.3 An example approach for selecting QC check ranges

1) Take 3 years of 8-hour or 1-hour max values (101 ppb is highest 8-hour max for this example).
2) Multiply the highest 8-hour or 1-hour max by 1.5, to establish the calibration scale (150 ppb). If the calibration scale is below the NAAQS, use 1.1 to 1.5x of the controlling NAAQS (if sites are used for regulatory purposes).
3) Take 80% of calibration scale (120 ppb, if the scale is 150) to establish the span check value. The span check can now serve as a bi-weekly check to protect the NAAQS.
4) Use the current CFR requirements to select 1-point QC checks. Since the current 1-point QC check range is 5-80 ppb for O_3, and the mean 8-hour max is around 50 ppb in this example, 50 ppb would be an adequate concentration for this site.

[6]Guidance on Statistics for Use at Audit Levels 1 and 2 of the Expanded List of Audit Levels for Annual Performance Evaluation for SO_2, NO_2, O_3, and CO as Described in 40 CFR Part 58 Appendix A Section 3.2.2 http://www.epa.gov/ttn/amtic/files/ambient/pm25/datamang/20110217lowlevelstatmemo.pdf

5) This information can be used to select the annual PE audit levels. In this example the MDL for the ozone instruments in the PQAO are 3 ppb. Audit level 2 would be required for one of the audit points and audit points two and three could be selected from audit levels 3-7.

The approached described above is an example that allows for flexibility depending on the sites and the concentrations measured within a monitoring network. This approach can be used for individual sites (where there is greater variability in concentrations across the network) or it can be used for an aggregate of sites within a PQAO (where less variability in concentrations exist). The approach can be used with one year of data or it can be used with multiple years of data. Two issues should dictate the approach used:

- Ensure that the calibration scale exceeds the range of real and possible routine concentrations and is above any primary and secondary NAAQS.
- Ensure the span check is protective of the NAAQS.

The monitoring organization's QAPP should document the approach used.

Stability

When challenging an analyzer with test atmospheres, such as during a routine biweekly one-point QC check or an annual performance audit, the operator/auditor should pay close attention to the stability of the analyzer and the associated gas delivery system. There are several factors that can influence the stability of a reading, including the analyzer's response time. At a minimum, the operator should allow the challenge gas to saturate the delivery system, then wait at least the analyzer's lag and rise time (see 40 CFR §53.23) for each targeted concentration level. These two parameters, however, are not meant as a measure of when an instrument is stable enough to take a reading, but rather serve as a mark of the time the instrument takes to respond to a change in the test concentration. The longer the operator waits to take a reading, the better the results. At a minimum, EPA recommends that an operator wait 5 additional minutes after the analyzer has begun to measure consistent, instantaneous concentrations that show minimal variability and no discernible slope.

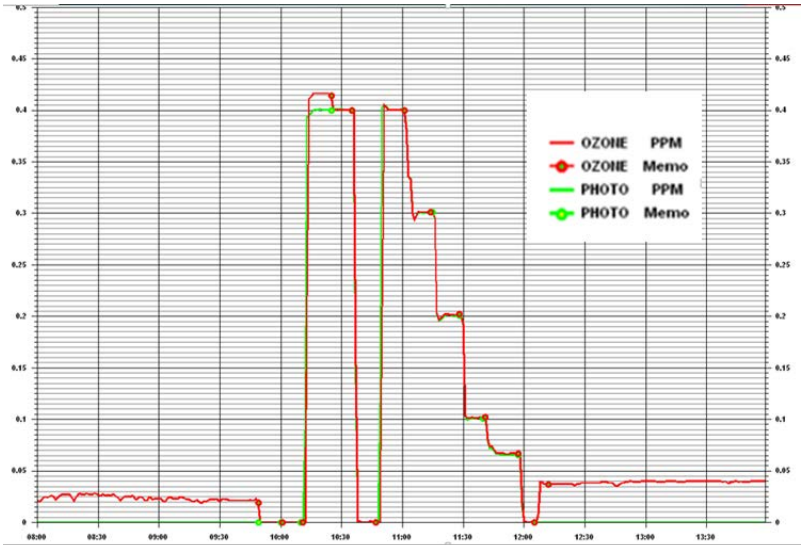

Figure 10.4: Ozone Calibration

Some analyzers display diagnostics that alert the operator as to their stability, which typically represents the standard deviation of the concentrations collected by the analyzer (generally using second data readings held internally within the analyzer). For these analyzers with a stability indicator, the manufacturer will define in the user manual what value indicates that the analyzer has reached stability. If the operator utilizes the analyzer's stability readout as an indicator for when it is a safe time to take a concentration reading, it is recommended that he/she wait an

additional 5 minutes to ensure a static system before taking the reading.

If possible, it is recommended that the operator utilize an electronic strip chart, or similar display, to view the minute data collected by the datalogger (or analyzer) in conjunction with any QA/QC procedure. While conducting the QA/QC check, the operator should view the analyzer response to each concentration level during the test procedure, as well as the calibrator's response (if it is possible to poll and graph the minute data from the calibrator). The graphical display of the minute data is an excellent tool to assist the operator in determining the stability of each concentration level. Figure 10.4 is an electronic strip chart graph of an ozone calibration procedure that shows the output of both the analyzer and the calibrator (photometer). In this figure, which shows the instrument response over a 6-hour time period, each individual concentration level can be easily seen. The concentration levels appear as "walkable stair steps" on the graph, which clearly illustrate that the instrument response had stopped changing and has, therefore, stabilized. Depending on the averaging time of the DAS in use by the monitoring organization, the graph of the electronic strip chart may vary. EPA suggests the collection of 5 data points, at a minimum, is needed to produce a chart that will show "walkable stair steps".

The monitoring organization should indicate in their QAPPs and SOPs how they will define stability, and through what means it will be verified, so that operators can perform procedures consistently and produce high quality checks.

10.5 Use of Computers for Quality Control

With the wide range of computers now available, and the advancements in data acquisition system (DAS) technologies, 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

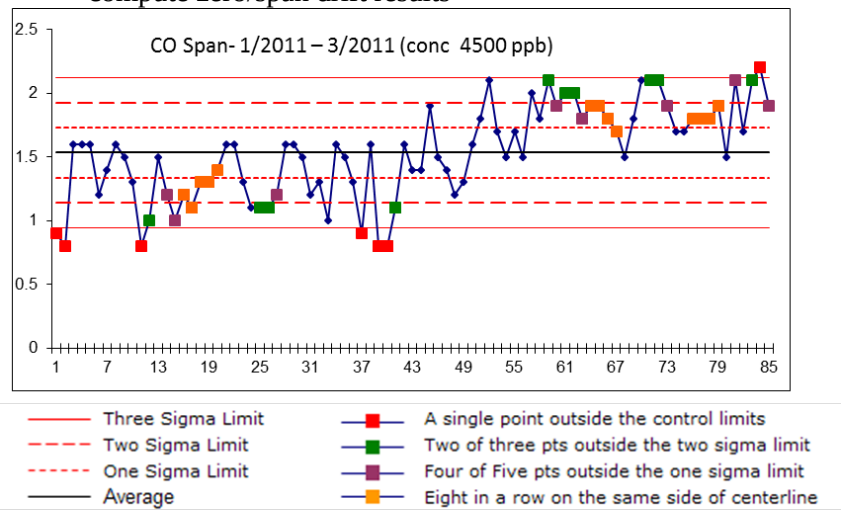

Figure 10.5 Control chart example (courtesy of ASQ))

- plot zero/span drift data
- compute precision and bias results
- compute control chart limits
- plot control charts
- automatically flag out-of-control results
- maintain and retrieve calibration and performance records
- format data for reporting to AQS

Some of these checks (e.g., calibrations) only need to be

reviewed as needed or when the actual check is performed. Other checks, like zero/span/one-point QC checks or programmed routine data range or outlier checks that may occur every day, are much more easily performed automatically by properly programmed computer systems. Earlier versions of this Handbook provided examples of quality control charts for zero and span drifts, but with the advanced data acquisition system technologies available, the development of these charts is fairly straight forward. Figure 10.5 represents daily CO span checks over a 3-month period. This control chart can be downloaded from the American Society for Quality (ASQ) web site[7].

Many vendors offering newer generation data loggers and ambient air information management systems provide programming of some of the QC checking capabilities listed above. EPA has also provided guidance and a Data Assessment Statistical Calculator[8] (DASC) tool for the precision and bias calculations of the quality control checks required in CFR Part 58, Appendix A. In addition, the AMP 256 Report in AQS also provides these statistics for many of the QC samples described in Table 10-3, but use of the 256 Report requires data reporting to AQS which does not usually occur in time frames needed for quality control.

[7] http://asq.org/learn-about-quality/data-collection-analysis-tools/overview/control-chart.html

[8] DASC tool on AMTIC at http://www.epa.gov/ttn/amtic/qareport.html

11.0 Instrument/Equipment Testing, Inspection, and Maintenance

Implementing an ambient air monitoring network, with the various types of equipment needed, is no easy task. Through appropriate testing, inspection, and maintenance programs, monitoring organizations can be assured that equipment is capable of operating at acceptable performance levels. Every piece of equipment has an expected life span, and its use should be discontinued if its performance quality ceases to meet appropriate standards. As ambient air concentrations decrease and as NAAQS are strengthened the EPA will reduce QC check concentrations. These reduced concentrations will be achievable by newer and more sensitive equipment. For amortization purposes, EPA estimates a 7-year lifespan for most monitoring instruments and a somewhat longer lifespan for more permanent types of equipment (instrument racks, monitoring shelters, etc.). Monitoring organizations accepting EPA grants receive funds which can be used for replacing capital equipment. With that in mind, the monitoring organizations should actively track the age and condition of their instruments/equipment and develop replacement schedules that make best use of the resource allocations provided. EPA Regions will be checking age and condition of equipment during TSAs. Monitoring organizations may be able to prolong the life of equipment, but in doing so they may run the risk of additional downtime, more upkeep, and a greater chance of data invalidation, while simultaneously losing out on newer technologies, better instrument sensitivity/stability, and the opportunities for better information management technologies.

Due to the many types of equipment that can be used in an ambient air monitoring program, this section provides general guidance on testing, inspection, and maintenance procedures for broad categories of equipment only. In most cases, equipment manufacturers include inspection and maintenance information in the operating manuals. The role of monitoring organizations, in developing a quality system, is to address the scheduling and documentation of routine testing, inspection, and maintenance. Detailed maintenance documents should be available for each monitoring site. Elements incorporated into testing, inspection, and maintenance documents include:

- equipment lists - by organization and 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; and
- monthly check sheets and data entry forms for documenting testing, inspections, and maintenance performed.

11.1 Instrumentation

11.1.1 Analyzers and Samplers

Aside from the specific exceptions described in Appendix C of Part 58[1], monitoring methods used for SLAMS monitoring must be a reference or equivalent method, designated as such by 40 CFR Part 53[2] and labeled accordingly[3]. Reference or equivalent methods also must be used at NCore monitoring sites intended for comparison with any NAAQS. Among reference and equivalent methods, a variety of

[1] 40 CFR Part 58, Appendix C http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl
[2] 40 CFR Part 53
[3] 40 CFR Part 53.9(d)

analyzer designs and features are available. For the following sections the term "analyzer", where applicable, will also mean monitor or sampler. For certain pollutants, analyzers employing different measurement principles are available. Some analyzer models only meet the minimum performance specifications (see Table 7-6), while others provide a higher level of performance. Section 7 provides information on what aspects to consider when selecting a particular monitoring instrument/analyzer. Upon receiving the new analyzer, the user should carefully read the instructions or operating manual provided by the manufacturer. Information or instructions concerning the following should be found in the manufacturer's manual:

- 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;
- electrical and plumbing diagrams;
- preventive maintenance schedule and procedures;
- troubleshooting; and
- a list of expendable parts.

NOTE: Many vendors have specific time periods when the initial checks for damage in transit need to be made; therefore, it is important to perform an initial check/verification of the equipment as soon as possible. The monitor should be assembled and set up according to the instructions in the manufacturer's manual.

Initial Set-up and Acceptance Testing

When an instrument receives an FRM/FEM designation, the make/model has been shown to meet the performance specifications established in 40 CFR Part 53. However, that designation does not imply that an individual instrument, newly purchased, is "field ready" and/or without any technical issues. With that in mind, it is important for a monitoring organization to thoroughly test a newly purchased instrument's performance upon receipt. The monitoring organization is encouraged to conduct the initial set up and performance acceptance testing at the main office or laboratory facility (see Section 11.1.3), as opposed to testing the equipment "live" in the field. It is further recommended that the performance testing occur over a series of days or even weeks, if feasible and resources allow, before the instrument is deployed to a field site. To test the instrument, the following is generally recommended. Following analyzer set-up, and allowance for the instrument to reach required operating conditions, an initial verification of performance characteristics such as power, flow, noise, detection limit, and response time should be conducted; a multi-point verification should also be performed to determine if the analyzer is operating properly. These guidelines assume that the instrument has been previously calibrated. However, if the instrument was disassembled after calibration, or no calibration of the instrument had previously been performed and documented, the monitor must have a calibration, followed by a multi-point verification, to ensure it is within acceptable calibration requirements prior to use. Zero/span drift and precision should be checked during the initial calibration/verification or measured using abbreviated forms of the test procedures provided in 40 CFR Part 53. Acceptance of the analyzer should be based on results from these performance tests. If the analyzer does not perform to stated specifications, document the testing procedures and data and contact the manufacturer for corrective action. Once accepted, reference and equivalent analyzers are guaranteed by the manufacturer to operate within the required performance

specifications for one year[4], unless major repairs are performed or parts are replaced. In such instances, the analyzers must be recalibrated before use.

11.1.2 Support Instrumentation

Experiences of monitoring organization staff, preventive maintenance requirements, ease of maintenance, and general reliability play crucial roles in the selection of support equipment. The following examples depict general categories of support equipment and typical features to look for when selecting this equipment. This list is meant to guide monitoring organizations in the selection of equipment and does not represent required specifications.

- **Calibration Standards:** Calibration standards fall into several categories, which may include the following.
    - Mass flow controlled (MFC) devices;
    - Standards that meet the 2012 *Traceability Protocol for Gaseous Calibration Standards*[5]*;*
    - Permeation devices;
    - Voltage standards for equipment testing;
    - Photometers;
    - Flow measurement devices;
    - Barometric pressure measurement devices; and
    - Temperature measurement devices.

  It is recommended that the devices be 110 VAC, be compatible with data acquisition systems for automated calibrations, and have digital compatibility or true transistor-transistor logic (TTL). The most common standards are MFC devices and permeation devices. Both use dilution air to obtain the needed output pollutant concentration.

- **Data Acquisition Systems (DAS):** DAS should have at least 32-bit logic for improved performance (DAS with at least 16-bit logic can still be used); have modem and internet capabilities; allow remote access and control; allow for digital input; and be able to initiate automated calibrations and polling. It is also recommended that DAS have software compatible with AQS and AQI reporting and editing. Both data loggers and analog chart recorders may be used for recording data; however, the storage, communicability, and flexibility of DAS coupled with data loggers makes the DAS systems the preferred option. More information on DAS is found in Section 14.

- **Instrument Racks:** Instrument racks should be constructed of steel and be able to accept sliding trays or rails. Open racks help to keep instrument temperatures down and allow air to circulate freely.

- **Instrument Benches:** Instrument benches should be of sufficient space to allow adequate room for multiple instruments, allow work space for the operator, and be capable of supporting a fair amount of weight (> 100 lbs). Slate or other hard, water-proof materials (e.g., steel) are recommended.

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[4] 40 CFR Part 53.9 (c)
[5] EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards (EPA-600/R-23/531) http://www.epa.gov/air-research/epa-traceability-protocol-assay-and-certification-gaseous-calibration-standards

- **Zero Air Systems and Standards:** Zero air systems should be able to deliver 10 liters/min of air that is free of ozone, NO, NO_2, and SO_2 to 0.001 ppm, and CO and non-methane hydrocarbons to 0.1 ppm or below the instruments method detection limit (whichever is lower). With NCore monitoring and the use of trace-gas monitors, there may be a need to audit and calibrate at lower levels. Therefore, monitoring organizations may need to acquire zero air systems capable of delivering zero air at 20 to 30 liters/min. There are many commercially available systems; however, simple designs can be obtained by using a series of canisters. In addition, the 2012 *Traceability Protocol for Gaseous Calibration Standards* includes a discussion of zero gas standards which are commercially available. Although not required for use under protocol gases, the standards can be used as a check on zero air systems. Appendix K provides some guidance on checking zero air systems.

11.1.3 Laboratory Support

While it is not required, monitoring organizations should employ full laboratory facilities. These facilities should be equipped to test, repair, troubleshoot, and calibrate all analyzers and support equipment necessary to operate the ambient air monitoring network. In cases where individual laboratories are not feasible, a monitoring organization may be able to find a central laboratory (PQAO) where these activities can be performed.

It is recommended that the laboratory be designed to accommodate the air quality laboratory/shop and PM_{10} and $PM_{2.5}$ filter rooms[6], as well as 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, a sample cane that passes through the roof to allow analyzers that are being tested to sample outside air should be mounted to the bench. This configuration also allows any excess calibration gas to 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 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, these activities 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 were being operated within a monitoring station. The analyzer is connected to an acquisition system (e.g., DAS, data logger, chart recorder, etc.) and allowed to operate. Any intermittent problems that occur can be observed on the data logger/chart recorder. The analyzer can be allowed to operate over several days to see if anomalies or problems recur; if they do, there is a record of them. If the instrument rack has a DAS and calibrator, nightly auto QC checks can be performed to see how the analyzer reacts to known gas concentrations. These checks can also be used to establish a method detection limit for the instruments. In addition, the ozone recertification bench and rack should be attached to a work bench. The rack should house the local ozone level 2 standard[7] and the ozone transfer standards (level 3 and

[6] Guidance on filter room requirements can be found in methods 2.10 and 2.11 for PM_{10} and 2.12 for $PM_{2.5}$
[7] http://www.epa.gov/ttn/amtic/files/ambient/qaqc/OzoneTransferStandardGuidance.pdf

greater) that are being checked for recertification. Zero air is plumbed into this rack for the calibration and testing of ozone analyzers and transfer standards.

During FRM/FEM testing, EPA tries to ensure that monitoring equipment manufacturers test instruments at varying environmental extremes. However, within the period of testing some extremes that exist in some monitoring areas may not be achieved. Monitoring organizations that have large regions with varying extremes of temperature, humidity, and pressure may want to invest in an environmental chamber that can be used to test monitoring instruments against the manufacturer's advertised performance standards.

11.2 Preventive Maintenance

Every monitoring organization should develop a preventive maintenance program. Preventive maintenance is what its name implies: maintaining the equipment within a network to prevent downtime, costly repairs, and data loss. Preventive maintenance is an ongoing element of quality control and is typically enveloped into the daily routine. In addition to the daily routine, scheduled activities must be performed monthly, quarterly, semi-annually and annually. Often the standard operating procedures and/or operation manuals will provide preventative maintenance activities for the particular instrument/method. It is suggested that these sections be assembled into a preventative maintenance document that could be kept at each site and accessed electronically, so that maintenance can be implemented and documented in a consistent manner.

Preventive maintenance is the responsibility of the monitoring staff (e.g., station operators, lab technical staff) and the supervisory staff. It is important that the supervisor review the preventive maintenance work and continually check the schedule. The supervisor is responsible for making sure that 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. The preventive maintenance schedule is changed whenever an activity is completed or performed at an alternate time. For instance, if a multi-point calibration is performed in February instead of on the scheduled date in March, then the subsequent six-month calibration date moves from September to August. On a regular basis, the supervisor should review the preventive maintenance schedule with the station operators. Following all repairs, the instruments must be verified (multi-point) or calibrated.

Lists can facilitate the organization and tracking of tasks and improve the efficiency of preventive maintenance operations. A checklist of regular maintenance activities (e.g., zero-span checks, daily routine checks, data dump/collection, calibrations, etc.) is recommended. A spare parts list, including relevant catalog numbers, is also recommended, as it facilitates the ordering of replacement parts. Such a list should be readily accessible and should include the types and an inventory of spare parts already on-hand.

11.2.1 Station Maintenance

Station maintenance is an element of preventive maintenance that may not occur on a routine basis; rather, these tasks usually occur on an "as needed" basis. Station maintenance items are checked monthly or whenever the monitoring organization knows that the maintenance needs to be performed. Examples of station maintenance items include:

- floor cleaning;

- shelter inspection;
- security inspection (fencing, locks, surveillance cameras, lighting);
- visual inspection of probes and meteorological gear;
- air conditioner repair;
- AC filter replacement;
- weed abatement and grass cutting;
- roof repair;
- general cleaning;
- inlet and manifold inspection, testing and cleaning;
- manifold exhaust blower lube;
- desiccant replacement; and
- safety inspection, including ladder and guard rails, if applicable.

Simple documentation of these activities, whether in station logs or electronic logs, helps provide evidence of continuous attention to data quality.

11.2.2 Routine Operation Checks

Routine operation checks occur at specified frequencies. These duties must be performed and documented in order to operate a monitoring network at optimal levels. Examples of typical routine operations are detailed in Table 11-1.

Table 11-1 Routine Operation Checks

Item	Each Visit	Weekly/Monthly	Minimum
Observation of unusual conditions/events	X		
Review Data	X		
Mark charts, where applicable	X		
Check/Oil Exhaust Blower	X		
Check Exterior		X	
Check/Change Desiccant	X		
Manifold Leak Test		X	
Clean inlet funnel		X	
Inspect tubing	X		
Clean or Replace Tubing			Annually[1]
Inspect manifold and cane	X		
Clean manifold and cane			Every 6 months or as needed
Check HVAC systems		X	
Check electrical connections		X	
Field site supply inventory		X	
Residence time calculation			If manifold and inlets altered

[1]If tubing is used externally as an inlet device, it may need to be replaced every 6 months or more frequently depending upon site-specific issues. Zero/span and precision checks performed through the probe and inlet tubing can provide a good test for the cleanliness of the ambient air collection system and when replacement or cleaning is required. Cleaning is an option, but not the recommended method.

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.

11.2.3 Instrument Logs and Site Logs

Each instrument and piece of support equipment (with the exception of the instrument racks and benches) should have an Instrumentation Repair Log (either paper or electronic). The log should contain the repair and calibration history of that particular instrument. Whenever instrument multi-point verification/calibration, maintenance, repair, or relocation occurs, detailed notes are written in the instrumentation log. The log contains the most recent multi-point verification/calibration report, a preventive maintenance sheet, and the acceptance testing information (or reference to the location of this information). If an instrument is malfunctioning and a decision is made to relocate the 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, it is recommended that a copy of the log be sent with the instrument. This information helps non-agency repair personnel with troubleshooting instrument problems. Improper recording of instrument maintenance can complicate future repair and maintenance procedures. The instrument log should be detailed enough to determine easily and definitively which instrument was at which site(s) over any given time period. If a problem is found with a specific instrument, the monitoring staff should be able to track the problem to the date it initially surfaced and invalidate data, even if the instrument was used at multiple sites.

A site log should be kept documenting maintenance of a specific monitoring site and the auxiliary monitoring equipment located there. Information that could be recorded includes the activities listed in the Station Maintenance and Routine Operations sections (Sections 11.2.1 and 11.2.2).

The site log is a chronology of the events that occurs at the monitoring station. The log is an important part of station maintenance because it contains the narrative of past problems and solutions to those problems. Site log notes should be written in the form of a narrative, rather than shorthand notes or bulleted lists which may not provide a full explanation of issues that may be important information for site operators in the future, during data validation, or for defending the quality of data in legal proceedings. Examples of items that should be recorded in the site log are:

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

It is not required that the instrument and site logs be completely independent of each other. However, there is an advantage to having separate instrument logs. If instruments go in for repair, they may eventually be sent to another site. Having a separate instrument log allows the log to “travel” with the instrument. Keeping electronic instrument and station maintenance logs at stations and at centralized facilities (see LIMS discussion, Section 8) also has recordkeeping advantages, but there needs to be a way that these records can be considered official and not be tampered with or falsified. Newer electronic signature technologies are helping ensure that electronic records can be considered official. It is

important, however, that all of the required information for each instrument and site be properly recorded using a method that is comprehensive and easily understood. Many monitoring organizations have developed standard station maintenance forms that contain all the items to be checked and the frequency of those checks. It then becomes a very simple procedure to use this form to check off and initial the activities that were performed. Appendix J provides more detailed information on the use of electronic logbooks.

12.0 Calibrations

Calibration is defined as:

> *the comparison of a measurement standard, instrument, or item with a standard or instrument of higher accuracy to detect and quantify inaccuracies and to report or eliminate those inaccuracies by* ***adjustment***[1].

Calibration of an ambient air monitoring analyzer adjusts the analytical response of the analyzer to more closely agree with a measurement standard of higher accuracy. Generally speaking, a calibration is a two-part process. The first part involves the actual adjustment of the analyzer: setting the internal zero and span controls, which are adjusted based on known zero and upscale (span) test concentrations, to provide the desired calibration scale. After the adjustment is completed, the analyzer is, in essence, calibrated. The second part of the process includes conducting a multi-point verification over the analyzer's calibration scale. The multi-point verification does not involve making any additional instrument adjustments, but rather ensures the zero and span settings have been successfully set within the analyzer. The verification also confirms the analyzer's linearity. These processes will be discussed in more detail in Sections 12.2 and 12.3 below.

Prior to the implementation of any ambient air monitoring activities in the field, the ambient sampler or analyzer must be verified to ensure the accuracy of its response is within specified tolerances (typically established by the instrument manufacturer in the appropriate operation's manual, and/or in the monitoring organization's QAPP and SOPs). A multi-point verification is conducted in order to make this determination. If the sampler or analyzer's response exceeds the established tolerances during the verification, then the instrument must be appropriately calibrated – by means of an **adjustment**.

> **NOTE:** When the term "calibration" is used in the remainder of this section, it is assumed that a multi-point verification is initially performed and the operator has concluded that calibration (i.e., adjustment) is necessary.

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 CO, NO_2, SO_2 and O_3 analyzers, detailed calibration procedures may also be found in the appropriate reference method located within the Appendices of 40 CFR Part 50[2], as well as within the method guidance and technical assistance documents listed in the fact sheets in Appendix A of this Handbook.

All analyzer preventive maintenance and diagnostic checks should be completed prior to the calibration. Multi-point verifications and 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. The operator should verify that no alarms or warnings are displayed on the analyzer prior to initiating the calibration procedure. During the calibration, the analyzer should be operating in its normal sampling mode, and it should sample the test

[1] American National Standard Quality Systems for Environmental Data and Technology Programs ANSI /ASQ E4 http://www.asq.org/
[2] http://www.access.gpo.gov/nara/cfr/cfr-table-search.html

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. Some analyzers can be operated on more than one range. For sites requiring the use of FRM or FEMs (NAAQS sites), the appropriate ranges are identified in the *Designated Reference and Equivalent Method List* found on AMTIC[3].

In the case of particulate matter and Pb samplers where concentration standards are not available and impractical, calibrations take place on the samplers' flow, temperature and pressure devices. At times this may need to be accomplished in a laboratory setting rather than in the field.

Calibration documentation should be maintained with each analyzer/sampler and also in a central backup file. Documentation should be readily available for review and should include calibration data, analyzer identification number, calibration date, analyzer location, calibration standards used and their traceability, identification numbers of calibration equipment used, and the person conducting the calibration.

Full Scale versus Calibration Scale

Many older documents and some of the CFR reference methods refer to calibration at "full scale". The interpretation of this meant that monitoring organizations would calibrate to full scale of one of the FRM/FEM approved operating ranges of the instrument. For example, ozone instruments are approved at 0-500 ppb or 0-1000 ppb. Many monitoring organizations calibrate the instrument by evenly spacing four upscale points up to around 500 ppb (if that is the operating range they are using). In this scenario, with most sites reading less than 80 ppb, the majority of the upscale calibration points would be at levels not measured in ambient conditions. EPA suggests monitoring organization calibrate using points that are more applicable to the concentrations found in their networks while still being protective of concentrations exceeding the NAAQS. For example, an ozone analyzer may be calibrated on a 0-150 ppb scale, as opposed to 0-500 ppb. For convenience, EPA will use the term "calibration scale" to refer to the concentration range used for calibrating the monitoring instruments. Section 10.4 of this Handbook provides more details on this concept and process.

[3] http://www.epa.gov/ttn/amtic/criteria.html

12.1 Calibration Standards and Reagents

Calibration standards are:

- Reagents of high grade
- Gaseous standards of known concentrations that are certified as EPA protocol gases
- Instruments and/or standards of high sensitivity and repeatability
- Devices that are used to calibrate air monitoring instruments.

The reference and equivalent methods define the grades and purities needed for the reagents and gases required in the Ambient Air Quality Monitoring Program. Information for each criteria pollutant can be found in the Appendices of 40 CFR Part 50. Calibration standards utilized should be accompanied by documentation that supports their accuracy and traceability.

The highest authority standards lie with the National Institute of Standards and Technology (NIST). The NIST keeps a set of standards that is referenced by all manufacturers of glassware, standard equipment, and electronic primary standards. **Traceable** is defined in 40 CFR Parts 50 and 58 as meaning that a local standard (i.e., one maintained by a monitoring organization) has been compared and certified, either directly or via not more than one intermediate standard, to a primary standard such as a NIST Standard Reference Material (NIST SRM) or an EPA/NIST-approved Certified Reference Material (CRM). Similarly, **traceability** is the "property of a measurement result whereby the result can be related to a stated reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty" (ISO).[4] Standard traceability, therefore, is the process of transferring the accuracy or authority of a primary standard to a field-usable standard, resulting in a documented unbroken chain of calibrations/certifications. Recommended timeframes for certifications of various calibration standards are defined in Appendix D of this Handbook; however, if not specified, the monitoring organization should follow the manufacturer's recommendation.

Primary Reference Standards: A primary reference standard can be a defined measurement standard designated for the calibration of other measurement standards for quantities of a given kind in a given organization[5]. In short, any standard that is not subordinate to another standard is considered a primary standard. NIST's standard reference materials (SRMs) are examples of primary reference standards. NIST also describes a Primary Reference Standard as a standard that is designated or widely acknowledged as having the highest metrological qualities and whose value is accepted without reference to other standards of the same quality. For example, the NIST-F1 Atomic Clock[6] is recognized as a primary standard for time and frequency. A true primary standard like NIST-F1 establishes maximum levels for the frequency shifts caused by environmental factors. By summing or combining the effects of these frequency shifts, it is possible to estimate the uncertainty of a primary standard without comparing it to other standards. NIST maintains a catalog of SRMs that can be accessed through the Internet[7]. Primary reference standards are usually quite expensive and are often used to calibrate, develop, or assay

[4] International Standards Organization (ISO)- International Vocabulary of Basic Terms in Metrology
[5] definition of reference measurement standard from International vocabulary of metrology – Basic and general concepts and associated terms (VIM) http://www.bipm.org/en/publications/guides/vim.html
[6] http://www.nist.gov/pml/div688/grp50/primary-frequency-standards.cfm
[7] http://www.nist.gov

secondary standards. In order to establish and maintain NIST traceability, the policies posted at the NIST Website[8] should be observed.

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

Transfer Standards: In a transfer standard, traceability to the more authoritative primary reference standard is "transferred" to a secondary device. In other words, a transfer standard is a device that is certified against a primary standard. The EPA Technical Assistance Document, *Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone*, further defines a transfer standard as, "a transportable device or apparatus which, together with associated operational procedures, is capable of accurately reproducing pollutant concentration standards or of producing accurate assays of pollutant concentrations which are quantitatively related to a higher level and more authoritative standard."[9] Transfer standards can be many different devices. It is recommended that one type of device be used as the principle transfer standard for the monitoring organization. This will eliminate any error that may occur from different types of standards. It is recommended that transfer standards be certified against a primary standard on a set frequency (typically, on an annual basis). Electronic types 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 organization is small, one transfer standard may be sufficient. However, most organizations will have many transfer standards for use throughout their monitoring network and will probably need to verify them on a staggered schedule.

EPA recommends, as a best practice, that monitoring organizations maintain calibration standards that are separate from those standards used for routine quality control checks. However, depending on the size of the monitoring organization's network, separate equipment for calibrations and QC checks may not be feasible due to resource limitations. It is acceptable to use the same standards to both calibrate and verify an instrument; however, EPA notes that, under this scenario, the monitoring organization will be unable to detect issues with the calibration standards. Therefore, the monitoring organization is strongly encouraged to conduct more frequent performance evaluations (i.e., audits, using independent standards) if the calibration and verification equipment are the same. At a minimum, a monitoring organization must maintain two separate sets of equipment: one designated for calibrations/verifications, and the other designated for independent performance evaluations (audits).

12.1.1 Reagents

For CO, SO_2, NO_2, and O_3, the reagents defined in the appendices of 40 CFR Part 50 include gaseous standards and zero air sources. For these pollutants, the field analyzer is able to generate concentrations in situ. For other pollutants, however, a laboratory is required to analyze the samples collected in the field. Towards that end, the analytical instrumentation must be calibrated and maintained – which will often involve preparation of laboratory reagents. In some cases, the 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 them, the

[8] http://ts.nist.gov/traceability/
[9] https://www3.epa.gov/ttnamti1/files/ambient/qaqc/OzoneTransferStandardGuidance.pdf

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.

Chemical reagents, solvents, and gases are available in various grades. Reagents can be categorized into the following six grades[10]:

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.

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

12.1.2 Gaseous 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. The following is an excerpt from 40 CFR Part 58, Appendix A, Section 2.6.1:

"Gaseous pollutant concentration standards (permeation devices or cylinders of compressed gas) used to obtain test concentrations for CO, SO_2, NO, and NO_2 must be traceable to either a NIST-Traceable Reference Material (NTRM) or a NIST-certified Gas Manufacturer's Internal Standard (GMIS), certified in accordance with one of the procedures given in reference 4 of [Appendix A]. Vendors advertising certification with the procedures provided in reference 4 of [Appendix A] and distributing gases as "EPA Protocol Gas" for ambient air monitoring purposes must participate in the EPA Ambient Air Protocol Gas Verification Program or not use "EPA" in any form of advertising. Monitoring organizations must provide information to the EPA on the gas producers they use on an annual basis and those PQAOs purchasing standards will be obligated, at the request of the EPA, to participate in the program at least once every 5 years by sending a new unused standard to a designated verification laboratory."

Normally, the calibration gas standard used routinely by the monitoring organization for quality control

[10] Quality Assurance Principles for Analytical Laboratories, 3rd Edition. By Frederick M. Garfield, Eugene Klesta, and Jerry Hirsch. AOAC International (2000). http://www.aoac.org/

purposes (commonly referred to as 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 SRMs. 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 a NIST primary standard;
- include a test of the stability of the working standard over several days; and
- 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. As described in CFR, gas suppliers advertising "EPA Protocol Gas" will be required to participate in the EPA Protocol Gas Verification Program. Information on this program, including the gas suppliers participating in the program, can be found on AMTIC[11]. EPA has developed procedures for the establishment of protocol gases in the EPA document *Traceability Protocol for Assay and Certification of Gaseous Calibration Standards*[12]. Table 2-3 in the Traceability Document provides the maximum certification periods for verification and calibration standards used in the ambient air monitoring program. Since these periods sometimes change the table is not presented here. In addition, because monitoring organization move standards about (travel to sites for audits, etc.) and are used in different environments compared to laboratory standards, these maximum certification periods may not be applicable to the manner in which the standards are used. Care should be taken before utilizing standards up to the maximum certification period.

Certification periods decrease for concentrations below the applicable concentration ranges provided in Table 2-3 of the traceability document. For example, the certification period for SO_2 standards between 1-50 ppm is 4 years. This value may be applicable to standards that are housed in laboratories under stable temperature and humidity conditions, but should be checked more frequently when being used in field situations. Also, tank size may affect stability in low level standards. Some gas manufacturers claim that standards supplied in smaller tanks are stable for longer periods of time than the same concentration in larger tanks. Although this claim has not been verified, if true it may be helpful in making purchasing decisions.

Test concentrations of ozone must be traceable to a primary standard UV photometer as described in 40 CFR Part 50, Appendix D, and the guidance EPA document *Transfer Standards for the Calibration of Ambient Air Monitoring Analyzers for Ozone*[13].

For ambient air monitoring activities, zero concentrations can be acquired through zero air generation devices or purchased as standards. Although zero concentrations are not required to be traceable to a primary standard, care should be exercised to ensure that zero device or standards used are adequately free of all substances likely to cause a detectable response from the analyzer and, at a minimum, below the lower detectable limit of the criteria pollutants being measured. Periodically, several different and

[11] https://www3.epa.gov/ttn/amtic/aapgvp.html
[12] https://www.epa.gov/air-research/epa-traceability-protocol-assay-and-certification-gaseous-calibration-standards
[13] http://www3.epa.gov/ttn/amtic/files/ambient/qaqc/OzoneTransferStandardGuidance.pdf

independent sources of zero should be compared. The one that yields the lowest response can usually (but not always) be assumed to be the "best zero device/standard." If several independent zero device/standards produce exactly the same response, it is likely that all the standards are adequate. Appendix K of this Handbook provides some additional guidance on testing zero air generators.

12.2 Calibration Procedures

Ambient air monitoring technology has significantly advanced in recent years. With those advancements, some of the calibration techniques and manual calculations discussed in earlier versions of this Handbook are no longer necessary. Most continuous analyzers in use today have a linear response across their operating range, in part because of the sophistication of the electronics housed within the analyzers. This advancement in technology has led to a simplification of the calibration process.

For example, many older analyzers required operators to make coarse adjustments during calibrations by manually adjusting potentiometers, with repeated adjustments necessary in order to fine-tune the instrument's response. The recorder outputs of these older analyzers were connected to the input terminals of a paper strip chart recorder (or similar data collection device); adjustments to the analyzer were judged by observing the analyzer's response on the paper strip chart. Using this set-up, after successfully adjusting the analyzer's zero and span potentiometers, the operators would generate additional concentrations and, afterwards, manually calculate a best-fit straight line using the method of least squares. Subsequent analyzer concentrations would be determined using that manually calculated slope/intercept. Today, however, modern analyzers are calibrated by simply tapping a series of buttons on the analyzer's touch screen, located within an electronic calibration submenu. The calibration consists of an adjustment to the analyzer's zero and span settings only; pressing the appropriate pushbuttons on the analyzer's front panel or touch-screen effectively adjusts the analyzer's stored settings and, thus, calibrates (adjusts) the analyzer. (These zero and span settings may be referred to by other names depending upon the instrument manufacturer.) Subsequent concentrations are automatically computed by the analyzer.

With this in mind, to perform a calibration on a modern ambient air monitoring analyzer, the operator will first generate a zero concentration using a high quality zero air source. Once the analyzer response has stabilized on the zero reading (see Section 10 for a discussion on stability), the operator will adjust the analyzer's internal zero setting (using the appropriate pushbuttons on the front panel or touch screen), so that it matches the concentration supplied by the zero air source. Next, the operator will generate a high test (span) concentration using a certified standard (e.g., an ozone photometer, an EPA protocol gas cylinder). As with the zero reading, the operator will allow the analyzer's response to the known span gas concentration to stabilize. Afterwards, the operator will adjust the analyzer's internal span setting so that it matches the known concentration of the certified standard. In some cases, adjustment of zero affects span response or vice versa; therefore, this process may need to be repeated to obtain the desired response. Once completed, the analyzer is, technically, "calibrated" (adjusted). The operator may need to modify its data acquisition system (DAS) channel configurations as a result of this adjustment process, depending on instrument set-up (see below).

Monitoring organizations should reference the analyzer's user manuals for more detailed explanation and specific instructions regarding calibration procedures. After adjusting the analyzer's internal zero/span settings, a multi-point verification will need to be completed in order to determine the analyzer's linearity (see Section 12.3).

Digital versus Analog Configurations

The operator may need to perform a few additional steps in conjunction with an analyzer calibration, in order to ensure accurate data collection. Whether these additional steps are necessary depends on whether the analyzer is connected to the DAS using analog or digital outputs. The preferred approach, and most simplistic, is to operate the analyzer using digital outputs to the DAS. In this configuration, the data that is collected by the DAS is the same as that determined internally and displayed on the front-panel of the analyzer. With that in mind, once the analyzer's internal zero and span settings are adjusted, the operator does not need to take any more actions.

If the analyzer is connected to the DAS using analog outputs, however, additional actions are needed in order to ensure the analyzer and DAS successfully work in tandem. Unlike the digital analyzer/DAS configuration which results in a direct throughput, using analog, the analyzer outputs a voltage signal to the DAS. The DAS then interprets (scales) the voltage and converts it into the appropriate engineering unit (i.e., ppm, ppb, etc). With that in mind, a separate analog output verification/calibration procedure should be conducted prior to the calibration. (The analog output board of the analyzer, as well as the input board of the DAS, may need to be calibrated as part of this process. See Appendix G of this Handbook for more information.) The analog output calibration ensures that the values recorded by the DAS will match the internally-calculated values that are produced by the analyzer. Some monitoring organizations may also configure DAS channels that correct output voltages to concentrations within the DAS by applying a regression curve to the input signals (voltages). In this configuration, a "math channel" is essentially programmed within the DAS that will apply a regression analysis to all subsequent voltages. This approach requires the math channel to be properly updated during each subsequent calibration (i.e. correct scaling values (slope/intercept) are programmed into the DAS). The caveat to this approach is, if the math channel is not properly updated, the DAS and analyzer may not be accurately synced, causing resulting data values to be skewed.

Both digital and analog configurations are acceptable for use in monitoring networks. However, as many analyzers and dataloggers are currently digital-capable, and it is anticipated that more makes and models of instruments will become digital-capable in the future, EPA strongly encourages monitoring organizations to upgrade from analog to digital communications. The calibration process itself is simplified when using digital outputs, and the quality of data potentially enhanced due to the reduced risk of errors associated with configuring DAS channels for analog communications. Another advantage to a digital set-up is that physical adjustments to the analyzer's zero and span settings can be completed remotely, if necessary, and instrument diagnostics can be viewed in real-time. Monitoring organizations should make provisions for the digital upgrade in their 5 to 7-year equipment replacement plans.

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. EPA discourages the use of both zero and automatic span adjustments (which would impact the analyzer's slope), but considers automatic zero adjustments reasonable when: 1) the automatic zero standards pass through the sample probe inlet and sample conditioning system, 2) the zero test is performed every day and applied to the following 24-hour period, 3) the zero reading is within the 24-hour acceptance criterion, and 4) both the adjusted and unadjusted zero response readings can be obtained from the data recording device. Zero adjustments cannot be used to correct data prior to zero test. EPA does not suggest zero adjustments be performed if the zero checks occur once every two weeks.

Self-adjustments to the analyzer's zero setting are an electronic means to fine-tune the analyzer's baseline; the zero offset is, in essence, "reset" every 24 hours. It is expected that the difference between the unadjusted and adjusted zero response is negligible and not greater than the zero drift acceptance criterion listed in the appropriate data validation template (see Appendix D of this Handbook). Corrective actions and data invalidation should occur if the differences between the 24-hour unadjusted and adjusted zero drift is greater than the validation template acceptance criterion**.** Dataloggers should be programmed to provide flags or warnings of this occurrence.

Automated zero adjustment does not correct the routine data collected before the adjustment. With that in mind, EPA emphasizes that zero adjustment as discussed here does not mean a post-processing correction on zero (i.e., adjusting the previous 24 hours of routine data based on the difference between the current zero reading and the previous 24-hour reading). Furthermore, EPA does not recommend making automatic or manual adjustments (corrections) to the span singly under any circumstances. If the analyzer's span has drifted such that the span drift acceptance criterion listed in the appropriate data validation template has been exceeded, corrective actions are required, including a complete recalibration of the analyzer (i.e., adjusting the analyzer's internal zero/span settings, followed by a multi-point verification).

12.3 Multi-point Verifications

As discussed earlier the term "calibration" means an **adjustment** – in either the instrument or software. Multi-point verifications, on the other hand, are considered "checks without correction" (i.e., **no adjustment**) and are used to ensure the instruments are within their respective calibration tolerances. With that in mind, multi-point verifications are sometimes referred to as "calibration verifications." Generally speaking, as long as the instrument is within its established calibration tolerances, adjustments do not need to be made.

As stated previously, calibration of an ambient air monitoring analyzer is a two-part process. After the analyzer's internal zero/span settings have been calibrated (i.e., adjusted), the second stage of the process involves the multi-point verification – i.e., the check of the analyzer's responses across its calibration scale to confirm linearity and assess the overall success of the calibration (adjustment).

Multi-point verifications generally consist of a zero and 4 upscale points. Traditionally, the upscale points encompassed the full scale operating range of the instrument, as defined in its FRM/FEM approval documentation. The concentration points were evenly spaced across that range, with the highest test concentration generated at approximately 80% full scale. Today, however, it is acceptable for the analyzer to be adjusted on a reduced "calibration scale" (see *Full Scale versus Calibration Scale* above), with the highest calibration concentration to be one above the NAAQS (for SLAMS criteria pollutants) and higher than any routine values one might expect at the site. For example, an analyzer may be calibrated to a 0-150 ppb calibration scale. Under this scenario, the multi-point verification may be performed using test concentrations such as 0, 120 ppb (~80% calibration scale), 90 ppb, 60 ppb, and 30 ppb. Other variations of the test gas concentrations are acceptable. It is important to note, however, that test concentrations should not be generated that are outside of the calibration scale. For example, it is unacceptable for a monitoring organization to calibrate their analyzers on a 0-100 ppb scale and then run verification points that are at 250 ppb or 180 ppb, for example. All test concentrations should be generated **within** the specific calibration scale upon which the analyzer has been adjusted.

After the zero and span adjustments described in Section 12.2 have been completed, the operator should allow the analyzer additional time to stabilize on the new zero and span settings prior to beginning the multi-point verification. Upon commencement of the multi-point verification, the operator should generate a zero test concentration to confirm that the setting of the analyzer's internal zero was successful and showed no "drift", as defined in the monitoring organization's SOP. Afterwards, the concentration used to set the analyzer's span should be generated again in order to confirm the span adjustment was successful and also showed no "drift". Afterwards, additional test concentrations should be generated that fall within the calibration scale of the analyzer. All test concentrations should be introduced into the analyzer, with response readings obtained from the same device (chart recorder, data acquisition system, etc.) that will be used for subsequent ambient measurements. Figure 12.1 below provides a visual representation of this process as it would appear on an electronic strip chart that works in conjunction with the analyzer and DAS.

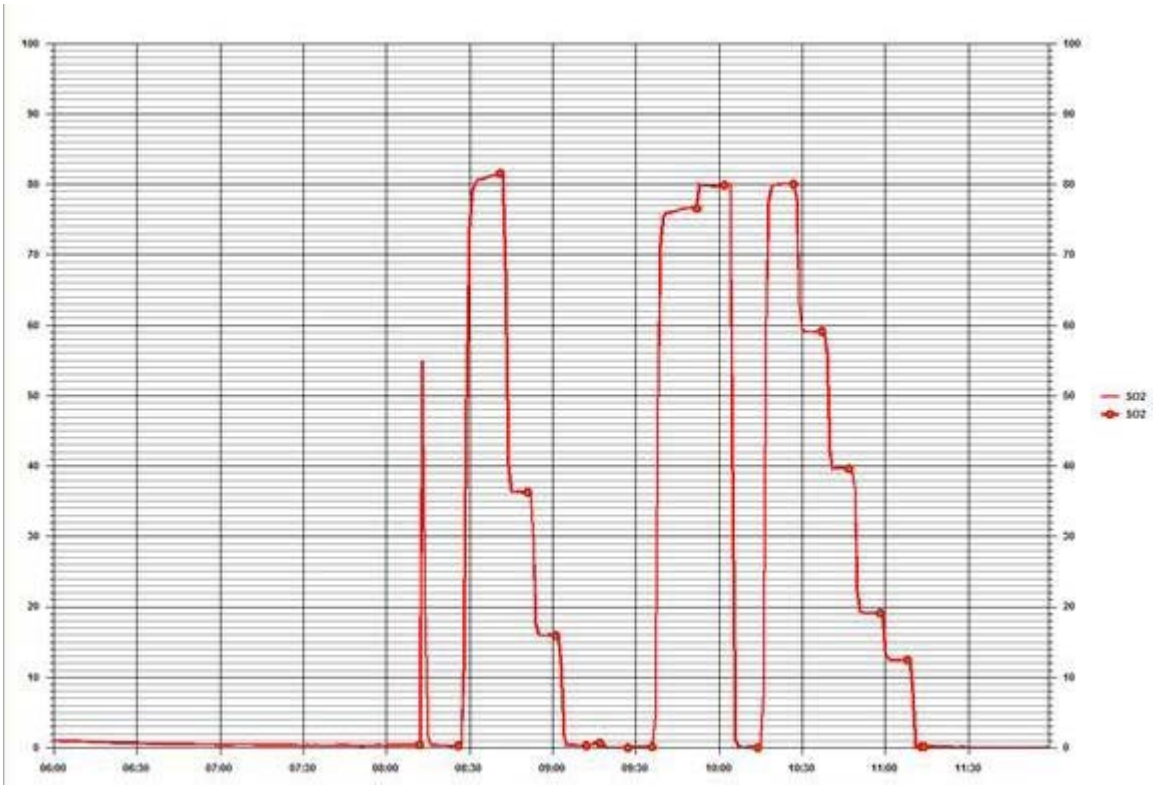
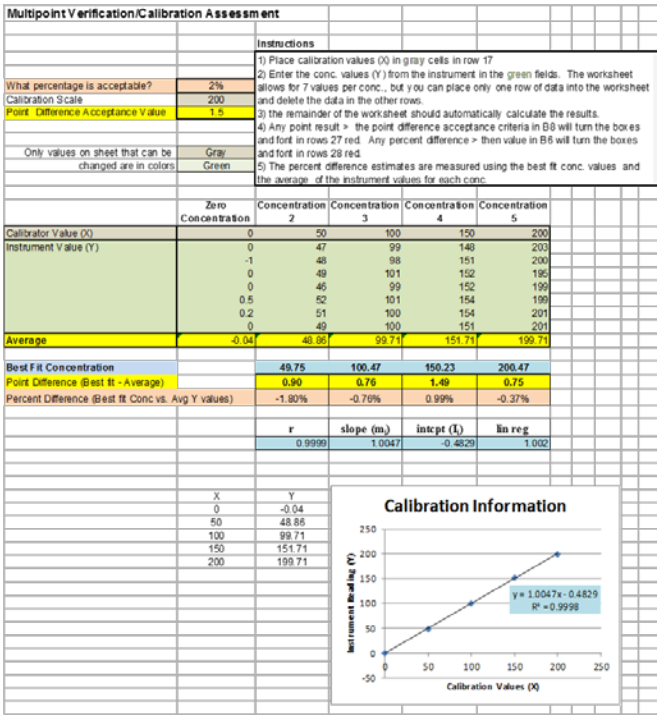


Figure 12.1 Electronic Chart Display of an SO_2 Calibration Procedure

The figure provides a 6-hour snapshot of an SO_2 analyzer's readings. The first set of "stair-steps" on the graph represents a quality control check which indicates that acceptance criteria have been exceeded and an adjustment is needed. The setting of the analyzer's zero and span settings can be observed next, followed by the multi-point verification. The "dots" on the graph represent annotations made by the operator to document this process.

During a multi-point verification, concentration points should be plotted against their respective test concentrations, and the best linear (or nonlinear, if appropriate) curve to fit the points should be determined. EPA notes that most modern analyzers have a linear or very nearly linear response with

concentration. 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 $y = mx + b$, where y represents the analyzer response, x represents the pollutant concentration, m is the slope, and b is the y-axis intercept of the best-fit calibration line. EPA has developed a Data Assessment Statistical Calculator (DASC)[14] tool that automates this process for data evaluation (See Figure 12.1), which monitoring organizations may wish to utilize. Any deviant points should be investigated or repeated immediately before the analyzer is assumed to be ready for ambient data collection.



Multipoint Verification/Calibration Assessment

Instructions

1) Place calibration values (X) in gray cells in row 17
2) Enter the conc. values (Y) from the instrument in the green fields. The worksheet allows for 7 values per conc., but you can place only one row of data into the worksheet and delete the data in the other rows.
3) the remainder of the worksheet should automatically calculate the results.
4) Any point result > the point difference acceptance criteria in B8 will turn the boxes and font in rows 27 red. Any percent difference > then value in B6 will turn the boxes and font in rows 28 red.
5) The percent difference estimates are measured using the best fit conc. values and the average of the instrument values for each conc.

What percentage is acceptable?	2%
Calibration Scale	200
Point Difference Acceptance Value	1.5
Only values on sheet that can be changed are in colors	Gray
	Green

	Zero Concentration	Concentration 2	Concentration 3	Concentration 4	Concentration 5
Calibrator Value (X)	0	50	100	150	200
Instrument Value (Y)	0	47	99	148	203
	-1	48	98	151	200
	0	49	101	152	195
	0	46	99	152	199
	0.5	52	101	154	199
	0.2	51	100	154	201
	0	49	100	151	201
Average	-0.04	48.86	99.71	151.71	199.71
Best Fit Concentration		49.75	100.47	150.23	200.47
Point Difference (Best fit - Average)		0.90	0.76	1.49	0.75
Percent Difference (Best fit Conc vs. Avg Y values)		-1.80%	-0.76%	0.99%	-0.37%

r	slope (m_1)	intcpt (I_1)	lin reg
0.9999	1.0047	-0.4829	1.002

X	Y
0	-0.04
50	48.86
100	99.71
150	151.71
200	199.71

Figure 12.2 Calibration Section of DASC Tool

For the gaseous pollutants, the calibration (including the multi-point verification) is considered acceptable if all test concentrations fall within 2%, or an absolute difference of 1.5 ppb for O_3, SO_2 and NO_2 and 0.03 ppm for CO, of the calibration scale, best-fit straight line Which acceptance criteria (percent or absolute difference) is used depends on the concentration of the calibration points. It is also recommended that the slope is within 1±.05.

NOTE: For manual PM and Pb samplers, the flow rate, temperature, and pressure devices are checked at different settings. Acceptance criteria for these devices can be found in the MQO Tables in Appendix D.

As another 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.

Once the operator has completed the multi-point verification and determined that the analyzer's response falls within the acceptance criteria, no additional adjustments to the analyzer or DAS are needed. The operator can then enable the analyzer to resume ambient data collection. However, if the verification exceeds acceptance criteria, the operator should repeat the entire process, including resetting the analyzer's internal zero/span (as described in Section 12.2).

12.4 Frequency of Calibration and Analyzer Adjustment

Once an analyzer's calibration is established, it should be checked at reasonable frequencies to verify that it remains in calibration. The monitoring organization is charged with developing a quality system that

[14] http://www3.epa.gov/ttn/amtic/qareport.html

includes routine quality control checks to ensure the instrument continues to perform within the calibration tolerances. Multi-point verifications can be performed on a routine schedule (e.g., quarterly) to serve this purpose, in addition to other quality control checks (e.g., 1-point QC, flow rate verifications, etc). The multi-point verification (often referred to as an "unadjusted calibration") is an optimum QC check, because it challenges the analyzer with known test concentrations across its calibration scale. When performed on an operational analyzer in the field, the verification demonstrates the "as found" status of the analyzer and can be used for data validation purposes (see Section 12.5). Generally speaking, as long as the analyzer is found to be within the established acceptance limits, adjustments do not need to be made.

Given the advances in current monitoring technology, it is EPA's position that frequent **adjustments** (i.e., calibrations) of instruments should not be necessary and may in fact lead to more data quality uncertainty. Therefore, adjustments should be minimized as much as possible. Performing frequent adjustments to provide the "most accurate data possible" can sometimes be self-defeating and result in additional measurement uncertainty. For example, adjusting an instrument based upon a standard that might be degrading or contaminated may actually cause data to be farther from the true concentration. Moreover, some acceptable level of drift (i.e., deviation from an original or nominal response curve) is expected and therefore allowed before physical adjustments (i.e., calibration) must be made to an analyzer. Please see the Data Validation Templates in Appendix D of this Handbook for recommended acceptance criteria.

There are times, however, when adjustment (i.e., calibration or recalibration) of an analyzer is necessary. These include:

- upon initial installation,
- following physical relocation,
- after any significant repairs or service that might affect its calibration,
- following an interruption in operation (e.g., power failure) of more than a few days,
- upon any indication of analyzer malfunction or change in calibration (such as a failed QC check or audit), and
- at some prescribed routine interval (e.g., annually).

The monitoring organization should detail their business rules for conducting calibrations (recalibrations) in their QAPPs and SOPs, clearly specifying the circumstances under which adjustments are to be made to the analyzer. Multi-point verifications should be performed in conjunction with calibrations (recalibrations) to confirm the linearity of analyzers. Figure 12.3 below provides a flow chart that summarizes the calibration and multi-point verification process.

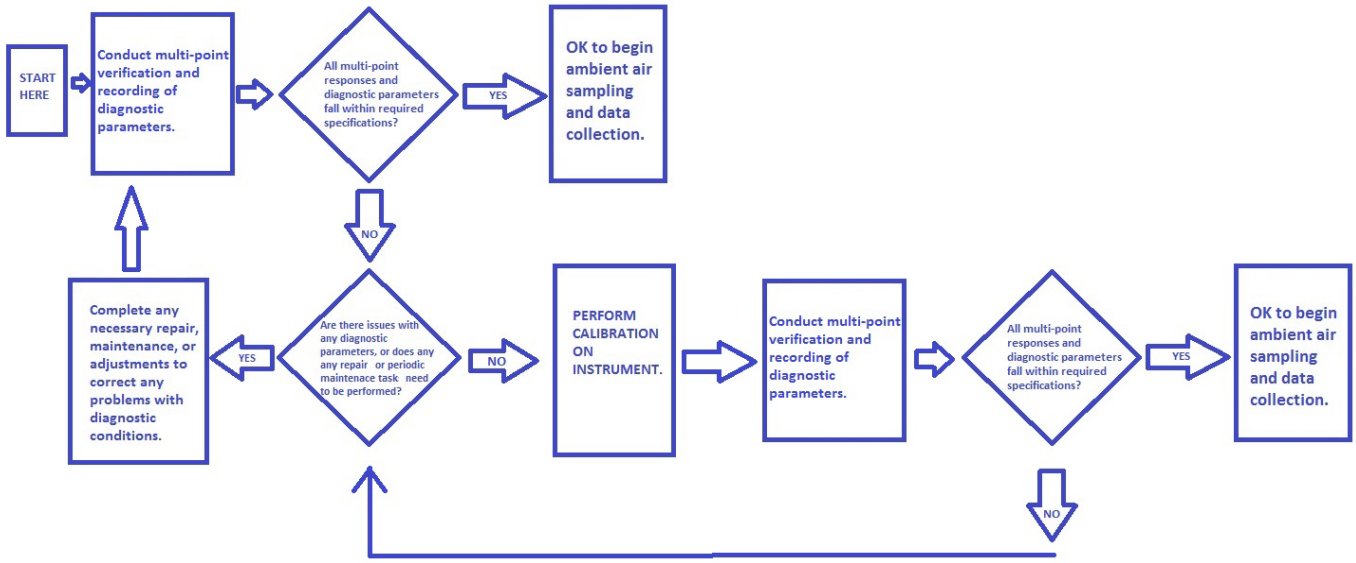


Figure 12.3 Calibration/Verification Process Flow Chart

> **NOTE:** EPA does **not** allow span adjustments be made between calibrations. If the span has drifted such that it exceeds the established acceptance criterion, the analyzer should be recalibrated (including appropriate adjustments and a multi-point verification). Zero (baseline) adjustments between calibration procedures are allowed, although not recommended. See Section 10.4 in this Handbook (*Zero Point* subsection) for more information.

To assist the monitoring organization in determining when a calibration (recalibration) is necessary, it is strongly recommended that control charts be used to monitor the zero/span and 1-point QC drift performance of each analyzer. Control charts can be constructed in different ways, but the important points are to visually represent and statistically monitor drift, and to be alerted if the drift becomes excessive so that corrective action can be taken. Such control charts make important use of the unadjusted zero and span response readings. (See Figure 10.5 in Section 10 of this Handbook for an example control chart.)

As a best practice, when a new monitoring instrument is first installed at a site, EPA recommends that zero/span and 1-point QC checks be performed frequently, perhaps daily or 3 times per week, because little or no information is available on the drift performance of the analyzer. With the advancement in data acquisition system technology, many monitoring organizations are running these QC checks daily. However, the QC checks are required to be implemented every two weeks. 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, if needed, to provide a suitable compromise among the various considerations mentioned above.

Ultimately, the frequency of this 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.

12.4.1 Instruments

The accuracy of various measurement devices in sampling is very important to data quality. For example, in order to produce the correct flow rate to establish an accurate $PM_{2.5}$ cut point, the temperature and barometric pressure sensors, as well as the flow rate device, must be producing accurate measurements. Table 12-1 provides some of the more prevalent instruments that need to be calibrated annually, at a minimum, or when shown through various verification checks to be out of acceptable tolerances. In addition, the audit standards used to implement the checks and calibrations should be certified annually in order to establish their accuracy and traceability to higher standards. Higher or more authoritative standards are those standards that are more precise, sensitive, and are closer in the certification chain to a NIST primary standard.

Table 12-1 Instruments and Devices Requiring Calibration and Certifications.

Criteria	Acceptable Range	40 CFR Reference
Verification/Calibration of Devices in sampler/analyzer/laboratory against an authoritative transfer standard		
Barometric Pressure	$\leq \pm$ 10.1 mm Hg	Part 50, App.L, Sec 9.3
Temperature	$\leq \pm$ 2.1^{o} C of standard	Part 50, App.L, Sec 9.3
Flow Rate	$\leq \pm$4.1% of transfer standard	Part 50, App.L, Sec 9.2
Design Flow Rate Adjustment	$\leq \pm$ 2.1% of design flow rate	Part 50, App.L, Sec 9.2.6
Clock/timer Verification	1 min/mo	Part 50, App.L, Sec 7.4
Microbalance Calibration	Readability 1 µg Repeatability 1 µg	Part 50, App.L, Sec 8.1
Verification/Calibration Standards requiring certification annually		
Standard Reference Photometer (SRP)[15]	Regression slope = 1.00 + 0.01 and intercept $\leq \pm$ 1 ppb	not described
Level 2 ozone standard reverification to SRP	Each individual point difference $\leq \pm$ 3%	not described
Flow rate	$< \pm$ 2.1% of NIST–Traceable Standard	Part 50, App L Sec 9.2
Pressure	$\pm$ 1 mm Hg resolution, $\pm$ 5 mm Hg accuracy	not described
Temperature	$\pm$ 0.1^{O}C of standard resolution, $\pm$ 0.5 ^{O}C accuracy	not described
Gravimetric Standards	Tolerance = Class 2 or better	not described

[15] For more information on ozone standards see *Transfer Standards For Calibration of Air Monitoring Analyzers for Ozone* https://www3.epa.gov/ttn/amtic/qapollutant.html

12.5 Validation of Ambient Data Based on Calibration Information

When zero or span drift validation limits are exceeded, ambient measurements should be invalidated back to the most recent acceptable zero/span/1-point QC check where such measurements are known to be valid. Also, data following an analyzer malfunction or period of non-operation should be regarded as invalid until the next subsequent calibration, unless unadjusted zero and span readings at that calibration can support its validity.

EPA does not recommend post-processing data to "correct" for data failing QC checks (e.g., span or 1-point QC), multi-point verifications, or performance evaluations (i.e., audits). For example, if after failure of a 1-point QC check a subsequent verification and calibration found that data was biased high by 15%, the previous routine data up until the last acceptable 1-point QC check is not adjusted down by 15% and reported. Based upon validation criteria, the data is either reported as initially measured or invalidated.

Documentation

All data and calculations involved in calibration activities should be recorded in the instrument log book described in Section 11.

13.0 Inspection/Acceptance for Supplies and Consumables

Both field operations and laboratory operations need supplies and consumables. The focus of this section is the management of laboratory and field sampling supplies and consumables. For information on the actual field/lab supplies and consumables needed for any specific method, see the reference method in 40 CFR Part 50[1], the general guidance methods and technical assistance documents on AMTIC[2], and the manufacturer's operations manuals. From this information, monitoring organizations, as part of the QAPP requirements, will develop specific SOPs for its monitoring and analytical methods. One section of the SOPs requires a listing of the acceptable supplies and consumables for the method.

Pollutant parameters are measured using electronic (e.g., continuous monitors, FTIRs, etc.), wet chemical techniques, or physical methods. Chemical analysis 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 collected. Frequently used chemical methods require adequate supplies of chemicals for operation (e.g., three months) so that the supplier can comply with the delivery schedules and there is no downtime waiting for supplies. 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*[3].

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/sample containers with due consideration for the need for special treatment of glassware/sample containers used in trace analysis.
- Establish a useful life for glassware/sample containers and track this.
- Discard chipped and etched glassware or damaged containers.

[1] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl
[2] http://www.epa.gov/ttn/amtic/
[3] Quality Assurance Principles for Analytical Laboratories, 3rd Edition. By Frederick M. Garfield, Eugene Klesta, and Jerry Hirsch. AOAC International (2000). http://www.aoac.org/

13.2 Standards and Reagents

Discussions on gaseous standards and reagents are found in Section 12. What is most important is that the standards and reagents used are of appropriate purity and certified within the acceptable limits of the program for which they are used. Table 12-1 provides certification frequencies for gaseous standards, but within these timeframes, and as new cylinders are purchased, monitoring organizations need to develop a standard checking scheme to establish ongoing acceptance of standards. A new SRM should be purchased months prior to the expiration (or need for recertification) or complete use of an older standard, in order to develop an overlapping cylinder acceptance process that maintains traceability and consistency in monitoring. For example, if a new SRM is put into use in a monitoring organization and all monitoring instruments traced to the cylinder start failing calibration, it may mean that either the new or older cylinder was not properly certified or has integrity problems. By checking both cylinders prior to new cylinder use, this issue can be avoided. Monitoring organizations need to consider participation in the Ambient Air Protocol Gas Verification Program (AA-PGVP). When purchasing cylinders, plan for additional lead time so a cylinder can be sent to a national regional air verification laboratory (RAVL) for verification. The RAVLs verify cylinders once a quarter and usually turn cylinders around in 30 days. The AA-PGVP is explained on AMTIC[4] and monitoring organizations may be required to participate in this program every 5 years.

13.2.1 Standard Solutions

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

- 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
- storage

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

13.2.2 Purified Water

Water is one of the most critical, but most often forgotten, reagents. 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.

[4] https://www3.epa.gov/ttn/amtic/aapgvp.html

13.3 Volumetric Glassware

Use of the appropriate glassware is important since many preparations and analyses 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 Sample Containers

Samples may be contaminated by using containers that have not been properly cleaned and prepared (e.g., VOC canisters, particulate filter cassettes/containers) or purchased from vendors without proper inspection prior to use. In addition, all sample containers have a "useful" life. Some containers, such as the low volume PM sample filter cassettes, can be damaged over time and cause leaks in the sampling system. It is important to track the inventory of sampling containers from:

- date of purchase;
- date of first use;
- frequency of use (estimate); and,
- time of retirement.

An inventory of this type can help ensure new containers are purchased before the expiration date of older containers. Use of appropriate sample containers is important since the construction material of the container could potentially affect the collected sample. Always refer to the specific method to see if a particular type of container (e.g., high density polyethylene [HDPE] bottles, amber glass) is required for the storage of the sample.

13.5 Particulate Sampling Filters

Filters are used for the collection of particulates using manual methods (e.g., PM_{10}, $PM_{2.5}$, $PM_{10-2.5}$, total PM, Pb, etc.). 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 provide detailed acceptance criteria for filters. Some of the basic criteria that must be met, regardless of the filter type, follow:

- **Visual inspection -** for pinholes, tears, creases, or other flaws that 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-weighing to assure the integrity of the filter is maintained throughout the data collection process.
- **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 in an inoperative sampler, removal from a sampler, re-equilibration, and final weighing).
- **Alkalinity** - less than 25 microequivalents/gram of filter following at least two months of storage at ambient temperature and relative humidity.

NOTE: 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 meeting 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 that will be supplied to monitoring organizations.

Monitoring organizations have reported what appears to be "rusting" or contamination on $PM_{2.5}$ backing screens which may be affecting the deposition of particulates on filters. Inspection of these backing screens and a procedure for replacement should be developed.

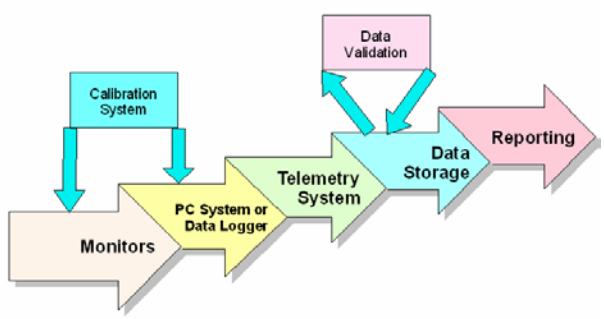
13.6 Field Supplies

Field instrumentation, which includes samplers and analyzers, require supplies for the actual collection process as well as quality control activities and crucial operational maintenance. These supplies can include, but are not limited to:

- Gas standards/Permeation standards
- HVAC units
- Maintenance equipment (tools, ladders)
- Safety supplies (first aid kits)
- Information technology supplies (PC, printers, cables, paper, ink, discs, flash drives)
- Sample line filters
- Charcoal
- Desiccant
- Gaskets and O-rings
- Sample lines and manifolds
- Disposable gloves
- Water/distilled water
- Pumps and motors
- Chart paper and ink
- Impaction oil
- TEOM FDMS filter

The site logbook discussed in Section 11 should include a list and inventory of these critical field supplies. As part of routine maintenance activities, this inventory can be reviewed to determine if any supplies are in need of restocking. If electronic logbooks are used, information from each site can be aggregated at the field office to better assess needs and develop efficient ordering processes.

14.0 Data Acquisition and Information Management



Achieving air monitoring objectives depends, in part, on collecting data that are:

- reliable;
- of known quality;
- easily accessible to a variety of users; and
- aggregated in a manner consistent with its primary use.

In order to accomplish this, information must be collected and managed in a manner that protects and ensures its integrity. Data management is the "development, execution and supervision of plans, policies, programs and practices that control, protect, deliver and enhance the value of data and information assets"[1].

Most of the data reported by the monitoring organization will be collected through automated systems. These systems must be effectively managed according to a set of guidelines and principles designed to ensure data integrity. The EPA document Good Automated Laboratory Practices (GALP)[2] defines six data management principles that are worth reviewing:

1. **Laboratory management must provide a method of assuring the integrity of all laboratory information management systems (LIMS) 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. **The formulas and decision algorithms employed by the LIMS must be accurate and appropriate.** Users cannot assume that the test or decision criteria are correct; those formulas must be inspected and verified.
3. **A critical control element is the capability to track LIMS raw data entry, modification, and recording to the responsible person.** This capability utilizes a password system or equivalent to identify the time, date, and person or persons entering, modifying, or recording data.
4. **Consistent and appropriate change controls, capable of tracking the LIMS operations and software, are a vital element in the control process.** All changes must follow carefully planned procedures, be properly documented, and when appropriate, include acceptance testing.
5. **Procedures must be established and documented for all users to follow. Control of even the most carefully designed and implemented LIMS will be thwarted if the user does not follow these procedures.** This principle implies the development of clear directions and SOPs, the training of all users, and the availability of appropriate user support documentation.
6. **The risk of LIMS failure requires that procedures be established and documented to minimize and manage their occurrence.** Where appropriate, redundant systems must be

[1] https://en.wikipedia.org/wiki/Data_management DAMA-DMBOK Guide (Data Management Body of Knowledge) Introduction & Project Status"
[2] Good Automated Laboratory Practices

installed and periodic system backups must be performed at a frequency consistent with the consequences of the loss of information resulting from a failure. The principle of control must extend to planning for reasonable unusual events and system stresses.

Although the GALP is written for LIMS, the principles listed above are applicable to ambient air monitoring information management systems in the field and at the central office. This section provides guidance in these areas, including identification of advanced equipment and procedures that are recommended for implementation. The recommended procedures rely on digital communication by the data acquisition system to collect a wider variety of information from the analyzers/samplers, to control instrument calibrations, and to allow for more routine, automated, and thorough data quality efforts. The section will discuss:

1. **Data acquisition-** collecting the raw data from the monitor/sampler, storing it for an appropriate interval, aggregating or reducing the data, and transferring this data to final storage in a local data base (i.e., monitoring organization's database);
2. **Data transfer**- preparing and moving data to external data bases such as AirNow or the Air Quality System (AQS); and,
3. **Data management**- the development, execution and supervision of plans, policies, programs, and practices that control, protect, deliver and enhance the value of data and information assets.

In response to guidelines issued by the Office of Management and Budget (OMB)[3], EPA developed the document titled *Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by the Environmental Protection Agency*[4] (The Guideline). The Guideline contains EPA's policy and procedural guidance for ensuring and maximizing the quality of information it disseminates. The Guideline also incorporates the following performance goals:

- Disseminated information should adhere to a basic standard of quality, including objectivity, utility, and integrity.
- The principles of information quality should be integrated into each step of EPA's information development process, including creation, collection, maintenance, and dissemination.
- Administrative mechanisms for correction should be flexible, appropriate to the nature and timeliness of the disseminated information, and incorporated into EPA's information resources management and administrative practices.

EPA suggests that monitoring organizations review this document, since it is relevant to the ambient air information they generate and can help ensure such data can withstand challenges to its quality.

[3] Section 515(a) of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554; H.R. 5658) https://www.whitehouse.gov/omb/fedreg_reproducible

[4] https://www.epa.gov/quality/guidelines-ensuring-and-maximizing-quality-objectivity-utility-and-integrity-information

14.1 Data Acquisition Systems

Continuing advances in computer technology used in monitoring instruments and data loggers are:

- Increasing the volume of the pollutant data stream by enabling the capture of more finely, time-resolved data,
- Providing operational data about instruments that supports data validation and helps to reduce data loss by identifying problems early, and
- Making more data available to users, sooner.

In order to take full advantage of these capabilities, data management software systems will need to support efficient processing and validation of data and provide communication of that data in a format and timeframe that serves the needs of multiple users. An example of a benefit from using these systems is the forecasting of pollution episodes with near real-time data captured from NCore and ozone monitoring networks.

This section provides information on Data Acquisition Systems (DAS), a term used for systems that collect, store, summarize, report, print, calculate or transfer data. The transfer is usually from an analog or digital format to a digital medium. This section will also discuss limitations of data collected with DAS.

14.1.1 Automated Data Acquisition Systems

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.

14.1.2 Instrument to Data logger

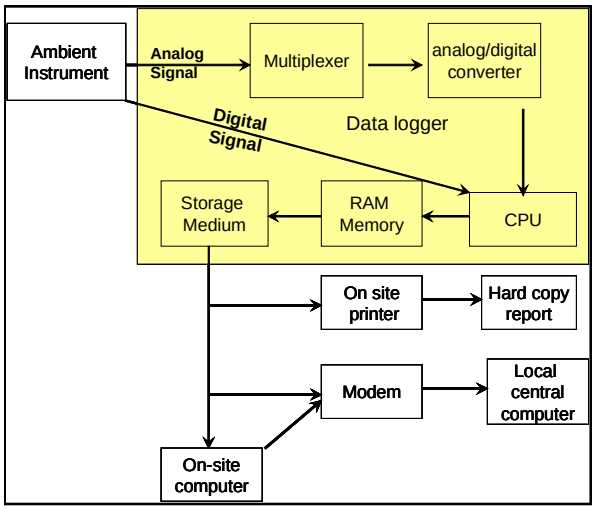


Figure 14.1 DAS data flow

Figure 14.1 shows the basic transfer of data from the instrument to the final product: a hard copy report, or data transfer to a central computer. Most continuous monitors have the ability to output data in at least two ways*:* analog output and an RS-232 digital port. Some instrumentation now includes USB, Ethernet, and firewire capability. The instrument usually uses 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 following provide a brief summary of the analog (A) or digital (D) steps.

- (A) The voltage is measured by the multiplexer, which allows voltages from many instruments to be read at the same time.
- (A) The multiplexer sends a signal to the analog/digital (a/d) converter, which changes

the analog voltage to a low amperage digital signal.

- (A) 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.
- (A/D) The CPU then shunts the data from the RAM to the storage medium, which can be magnetic tape, computer hard-drive, or computer diskette.
- (A/D) The computer storage medium can be accessed remotely or at the monitoring location.

The data transfer may occur via modem to a central computer storage area or printed out as hard copy. In some instances, the data may be transferred from one storage medium (e.g., hard drive to a diskette, tape, flash drive or CD) to another storage medium. 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 can be accomplished by polling a period of data directly from the monitor and comparing that data to data that's stored in the local central computer.

Analog Versus Digital DAS -

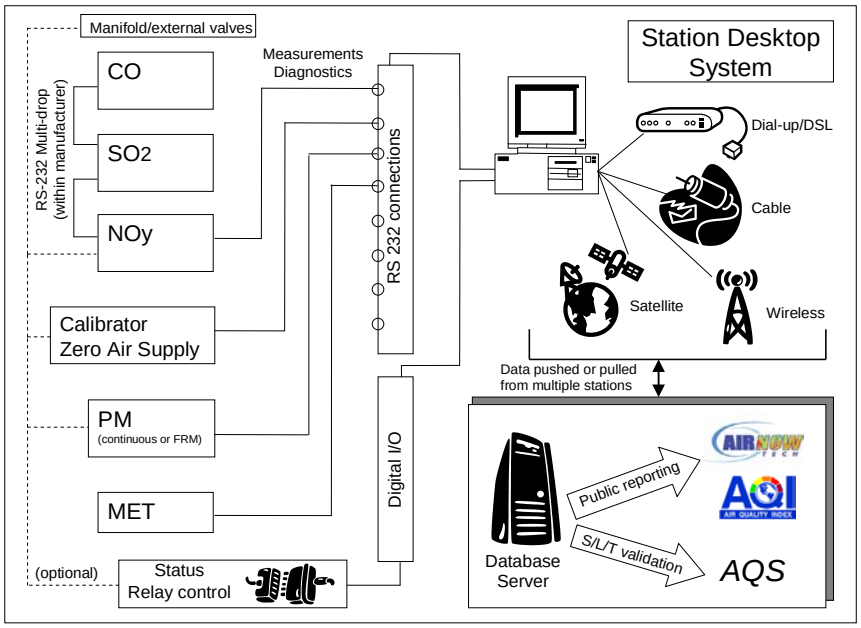


Figure 14.2 Flow of data from gas analyzers to final reporting

Most analyzers built within the last 15 years have the capability (RS-232 ports) to transfer digital signals, yet many monitoring organizations currently perform data acquisition of automated monitors by recording an analog output from each gas analyzer using an electronic data logger. As explained above, the analog readings are converted and stored in digital memory in the data logger for subsequent automatic retrieval by a remote data management system. This approach can reliably capture the monitoring data, but does not allow complete control of monitoring operations; additionally, the recorded analog signals are subject to noise that limits the detection of low concentrations. Furthermore, with the analog data acquisition approach, the data review process is typically labor-intensive and not highly automated. For these reasons, EPA encourages the adoption of digital data acquisition methods. In that regard, the common analog data acquisition approach often does not fully utilize the capabilities of the electronic data logger. Many data loggers have the capability to acquire data in digital form and to control some aspects of calibrations and analyzer operation, but these capabilities are not utilized in typical analog data acquisition approaches.

Digital data acquisition reduces noise in the recording of gas monitoring data, thereby improving sensitivity. It also records and controls the instrument settings, internal diagnostics, and programmed activities of monitoring and calibration equipment. Such data acquisition systems also typically provide automated data quality assessment as part of the data acquisition process.

It may be cost-effective for monitoring organizations to adopt digital data acquisition and calibration control simply by more fully exploiting the capabilities of their existing electronic data loggers. For example, many gas analyzers are capable of being calibrated under remote control. The opportunity to reduce travel and personnel costs through automated calibrations is a strong motivator for monitoring organizations to make greater use of the capabilities of their existing data acquisition systems. The NCore multi-pollutant sites are taking advantage of the newer DAS technologies. Details of these systems can be found in the NCore technical assistance document[5].

Figure 14.2 illustrates the recommended digital data acquisition approach for the NCore sites. It presents the data flow from the gas monitors, through a local digital data acquisition system, to final reporting of the data in various public databases. This schematic shows several of the key capabilities of the recommended approach. A basic capability is the acquisition of digital data from multiple analyzers and other devices, thereby reducing noise and minimizing the effort needed in data processing. Another capability is two-way communication, so that the data acquisition system can interrogate and/or control the local analyzers, calibration systems, and even sample inlet systems, as well as receive data from the analyzers. Data transfer to a central location is also illustrated, with several possible means of that transfer shown. Monitoring organizations are urged to take advantage of the latest technology in this part of the data acquisition process, as even technologies such as satellite data communication are now well established, commercially available, and inexpensive to implement for monitoring operations.

Depending on the monitoring objective, it may be important for data to be reported in formats that allow for immediate use in public databases such as AQS[6], and the multi-monitoring organization AirNow[7] sites. An advantage of DAS software is the ability to facilitate the assembly, formatting and reporting of monitoring data to these databases.

Digital data acquisition systems such as those in Figure 14.2 offer a great advantage over analog systems in the tracking of calibration data, because of the ability to control and record the internal readings of gas analyzers and calibration systems. That is, not only can a digital data acquisition system record the analyzer's output readings, but it can also schedule and direct the performance of analyzer calibrations, as well as record calibrator settings and status. Thus, flagging of calibration data to distinguish them from ambient monitoring data are conducted automatically during data acquisition with no additional effort or post-analysis. These capabilities greatly reduce the time and effort needed to organize and quantify calibration results.

[5] Version 4 of the Technical Assistance Document for Precursor Gas Measurements in the NCore Multi-pollutant Monitoring Network. http://www3.epa.gov/ttn/amtic/ncoreguidance.html
[6] http://www.epa.gov/aqs/
[7] https://cfpub.epa.gov/AirNow/

14.1.3 DAS Quality Assurance/Quality Control

Most automated data acquisition systems support the acquisition of QC data, such as zero, 1-point QC, span, and calibration data. When QC data are acquired automatically by a data acquisition system for direct computer processing, the system must be sufficiently sophisticated to:

- Ensure that the QC data are never inadvertently reported as ambient measurements,
- Ignore transient data during the stabilization period before the analyzer has reached a stable QC response (this period may vary considerably from one analyzer to another),
- Average the stable QC readings over some appropriate time period so that the readings obtained accurately represents the analyzer's QC response,
- Ignore ambient readings for an appropriate period of time immediately following a QC reading until the analyzer response has stabilized to the ambient-level concentration.

In relation to the DAS, quality assurance seeks to ensure that the DAS is being operated within defined guidelines. Usually, this means that each value that is collected by the DAS is the same value that is generated from the analyzer and reported to the Air Quality System (AQS) database. This usually is accomplished by DAS calibrations and data trail audits.

Calibration- In the case where analog signals from monitoring equipment are recorded by the DAS, the calibration of a DAS is similar to the approach used for calibration of a strip chart recorder. To calibrate the DAS, known voltages are supplied to each of the input channels and the corresponding measured response of the DAS is recorded. Specific calibration procedures in the DAS owner's manual should be followed when performing such DAS calibrations. For DAS that receive digital data from the instruments, a full scale check (i.e., the instrument is in a mode and the output is at the full scale of the instrument) should be performed to see if the data received digitally is the same as the display of the instrument. The DAS should be calibrated at least once per year. Appendix G provides a simple approach for calibration of the DAS.

In addition, gas analyzers typically have an option to set output voltages to full scale or to ramp the analog output voltages supplied by the analyzer over the full output range. Such a function can be used to check the analog recording process from the analyzer through the DAS.

Data Trail Audit- The data trail audit consists of following a value or values from the monitoring instrument to the DAS, from the DAS to the local central computer, and then from the local central computer to AQS. A person other than the normal station operator should perform this duty. A procedure similar to the following should be conducted:

- A data value(s) should be collected from the monitor (usually an hourly value or another aggregated value reported to AQS) and be compared to the data stored in the DAS for the same time period. Also, if strip chart recorders are used, a random number of hourly values should be compared to the data collected by the DAS. This audit should be completed on a regular defined frequency and for every pollutant reported.
- From the central computer, the auditor checks to see if this hourly value is the same.

The above actions should be completed well in advance of data submittal to AQS. If the data has been submitted to AQS, then the AQS database should be checked and modified as necessary per the appropriate AQS procedures.

Whether a monitoring organization is transferring the data from an instrument via an on-site DAS or transferring the data digitally, the data trail audit should be performed on a routine basis.

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 are collected and reported. Read the analyzer manufacturer's literature before parameters are collected. If the manufacturer does not 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 G 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 are collected during calibrations and down time should be flagged correctly.
- Check the DAS for excessive noise (variability in signal). Noisy data that are outside of the normal background are 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. However, EPA recommends that 45 minutes of data be considered a valid hour (see Section 6 of this Handbook for more information).

14.1.4 Data Logger to Database

Once data are on the data logger at the ambient air monitoring station, they need to be sent to servers where they can be summarized and disseminated to data users. In most cases this will occur by using a server at the office of the monitoring organization. The conventional way to get data from the monitoring stations has been to poll each of the stations individually. With more widespread availability of the internet, pushing data from monitoring sites on a regular basis will be especially effective in mapping and public reporting of data. Note, in some cases it is possible to report data directly from a monitor to a database without the use of a station data logger. This solution is acceptable so long as the monitor is capable of data storage for periods when telemetry is off-line.

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, internet, satellite or other advanced means of communication. Due to the desire for real time data for the Air Quality Index (AQI) and other related needs, monitoring organizations should plan to upgrade to digital data acquisition and communication systems.

Hard copy report- With the advent of sophisticated DAS networks and data backup systems, hard copy reports are being generated less frequently. Therefore, if hard copy reports are not being used, it is

strongly recommended that monitoring organizations create an electronic back-up of their data on a defined and frequent schedule. The frequency of the back-ups and any other associated information should be reflected in their Quality Assurance Project Plan (QAPP) and Standard Operating Procedures (SOP). However, for some smaller monitoring networks, hard copy reports have some advantages*:*

- They can be reviewed by the station operators prior to and/or during site visits to ascertain the quality of the data;
- They can be compared against the historical data stored on the DAS at the site for validation;
- Notes can be made on the hard copy reports for later review by data review staff; and
- They create a "back-up" to the electronically-based data.

External Storage- This term refers to storing and transferring the data on external media such as diskettes, flash drives, or CD-ROM's. Many new generation DAS are computer platforms that contain ports for these storage devices. If remote access via telephone is not an option, then data can be hand-transferred to a central office for downloading and data review. This is usually the method used to transfer data from manual methods (e.g., $PM_{2.5}$ FRM samplers).

Digital Transfer- All new generation DAS 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 appropriate staff at the central location can begin to diagnose problems and decide a course of action;
- Downloading the data allows the station operators, data processing team, and/or data validators to get a head start on reviewing the data; and
- When pollution levels are high or forecasted to be high, digital transfer allows the pollution forecaster the ability to remotely check trends and ensure proper operation of instruments prior to and during an event.

NOTE: In any of these systems it is necessary to plan for some type of system back-up in case of unexpected crashes in order to reduce and minimize data loss.

14.1.5 Manual Data Acquisition

Most of this section has been devoted to the collection of data through automated DAS. In some ways, once the DAS is properly set up and checked, the systems are reliable, can be checked remotely, and are easier to manage than manual data acquisition. Recovery and collection of data from manual samplers can be more complicated: it includes the retrieval of not only samples (which may include the use of hand-entered data sheets and chain-of-custody forms), but also electronic sampler information downloaded to USB flash drives or portable laptops for transfer to central offices. The process is further complicated by weather conditions and sample shipping to remote laboratories where additional logging of samples and data take place. Monitoring organizations should identify all critical information necessary for a sampling activity and have SOPs for the procedures necessary to collect all important information pertaining to the sample. As soon as possible, any hand-entered information should be recorded electronically. Samplers have some storage capacity, so it is suggested that no data be cleared off the samplers until it is confirmed that the sampler data has been downloaded and stored in the central office database. Once stored electronically, the management of this information should follow the same procedures as those for automated data retrievals.

14.2 Data Transfer – Public Reporting

The area of public reporting for air monitoring data may provide the largest number of data users. For public reporting of the AQI, the AirNowAirNow web site will remain the EPA's primary medium for distribution of near real-time air monitoring data. The additional continuous monitoring parameters collected from NCore will also be reported to AirNow. These parameters are expected to be made publicly available for sharing throughout technical user communities. However, they are not expected to be widely distributed through AirNow as products for public consumption.

This section will discuss the transfer of data from the monitoring organization to two major data repositories: 1) AirNow for near real-time reporting of monitoring data, and 2) AQS for long-term storage of validated data.

14.2.1 Real-time Data Reporting to AirNow

One of the most important emerging uses of ambient monitoring data has been public reporting of the Air Quality Index (AQI). This effort has expanded on EPA's AirNow web site from regionally-based near real-time ozone mapping products color-coded to the AQI, to a national multi-pollutant mapping, forecasting, and data handling system of real-time data. Since ozone and $PM_{2.5}$ drive the highest reporting of the AQI in most areas, these two pollutants are the only two parameters currently publicly reported from AirNow. This program allows for short-term, non-validated data to be collected by a centrally located computer that displays the data in near real-time data formats such as tables and contour maps.

While other pollutants such as CO, SO_2, NO_2, and PM_{10} may not drive the AQI, they are still important for forecasters and other data users to understand for model evaluation and tracking of air pollution episodes. Therefore, for the NCore sites, the goal is the report all gaseous CO, SO_2, NO and NOy data, as well as base meteorological measurements, to AirNow.

Reporting Intervals

Currently, hourly averages are the reporting interval for continuous particulate and gaseous data. These are the reporting intervals for both AQS (AQS supports a variety of reporting intervals) and AirNow for AQI purposes**.** These reporting intervals will meet most of the multiple objectives of NCore for supporting health effects studies, AQI reporting, trends, NAAQS attainment decisions, and accountability of control strategies. However, with these objectives also comes the desire for data at finer time resolutions: In 2010, EPA required the reporting of maximum 5-minute block average SO_2 concentration of each hour.. Examples of this need for finer time resolution of data include, but are not limited to: tracking air pollution episodes, providing data for exposure studies, model evaluation, and evaluating shorter averaging periods for potential changes to the NAAQS. Monitoring organizations generally have the hardware and software necessary to log and report this data. The challenge to obtaining and reporting the data is the current communication packages used, such as conventional telephone modem polling. One widely available solution to this would be the use of internet connectivity: allowing data at individual monitoring sites to be pushed to a central server rather than being polled. Monitoring organizations should begin to investigate the possibilities of using this media.

With the generation/reporting of data at shorter averaging intervals, the challenge becomes validation of all the data. The historical perception has been that each criteria pollutant measurement needs to be verified and validated manually. With the amount of data generated, this would be a time-consuming task.

To provide a nationally consistent approach for the reporting interval of data, the NCore networks will take a tiered approach to data reporting. At the top tier, hourly data intervals will remain the standard for data reporting. Long term, the NCore networks will be capable of providing at least 5-minute intervals for those methods that have acceptable data quality at those averaging periods. For QA/QC purposes, such as zero/span and one-point QC, monitoring organizations should be capable of assessing data on a 1-minute interval, at a minimum.

With instantaneous data going to external websites, monitoring organizations operating their own websites containing the same local and/or regional data should add a statement about the quality of data being displayed at the site. This cautionary statement will notify the public that posted data has not been fully quality assured and discrepancies may occur. For an example, the AirNow Website makes the following statement:

> *"Although some preliminary data quality assessments are performed, the data as such are not fully verified and validated through the quality assurance procedures monitoring organizations use to officially submit and certify data on the EPA AQS (Air Quality System)…. AirNow data are used only to report the AQI, not to formulate or support regulation, guidance or any other EPA decision or position.*

14.2.2 Reporting Frequency and Lag Time for Reporting Data to AirNow

Continuous monitoring data that are being provided to AirNow in near real-time are to be reported each hour. Data should be reported as soon as practical after the end of each hour. For the near term, the goal is to report data within twenty minutes past the end of each hour. This will provide enough time for data processing and additional data validation at the AirNow Data Management Center (DMC), generation of reports and maps, distribution of those products to a variety of stakeholders and web sites, and staff review before the end of the hour. This is an important goal to support reporting of air pollution episodes on news media programs by the top of the hour. The long-term goal for NCore sites is to report all data within five minutes after the end of an hour.

14.3 Data Transfer-Reporting to External Databases

Today, the need for the ambient air monitoring data reaches outside the monitoring community. In addition to the traditional needs of the data (e.g., determination of NAAQS compliance and the daily AQI report), a health researcher or modeler may want a very detailed accounting of the available data in the shortest time intervals possible. Atmospheric scientists typically desire data in a relatively unprocessed yet comprehensive form with adequate descriptions (meta data) to allow for further processing for comparability to other data sets. These needs increase the demands for the data and require multiple reports of the information.

14.3.1 AQS Reporting

All ambient air monitoring data will eventually be transferred and stored in AQS. As stated in 40 CFR Part 58.16[8], the monitoring organization shall report all ambient air monitoring and associated quality assurance data and information specified by the AQS Users Guide into the AQS format. The data are to be submitted electronically and on a specified quarterly basis. Since changes in reporting requirements

[8] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl

occur, monitoring organizations should review CFR for the specifics of this requirement.

The AQS manuals are located at the AQS Website[9]. The AQS Data Coding Manual replaces the previous Volume II and provides coding instructions, edits performed, and system error messages. The AQS User Guide replaces the former Volume III and describes the procedures for data entry. Both manuals will be updated as needed and the new versions will be available on the website. Table 14-1 provides the units and the number of decimal places that, at a minimum, are required for reporting to AQS for the ambient air concentrations for criteria pollutants. These decimal places are used for comparison to the NAAQS and are displayed in AQS summary reports. However, AQS has been revised to allow monitoring organizations can report data up to 30 values to the right of the decimal and it is suggested that monitoring organization take advantage of reporting to more decimal places than required in Table 14-1. For QA/QC data reported to AQS, it is suggested that more decimals than those required in Table 14-1 be reported.

Table 14-1 AQS Data Reporting Requirements

Pollutant	Units	Decimal Places	Example	Minimum reporting requirement (as described in 40 CFR Part 50)
$PM_{2.5}$	$\mu g/m^3$	1	10.2	shall be reported to AQS in micrograms per cubic meter ($\mu g/m^3$) to one decimal place, with additional digits to the right being truncated (App. N)
PM_{10}	$\mu g/m^3$	1	26.2	***No description found***
Lead (Pb) TSP and PB-PM_{10}	$\mu g/m^3$	3	1.525	Pb-TSP and Pb-PM_{10} measurement data are reported to AQS in units of micrograms per cubic meter ($\mu g/m^3$) at local conditions (local temperature and pressure, LC) to three decimal places; any additional digits to the right of the third decimal place are truncated (App. R).
O_3	ppm	3	0.108	Hourly average concentrations shall be reported in parts per million (ppm) to the third decimal place, with additional digits to the right of the third decimal place truncated (App. P).
SO_2	ppb	1	35.1	reported to AQS in units of parts per billion (ppb), to at most one place after the decimal, with additional digits to the right being truncated with no further rounding (App. T)
NO_2	ppb	1	53.2	reported to AQS in units of parts per billion (ppb), to at most one place after the decimal, with additional digits to the right being truncated with no further rounding (App. S)
CO	ppm	1	2.5	***No description found***
$PM_{10\text{-}2.5}$	$\mu g/m^3$	1	10.2	***No description found – follow PM2.5 requirements***

14.3.2 Standard Format for Reporting to AQS

AQS allows flexibility in reporting formats. The formats previously used by AQS can be used for raw data (hourly, daily, or composite) and for reporting precision and bias data. The system also has new report formats for this data, as well as formats for registering new sites and monitors. These new formats are defined in the AQS Data Coding Manual. Work is also in progress to define an Extensible Markup Language (XML) schema for AQS reporting. Use of XML as a data format is consistent with EPA and Federal guidelines towards better data integration and sharing.

[9] https://www.epa.gov/aqs/aqs-manuals-and-guides

14.3.3 Important AQS Agency Roles

Some fields in AQS are key to identifying the agency or organization responsible for certain aspects of monitoring. Due to the fact that State agencies may play some overarching roles (such as reporting data or QA oversight as a PQAO), yet not be responsible for the monitoring of some sites (e.g., local organizations or Tribe), it is important to understand, identify, and use these roles correctly. Table 14-2 identifies the agency roles for AQS reporting.

Table 14-2 AQS Agency Roles

Role Name	Definition	Relationship to a monitor	Comments
Primary Quality Assurance Organization (PQAO)	Organization responsible for QA of the monitoring process at the monitor	Each monitor can only be associated with one PQAO at any particular date time	There can be multiple MAs in a PQAO and PQAO can be pollutant specific. QAPPs must be related to MA and PQAO
Monitoring Agency (MA)[10]	Organization that owns the monitor	Each monitor can only be associated with one MA at any particular date time	
Reporting Organization (RO)	Organization submitting the data to AQS	Each monitor can only be associated with one RO at any particular date time None	Data for particular monitors could be submitted by multiple organizations for example, field data by the MA and analytical data for an analyzing agency
Analyzing Agency	Organization performing the analysis on samples	None	
Collecting Organization	Organization responsible for collecting data or maintaining monitor	None	In some cases the MA may contract out monitoring activities
Certifying Agency (CA)	Organization responsible for certifying data from the monitor	Each monitor can only be associated with one CA at any particular date time	Some states perform certification even though they may not be the MO or PQAO
Audit Agency	Agency performing a particular audit.	None	This can be the agency performing a TSA or a performance evaluation audit. Usually this information is reported in QA Transactions

It must be mentioned that, at a minimum for any raw data submittal, the PQAO, MA, CA and RO fields must be entered. In many cases they may be the same organization; however, in other cases, they may not. Therefore, the population of these fields is important in order to clarify how these data are generated and reported.

14.3.4 Expanded QA Information Reported to AQS

In recent years, the process of reporting QA data to AQS has been improved. New QA transactions have been developed that support the reporting of additional quality control data that do not need to be "fit" into either an accuracy or precision transaction. Many of the transactions will be optional for use (e.g., duplicates, replicates, audit of data quality) depending on the monitoring program. However, QA transactions will be required for entry of the traditional Appendix A QC data, as well as pertinent information for quality management plans (QMPs), quality assurance project plans (QAPPs), and Regional Office technical systems audits (TSAs), since they are a requirement for receiving grant funds (QMP/QAPPs) and are included in 40 CFR Part 58, Appendix A.

[10] Monitoring Agency(MA) is a legitimate role name in AQS. In this section, monitoring organization (MO) that has been used throughout the Handbook, and monitoring agency (MA) are used somewhat synonymously

PQAO and MA Relationships Relative to QMPs and QAPPs

QMPs--

The following fields will be required for QMP reporting:

1. Submitting Agency Code – MA code
2. Submission Date- Date QMP submitted to EPA, helps with tracking approval process
3. Approving Agency Code – Code for EPA Region
4. Approval Date – EPA Approval Date
5. QMP Status Code-
6. Comments- free form comments

A MA meeting the definition above and receiving STAG funds must have a QMP approved by EPA. In most cases, the QMP is an overarching document that covers all the pollutants measured by the MA and is separate from the QAPP. In this case, the submitting agency code should be the MA associated with the QMP.

For smaller organizations (e.g., tribes and small local MAs), EPA has allowed for consolidation of QMP and QAPPs. In this case, even though it is one document, the MA should report a submission and approval date for the QMP and the same date for the QAPP as a separate submission (see QAPP information below).

For some pollutants there may be a number of local monitoring organizations that have consolidated to form a single PQAO. In this instance, there may be a possibility that a single QMP, or a consolidated QMP/QAPP, is developed. However, even in this case, each distinguishable MA should report a submission and approval date for the QMP and the same date for the QAPP.

QAPPs--

The following fields will be required for QAPP reporting:

1. Submitting Agency Code - MA code
2. PQAO Code- PQAO Code (may be the same as submitting agency but may not)
3. Parameter classification- Identifies the individual pollutants or the network (e.g., CSN, NATTS) for which the QAPP is developed.
4. Submission Date- Date QAPP submitted to EPA, helps with tracking approval process
5. Approving Agency Code –May be EPA or submitting agency
6. Approval Date- Date QAPP approved by EPA or submitting agency
7. QAPP Status Code- code identifying at what stage of review/approval the QAPP is in
8. Comments- free form comments

Since a MA can consolidate to larger PQAOs for a pollutant[11], there is a possibility that a QAPP can be submitted by a MA even though it references its association to a larger PQAO; or, a QAPP can be

[11] With the introduction of PQAOs in CFR in 2006, some local monitoring organizations consolidated to a larger PQAO for PM2.5 monitoring

developed by the PQAO that is utilized by all or some of the MAs within the PQAO. In order to determine this for each MA, the PQAO must also be reported. Therefore, each MA as defined in Table 14-2 must report QAPP data for any parameter or parameter classification. Since a MA may be consolidated into a PQAO for one pollutant and not another, the QAPP reporting process for the criteria pollutants will be on the pollutant level. For monitoring networks like NATTS or CSN, the information can be submitted at the network identifier level.

14.3.5 Annual Certification of Data

The annual data certification is also stored in AQS. The monitoring organization is required to certify the data (by formal letter) for a calendar year (Jan 1-Dec 31) by May 1 of the following year. See 40 CFR Part 58.15 for details since this time period can change. This certification requires the monitoring organization to review the air quality data and quality assurance data for completeness and validity and to submit a certification letter and accompanying data certification reports to the EPA Regional Office. In 2013, EPA developed an automated certification process that allows the EPA Regions to evaluate the monitoring organizations data certification. Instructions for this process can be found on AMTIC.[12] Table 14-3 identifies the potential flags that can be applied to the data. After certification/concurrence is complete, any updates to the data will cause the certification/concurrence flag to be dropped and replaced by an "M" qualifier. EPA Regions would have to review the modified data to set a final concurrence flag.

Table 14-3 Data Certification and Concurrence Flag Values

Flag Value	Application
X	Certification is not required by 40 CFR 58.15 and no conditions apply to be the basis for assigning another flag value
U	Uncertified. The certifying agency did not submit a required certification letter and summary reports for this monitor even though the due date has passed, or the state's certification letter specifically did not apply the certification to this monitor.
S	The certifying agency has submitted the certification letter and required summary reports. A value of "S" conveys no Regional assessment regarding data quality per se. This flag will remain until the Region provides an "N" or "Y" concurrence flag.
N	The certifying agency has submitted the certification letter and required summary reports, but the certifying agency and/or EPA has determined that issues regarding the quality of the ambient concentration data cannot be resolved due to data completeness, the lack of performed quality assurance checks or the results of uncertainty statistics shown in the AMP256 report or the certification and quality assurance report.
Y	The certifying agency has submitted a certification letter, and EPA has no unresolved reservations about data quality (after reviewing the letter, the attached summary reports, the amount of quality assurance data submitted to AQS, the quality statistics, and the highest reported concentrations).
M	The monitoring organization has revised data from this monitor since the most recent certification letter received from the state.

[12] https://www3.epa.gov/ttn/amtic/qacert.html

14.3.6 Summary of Desired Performance for Information Transfer Systems

To define the needed performance criteria of a state-of-the art information technology system, a table of needs has been developed. This table provides performance needs for an optimal information technology system, but is not intended to address what the individual components should look like. For instance, once low level validated data for a specific time period are ready to leave the monitoring station, a telemetry system may actually accomplish moving those data. By identifying the needed performance criteria of moving data, rather than the actual system to move it, monitoring organizations may be free to identify the most optimal system for their network. Table 14-4 summarizes the performance elements of the data management systems used to log, transfer, validate, and report data from NCore ambient air monitoring stations.

Table 14-4 NCore Information Technology Performance Needs[13]

Performance Element	Performance Criteria	Notes
Sample Periods	5 minutes (long-term goal), and 1-hour data (current standard)	5 minutes and 1-hour data to support exposure, mapping and modeling. 1-hour data for Air Quality Index reporting and NAAQS. Sample period may need to be higher for certain pollutant measurement systems depending on method sample period and measurement precision when averaging small time periods.
Data Delivery	Short-term goal: Within 20 minutes nationally each hour Long-term goal: Within 5 minutes nationally each hour	As monitoring organizations migrate to new telemetry systems, the goal will be to report data within 5 minutes. This should be easily obtained with broadband pushing of data to a central server.
Low Level Validation	- Last automated zero and QC check acceptable - Range check acceptable - Shelter parameters acceptable -Instrument parameters acceptable	Other validation should be applied as available: - site to site checks - rate of change -lack of change.
Data Availability	- All QC data, operator notes, calibrations, and pollutant data within network - Low level validated pollutant data externally	Create log of all monitoring related activities internally. Allow only validated data to leave monitoring organization network.
Types of monitoring data to disseminate-externally	-Continuous and semi-continuous pollutant data - accompanying meteorological data	Associated manual method supporting data (for instance, FRM ambient Temperature) should be collected but not reported externally.
Additional data for internal tracking	Status of ancillary equipment such as shelter temperature, power surges, zero air system, calibration system	
Relevant site information	Latitude, longitude, altitude, land use category, scale of representativeness, pictures and map of area	Other site information may be necessary.
Remote calibration	Ability to initiate automated calibrations on regular schedule or as needed	
Reviewing calibration	- Allow for 1-minute data as part of electronic calibration log	
Initialization of manual collection method	Need to be able to remotely initiate these or have them set at an action level from a specific monitor	
Reporting Format	Short-term: Maintain “Obs” file format and pipe delimited formats for AirNow and AQS reporting, respectively Long-term: XML	Need to coordinate development of XML schema with multiple stakeholders. XML is an open format that will be able to be read by most applications.

[13] See NCore Technical Assistance Document Version 4 https://www3.epa.gov/ttn/amtic/ncoreguidance.html

14.4 Data Management

Managing the data collected is just as important as correctly collecting the data. The amount of data collected will continue to grow based on the needs of the data users. Previous sections have confirmed this statement, providing a glimpse of the potential data users and the uses. Generally, data are to be retained for a period of 3 years from the date the grantee submits its final expenditure report unless otherwise noted in the funding agreement[14]. With electronic records and electronic media, this information can be stored and managed with less use of space than with the conventional paper records. However, even with today's technology there will be some paper records and those need to be managed in an orderly manner. The manner in which a monitoring organization manages its data is documented in its QMP and QAPP.

Challenges imposed by the need to capture increasing volumes of data and to make that data available to the public and other groups in various formats and in short timeframes require a strategy for obtaining enough of these resources:

- Computer processing capacity,
- Data storage, archival storage, paper file storage,
- Floor space, and
- Support staff; for deployment among central offices, local offices, and monitoring sites to capture data having the quality characteristics listed in Section 14.0.

Air monitoring organization managers may want to seek the assistance of their organization's IT staff and/or hardware/software maintenance contractors. Managers may find it helpful to consult these references:

- EPA's records management webpage[15]
- Section 5 of this document
- *Good Automated Laboratory Practices,* posted on the OEI website.

This information should be reviewed not only by those in a monitoring organization responsible for overall data management, but also by the monitoring organization's Systems or Network Administrator. The latter person(s) can provide helpful information in designing the overall data management system according to today's industry standards. Remember, the data has to be of known quality, reliable and defensible. In order for monitoring organizations to continue to meet those objectives, many sources of information need to be reviewed.

[14] 2 CFR 200.333
[15] http://www.epa.gov/records/

15.0 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. For the Ambient Air Quality Monitoring Program, the following assessments will be discussed here: network reviews, performance evaluations, technical system audits, and data quality assessments.

15.1 Network Reviews

As described in 40 CFR § 58.10[1]:

> *Beginning July 1,2007, the State, or where applicable, local agency shall submit to the Regional Administrator an annual monitoring network plan which shall provide for the documentation of the establishment and maintenance of an air quality surveillance system that consists of a network of SLAMS monitoring stations that can include FRM, FEM, and ARM monitors that are part of SLAMS, NCore, CSN, PAMS, and SPM stations. The plan shall include a statement of whether the operation of each monitor meets the requirements of appendices A, C, D, and E of Part 58, where applicable. The Regional Administrator may require additional information in support of this statement. The annual monitoring network plan must be made available for public inspection and comment for at least 30 days prior to submission to EPA and the submitted plan include and address, as appropriate, any received comments.*

The AMTIC Website has a page[2] devoted to the progress and adherence to this requirement. This page contains links to State and local ambient air monitoring network plans.

In addition to an annual network plan, starting in 2010, the State, or where applicable, local monitoring organization, is required to perform and submit to the EPA Regional Administrator an assessment of the air quality surveillance system every 5 years to determine, at a minimum, if the network meets the monitoring objectives defined in 40 CFR Part 58, Appendix D; whether new sites are needed; whether existing sites are no longer needed and can be terminated; and whether new technologies are appropriate for incorporation into the ambient air monitoring network. The 5-year network assessment must consider the ability of existing and proposed sites to support air quality characterization for areas with relatively high populations of susceptible individuals (e.g., children with asthma), and for any sites that are being proposed for discontinuance, the effect on data users other than the monitoring organization itself, such as nearby States and Tribes or health effects studies. For $PM_{2.5}$, the assessment also must identify needed changes to population-oriented sites. The state or, where applicable, local monitoring organization, must submit a copy of this 5-year assessment, along with a revised annual network plan, to the Regional Administrator.

In order to maintain consistency in implementing and collecting information from a network review, EPA has developed the document *Ambient Air Monitoring Network Assessment Guidance*[3]. The information presented in this section provides some excerpts from this guidance document.

[1] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl
[2] http://www3.epa.gov/ttn/amtic/plans.html
[3] https://www3.epa.gov/ttn/amtic/cpreldoc.html (3/1/2007)

15.1.1 Network Selection

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

- date of last review;
- areas where attainment/nonattainment designations are taking place or are likely to take place;
- results of special studies, saturation sampling, point-source oriented ambient monitoring, etc.; and,
- monitoring organizations 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 monitoring organizations 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 monitoring organization (including updated site information and site photographs);
- AQS reports (AMP220, 225, 380, 390, 450, 480, 600);
- air quality summaries for the past five years for the monitors in the network;
- emissions trend reports for major metropolitan areas;
- emission information, such as emission density maps for the region in which the monitor(s) is located and emission maps showing the major sources of emissions; and
- National Weather Service summaries for monitoring network area.

Upon receiving the information, it should be checked for consistency and to ensure it is the latest revision. Discrepancies should be noted on the checklist (Appendix H of this Handbook) and resolved with the monitoring organization 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 requirements, the network reviewer must determine the adequacy of the network in terms of number and location of monitors: specifically, (1) is the monitoring organization 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?

Number of Monitors

For SLAMS, NCore, and PAMs, the minimum number of monitors required is specified in the regulations. As revisions occur to the NAAQS, there is a possibility the number of required monitors will also change so the reader should keep abreast of the changes that can occur in Appendix D. 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;
- SIP requirements;
- revised monitoring strategies (e.g., lead strategy, reengineering air monitoring network); and
- best professional judgment.

Location of Monitors

Appendix D does provide a general description of the location of sites needed for NAAQS-related monitoring. EPA has also developed a technical assistance document for identifying SO_2 ambient air monitoring locations around sources[4]. The EPA Regional Office and monitoring organizations work together to identify the best location for the monitors based upon the siting/location requirements defined in Appendix D. Adequacy of the location of monitors can only be determined on the basis of stated objectives. Maps, graphical overlays, and GIS-based information can be 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.

15.1.3 Conformance to 40 CFR Part 58, Appendix E - Probe Siting Requirements

Applicable siting criteria for SLAMS, NCore, and PAMS are specified in 40 CFR Part 58, Appendix E. A site visit is necessary in order to best assess the monitoring station probes and inlets. The on-site visit should consist of the physical measurements and observations needed to determine compliance with the Appendix E requirements, such as height above ground level, distance from trees, paved or vegetative ground cover, and so forth. 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 H of this Handbook is also intended to assist the reviewer in determining conformance with Appendix E. 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 issues
- 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 the field notebook and/or checklist
- take photographs/video in the 8 cardinal directions
- document site conditions, with additional photographs/video

[4] https://www.epa.gov/so2-pollution/technical-assistance-documents-implementing-2010-sulfur-dioxide-standard

15.1.4 Checklists and Other Discussion Topics

Checklists are provided in Appendix H to assist network reviewers (SLAMS 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; and
- other issues (e.g., 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 monitoring organization network description and the AQS network description; and deficiencies in the number, location, and/or type of monitors.

NPAP through the probe audit

PEP Audit

15.2 Performance Evaluations

Performance evaluations (PEs) 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 or a laboratory[5]. EPA also uses it to evaluate instrument performance. The National Performance Evaluation Programs:

- Allow one to determine data comparability and usability across sites, monitoring networks (Tribes, States, and geographic regions), instruments, and laboratories.
- Provide a level of confidence that monitoring systems are operating within an acceptable level of data quality so data users can make decisions with acceptable levels of certainty.
- Help verify the precision and bias estimates performed by monitoring organizations.
- Identify where improvements (technology/training) are needed.

[5] American National Standard-Quality Systems for Environmental Data and Technology Programs-Requirements with Guidance for Use (ANSI/ASQC E4-2004)

- Assure the public of non-biased assessments of data quality.
- Provide a quantitative mechanism to defend the quality of data.
- Provide information to monitoring organizations on how they compare with the rest of the nation, in relation to the acceptance limits, and to assist in corrective actions and/or data improvements.

Some type of national PE program is implemented for all of the ambient air monitoring activities. Table 15-1 provides more information on these activities. It is important that these performance evaluations be independent in order to ensure they are non-biased and objective. With the passage of the Data Quality Act[6], there is potential for EPA to receive challenges to the quality of the ambient air data. Independent audits help provide another piece of objective evidence on the quality of a monitoring organization's data and can help EPA defend the quality of the data.

Table 15-1 National Performance Evaluation Activities[7] Performed by EPA

Program/ Lead Agency	Explanation
NPAP OAQPS	**National Performance Audit Program** provides audit standards for the gaseous pollutants either as devices that the site operator connects to the back of the instrument or through the probe, in which case the audits are conducted by presenting audit gases through the probe inlet of ambient air monitoring stations. Flow audit devices and lead strips are also provided through NPAP. NPAP audits are required at 20% of a primary quality assurance organization's sites each year, with a goal of auditing all sites in 5-7 years.
$PM_{2.5}$ PEP OAQPS	**Performance Evaluation Program**. The strategy is to collocate a portable FRM $PM_{2.5}$ air sampling audit instrument with an established primary sampler at a routine air monitoring site, operate both samplers in the same manner, and then compare the results. Each year, five PEP audits are required for primary quality assurance organizations (PQAOs) with less than or equal to 5 monitoring sites, or eight audits are required for PQAOs with greater than five sites. These audits are not required for PM_{10}
Pb-PEP OAQPS	**Performance Evaluation Program**. The strategy is to collocate a portable FRM Pb air sampling audit instrument with an established primary sampler at a routine air monitoring site, operate both samplers in the same manner, and then compare the results. Each year, five PEP audits (1 PEP collocated sample and 4 samples from the monitoring organization's routine collocated instrument) are required for primary quality assurance organizations (PQAOs) with less than or equal to 5 monitoring sites, or eight audits are required for PQAOs with greater than five sites (2 PEP collocated samples and 6 samples from the monitoring organization's routine collocated instrument).
NATTS PT OAQPS	A **National Air Toxics Trend Sites (NATTS) proficiency test (PT)** is a type of assessment in which a sample, the composition of which is unknown to the analyst, is provided to test whether the analyst/laboratory can produce analytical results within the specified acceptance criteria. PTs for volatile organic carbons (VOCs), carbonyls, and metals are performed quarterly for the NATTS laboratories.
SRP EPA-RTP	The **Standard Reference Photometer (SRP) Program** provides a mechanism to establish traceability among the ozone standards used by monitoring organizations with the National Institute of Standards and Technology (NIST). Every year NIST certifies an EPA SRP. Upon certification, this SRP is shipped to the EPA Regions, who then use this SRP to certify the SRP that remains stationary in the Regional Lab. These stationary SRPs are then used to certify the ozone transfer standards that are used by the State, Local and Tribal monitoring organizations, who bring their transfer standards to the Regional SRP for certification.
PAMS Cylinder Certs Nat Contract Lab	EPA developed a system to certify the standards used by the monitoring organizations to calibrate their PAMS analytical systems. The standards are sent to the NATTS national contract laboratory who perform an independent analysis/certification of the cylinders. This analysis is compared to the vendor concentrations to determine if they are within the contractually required acceptance tolerance.
CSN/IMPROVE Round Robins PTs and Audits OAQPS	$PM_{2.5}$ **Chemical Speciation Network (CSN) and IMPROVE** Round Robins are a type of performance evaluation where the audit samples are developed in ambient air; therefore, the true concentration is unknown. The Office of Indoor Air and Radiation (ORIA) in Montgomery, AL, previously implemented these audits for the CSN/IMPROVE programs and for the PEP weighing laboratories. In 2015, the management of these activities were transferred to OAQPS. The audit is performed by collecting samples over multiple days and from multiple samplers. These representative samples are then characterized by the referee lab and sent to the routine sample laboratories for analysis. Since the true concentrations are unknown, the reported concentrations are reviewed to determine general agreement among the laboratories.
Protocol Gas OAQPS- EPA Regions	EPA Protocol Gases are used in quality control activities (e.g., calibrations, audits etc.) to ensure the quality of data derived from ambient air monitors used by every State in the country. EPA developed the Protocol Gas Program to allow standards sold by specialty gas producers to be considered traceable to NIST standards. This program was discontinued in 1998. In 2010, EPA established an Ambient Air-Protocol Gas Verification Program[8] that utilizes volunteers from the ambient air monitoring community.

[6] see http://www.foreffectivegov.org/node/3479
[7] many of the National PEs can be found at the following website http://www3.epa.gov/ttn/amtic/npepqa.html
[8] http://www3.epa.gov/ttn/amtic/aapgvp.html

Although Table 15-1 lists seven performance evaluation programs operating at the federal level, the NPAP and PEP Programs will be discussed in more detail. Additional information on both programs can be found on the AMTIC Website[9]. The October 17, 2006 monitoring rule identified the monitoring organizations as responsible for ensuring the implementation of these audits[10]. Monitoring organizations can either self-implement the program or continue to participate in the federally-implemented program. This choice is provided to the monitoring organization on an annual basis through a memo from OAQPS through the EPA Regions. In order for the monitoring organization to self-implement the program, it must meet criteria related to the adequacy of the audit (number of audits and how it is accomplished) as well as meet independence requirements (see Figure 15.1).

15.2.1 National Performance Audit Program (NPAP)[11]

Monitoring organizations operating SLAMS/PAMS/PSD are required to participate in the National Performance Evaluation Programs by providing adequate and independent audits for its monitors as per Section 2.4 of 40 CFR Part 58, Appendix A. Organizations participating in the NPAP program can choose to partake either through self-implementation or through federal implementation.

The NPAP is a cooperative effort among OAQPS, the 10 EPA Regional Offices, and the monitoring organizations that operate the SLAMS/PAMS/PSD air pollution monitors. The NPAP's goal is to provide audit materials and devices that will enable EPA to assess the proficiency of monitoring organizations that are operating monitors in the SLAMS/PAMS/PSD networks. To accomplish this, the NPAP has established acceptable limits or performance criteria, based on the data quality needs of the networks, 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/PAMS/PSD networks. The audit levels used in the NPAP program are selected from the same 10 audit levels specified in 40 CFR Part 58, Appendix A, for a PQAO's annual performance evaluations.

Initially, the NPAP system was a mailable system where standards and gases were shipped to monitoring organizations for implementation. In 2003, OAQPS started instituting a through-the-probe audit system, where mobile laboratories traveled to monitoring sites and audit gases were delivered through the inlet probe of the analyzers. The goals of the NPAP are:

- Performing audits at 20 percent of monitoring sites per year, and 100% every 6 years;
- Data submission to AQS within 30 days of the audit;
- Development of a delivery system that will allow for the audit concentration gases to be introduced to the probe inlet where logistically feasible;
- Using audit gases that are verified against the NIST standard reference methods (or other special review procedures) and validated annually for CO, SO_2 and NO;
- Using ozone transfer standards that are verified against the EPA Region's Standard Reference Photometer on a quarterly basis, during that time period in which ozone audits are conducted;

[9] https://www3.epa.gov/ttn/amtic/npepqa.html
[10] https://www3.epa.gov/ttn/amtic/40cfr53.html -Final - Revisions to Ambient Air Monitoring Regulations (10/2017)
[11] https://www3.epa.gov/ttn/amtic/npaplist.html

- Validation/certification with the EPA NPAP program (if self-implementing) through collocated auditing at an acceptable number of sites each year. The comparison tests would have to be no greater than 5 percent different for ozone and 7 percent different for NO_2, CO and SO_2 from the EPA NPAP results; and,
- Incorporation of NPAP into the monitoring organization's quality assurance project plan.

As mentioned above, the PQAO may elect, on an annual basis, to utilize the federally-implemented NPAP program. If the PQAO plans to self-implement NPAP, the EPA will establish training and other technical requirements for PQAOs to establish comparability to the federally-implemented program. In addition to meeting the requirements above, the PQAO must:

- Meet the definition of independent assessment described in Figure 15.1.
- Utilize an audit system equivalent to the federally-implemented NPAP audit system and is separate from equipment used in annual performance evaluations.
- Perform a whole system check by having the NPAP system tested against an independent and qualified EPA lab, or equivalent.
- Evaluate the system with the EPA NPAP program through collocated auditing at an acceptable number of sites each year (at least one for an agency network of five or less sites; at least two for a network with more than five sites).
- Incorporate the NPAP in the PQAO's quality assurance project plan.
- Be subject to review by independent, EPA-trained personnel.
- Participate in initial and refresher training/certification sessions.

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 PE 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/monitoring personnel from its auditing personnel by two levels of management, as illustrated in the figure below. In addition, for $PM_{2.5}$ and Pb PEP the preparation and analysis of audit filters must be performed by separate laboratory facility using separate laboratory equipment. Field and laboratory personnel would be required to meet the NPAP/PEP field and laboratory training and certification requirements. The monitoring organizations are also asked to consider participating in the centralized field and laboratory standards certification process.

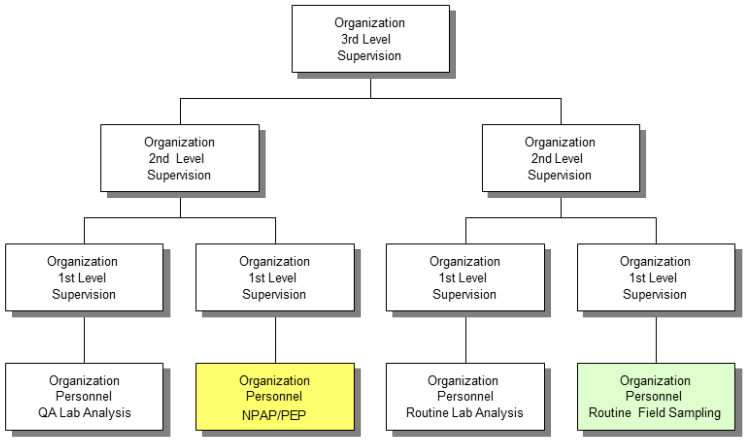


Figure 15.1 Definition of independent assessment

The validation template in Appendix D lists the acceptance limits of the NPAP audits.

NPAP Corrective Action

Since NPAP can only visit 20% of any monitoring organization's sites in a given year, the data is more useful in providing EPA with a national assessment of data comparability across the criteria pollutant network. However, when individual sites fail an audit, EPA will attempt to work with the monitoring organization to discover the reasons for the failure. Usually the failure is related to a site-specific issue (e.g., leak) and not a network issue (e.g. bad calibration gas used to calibrate all monitors). If time is available, the auditor can attempt to re-audit while at the site. If not, the EPA Region and monitoring organization can communicate on re-auditing the site at a later date. Unless the failure is

related to an issue with NPAP equipment, the original results will be reported along with any additional audit results after corrective action.

15.2.2 $PM_{2.5}$ and Pb Performance Evaluation Programs (PEP)

The Performance Evaluation Program[12] is a quality assurance activity which will be used to evaluate measurement system bias of the $PM_{2.5}$ and the Pb monitoring networks. The pertinent regulations for this performance audit are found in 40 CFR Part 58, Appendix A.

$PM_{2.5}$ PEP

For $PM_{2.5}$ PEP, the strategy is to collocate a portable PEP instrument with an established routine air sampler/monitor, operate both monitors in exactly the same manner, and then compare the results of this instrument against the routine sampler/monitor at the site. Primary quality assurance organizations (PQAOs) with 5 or less $PM_{2.5}$ monitoring sites are required to have 5 valid audits per year distributed across the 4 quarters; PQAOs with greater than 5 sites are required to have 8 valid audits per year distributed across the 4 quarters. The EPA requires:

- One hundred (100) percent completeness (meaning whatever it takes to get 5 or 8 valid samples).
- All samplers subject to an audit within 6 years.

A valid performance evaluation audit means that both the primary monitor and PEP audit concentrations are valid and are greater than or equal to 3 $\mu g/m^3$.

EPA has made arrangements to implement this audit. Monitoring organizations can decide, on a yearly basis, to either utilize federal implementation by directing their appropriate percentage of grant resources back to the OAQPS, or implement the audit themselves. The following activities will be established for federal PEP implementation:

- Field personnel assigned to each EPA Region, with hours based upon the number of required audits in the Region; and,
- One laboratory in Region 4 which will serve as the national gravimetric (weighing) laboratory, and will include data submittal to AQS.

Since performance evaluations are independent assessments, Figure 15.1 was developed to define independence for the NPAP and PEP programs to allow monitoring organizations to self-implement this activity. 40 CFR Part 58 Appendix A, Section 3.2.4 makes reference to the fact that the monitoring organizations are responsible for performing the evaluations, "…under the NPEP as described in section 2.4 of this appendix or a comparable program." Any self-implemented PEP program will be run similarly to the federal PEP, and will be periodically subject to performance evaluations with the federal PEP conducted within its respective EPA Region.

Pb-PEP

The Pb-PEP operates somewhat differently than the $PM_{2.5}$ PEP in that it includes a combination of independent audits *and* data obtained from the monitoring organization's collocated Pb sampler that is sent to the National PEP Laboratory. Each year, one performance evaluation audit, as described in Section 3.4.7 of 40 CFR Part 58, Appendix A, must be performed at one Pb site in each PQAO that has

[12] http://www.epa.gov/ttn/amtic/pmpep.html

less than or equal to five sites, and two audits at each PQAO with greater than five sites. In addition, each year, four collocated samples from each PQAO with less than or equal to five sites, and six collocated samples from each PQAO with greater than five sites, must be sent to an independent laboratory (i.e., the same laboratory as the performance evaluation audit) for analysis. The EPA requires:

- One hundred (100) percent completeness (meaning whatever it takes to get 5 or 8 valid samples).
- All samplers subject to an audit within 6 years.

More details on this process, including all documentation (e.g., the Pb-PEP Implementation Plan, QAPP, Field and Laboratory SOPs, and reports for each PEP) can be found on the AMTIC Bulletin Board at the PEP Website.

PEP Corrective Action

Unlike the NPAP, which can provide immediate feedback on results, the PEP results are not available until the monitoring organizations have reported their results (i.e., data from the routine monitor) to AQS. This process can take at least 3 months but sometimes longer. Therefore, feedback cannot be immediate and, as a result, the PEP has limited use (as compared to NPAP) for implementing corrective action at a monitoring organization level. However, over the years that the PEP has been implemented, EPA has been able to identify bias at the PQAO level, as well as national levels among method designations. With that in mind, the PEP helps to inform those monitoring organizations that may be outside the DQOs or the norm, or that have method designations that may need corrective action.

15.2.3 Ambient Air Protocol Gas Verification Program

In 2009, the Office of the Inspector General (OIG) published the report EPA Needs an Oversight Program for Protocol Gases13. One of the report's findings suggested that EPA "does not have reasonable assurance that the gases that are used to calibrate emissions monitors for the Acid Rain Program and continuous ambient monitors for the nation's air monitoring network are accurate." OIG recommended that OAR implement oversight programs to assure the quality of the EPA Protocol Gases that are used to calibrate these monitors. It also recommended that EPA's ORD update and maintain the document Traceability Protocol for Assay and Certification of Gaseous Calibration Standards to ensure that the monitoring programs' objectives are met.
In order to address the OIG findings for ambient air monitoring, in 2010, OAQPS, in cooperation with EPA Regions 2 and 7, developed an Ambient Air Protocol Gas Verification Program (AA-PGVP). The program establishes gas metrology laboratories in Regions 2 and 7 to verify the certified concentrations of EPA Protocol Gases used to calibrate ambient air quality monitors.
The program is expected to:

- ensure that producers selling EPA Protocol Gases participate in the AA-PGVP, and
- provide end users with information about participating producers and verification results.

The EPA Ambient Air Quality Monitoring Program's QA requirements for gaseous audit standards are codified in 40 CFR Part 58, Appendix A, and state the following:

> *2.6.1 Gaseous pollutant concentration standards (permeation devices or cylinders of compressed gas) used to obtain test concentrations for CO, SO_2, NO, and NO_2 must be traceable to either a*

[13] https://www.epa.gov/office-inspector-general/report-epa-needs-oversight-program-protocol-gases

National Institute of Standards and Technology (NIST) Traceable Reference Material (NTRM) or a NIST-certified Gas Manufacturer's Internal Standard (GMIS), certified in accordance with one of the procedures given in reference 4 of this appendix. Vendors advertising certification with the procedures provided in reference 4 of this appendix and distributing gases as "EPA Protocol Gas" for ambient air monitoring purposes must participate in the EPA Ambient Air Protocol Gas Verification Program or not use "EPA" in any form of advertising. Monitoring organizations must provide information to the EPA on the gas producers they use on an annual basis and those PQAOs purchasing standards will be obligated, at the request of the EPA, to participate in the program at least once every 5 years by sending a new unused standard to a designated verification laboratory.

This program is considered a verification program because its current level of evaluation does not allow for a large enough sample of EPA Protocol Gases from any one specialty gas producer to yield a statistically rigorous assessment of the accuracy of the producer's gases. Rather, the results provide information to end users that the specialty gas producer is participating in the program and the information in the verification report may be helpful when selecting a producer. Participation by monitoring organizations is important to the program. It is more advantageous to verify standards routinely sent to the monitoring organizations, who can then send them to the Region 2 or 7 laboratories, than to request cylinders directly from the gas producers who may perform additional checking on cylinders prior to submitting them for verification. Therefore, EPA has revised the CFR to add that the monitoring organization provide information, on an annual basis[14], on the producers they are using. Additionally, EPA may request standards once every five years from monitoring organizations if the Gas Verification Program does not get volunteers to send standards to the Region 2 or 7 laboratories. Annual results of the verifications are posted to AMTIC.[15]

15.2.4 State and Local Organization Performance Audits

Any of the performance evaluation activities mentioned in this section can be performed internally by the monitoring organizations. If the monitoring organization intends to self-implement NPAP or PEP, then they will be required to meet the adequacy and independence criteria mentioned in earlier sections. Since a monitoring organization may want more audits then can be supplied by the NPAP and PEP, it may decide to "augment" the federally implemented programs with additional performance audits. These audits can be tailored to the needs of the monitoring organization and do not necessarily need to follow NPAP and PEP adequacy and independence requirements. Some information on the procedures for this audit can be found in Appendix H of this Handbook.

15.3 Technical Systems Audits

A technical systems audit is an on-site review and inspection of a monitoring organization's ambient air monitoring program to assess its compliance with established regulations governing the collection, analysis, validation, and reporting of ambient air quality data. Technical systems audits of each PQAO shall be conducted at least every 3 years by the appropriate EPA Regional Office and reported to the AQS. If a PQAO is made up of more than one monitoring organization, all monitoring organizations in the PQAO should be audited within 6 years (two TSA cycles of the PQAO). As an example, if a state has five local monitoring organizations that are consolidated under one PQAO, all five local monitoring organizations should receive a technical systems audit within a 6-year period. TSA information from

[14] A website is available for this entry. Since the web address could change, it is not included here. Monitoring organizations are emailed every year to enter this information to the current website address.
[15] https://www3.epa.gov/ttn/amtic/aapgvp.html

these EPA Regional audits are required to be reported to AQS. A detailed questionnaire used to facilitate the audits performed by the EPA is found in Appendix H; the information presented in this section provides general guidance for conducting technical systems audits.

NOTE: As of the distribution of this document, an EPA Workgroup is developing a guidance document for TSAs. The information described here may change.

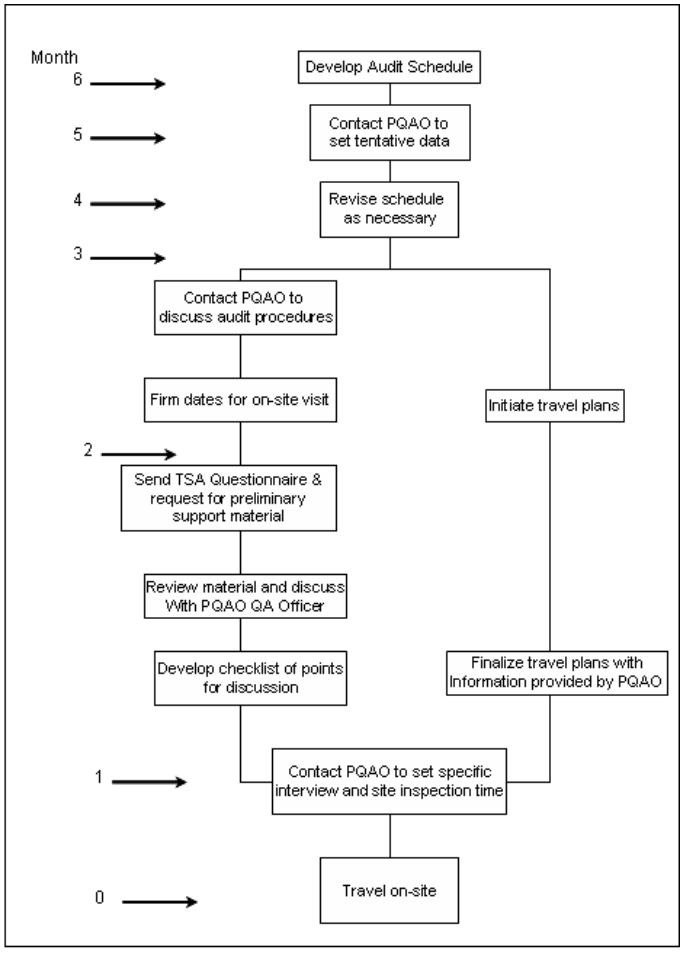


Figure 15.2 Pre-audit activities

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 Regional Office manager or his designee should establish a tentative schedule for on-site systems audits of the PQOAs within their Region. It is recommended that each scheduled TSA have a designated audit lead. It is further 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 appropriate organization representative (such as the monitoring program manager or quality assurance officer) to coordinate specific dates and schedules for the on-site audit. During this initial contact, the audit lead should arrange a tentative schedule for meetings with key personnel, as well as a schedule for inspection of selected ambient air quality monitoring and measurement operations. At the same time, a schedule should be tentatively set for the exit meeting used to debrief the monitoring organization 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 also inform the monitoring organization representative that the organization 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 checklists and reports
Date/Audit #	Date of audit, as well as a unique TSA/project identification number. For example, the year and number of audit can be combined to produce a project number, such as 08-1 or 08-2.
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 determine 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 TSA is found in Appendix H.
Audit team	Team lead and members.
Auditees	Personnel from the audited organization who should be available for participation/interview during the on-site TSA activities. This should include the program manager(s), principal investigator(s), monitoring leads, organization's QA representative(s), 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, QAPPs, 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 (or other time frame deemed appropriate) of receipt. The information within the questionnaire is considered a minimum, and both the EPA Region and the monitoring organization 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 AQS precision, bias, and completeness data, as well as any other information on data quality, can augment the documentation received from the monitoring organization under audit. After reviewing the questionnaire response, the audit lead should prepare a summary or checklist detailing specific points for discussion with monitoring organization personnel.

The audit team should be made up 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 optimized. A possible division may be that one group assesses the support laboratory and headquarters operations while another evaluates field sites, and subsequently assesses audit and calibration information. The audit lead should confirm the proposed audit schedule with the audited organization immediately prior to the start of the on-site activities.

15.3.2. On-Site Activities

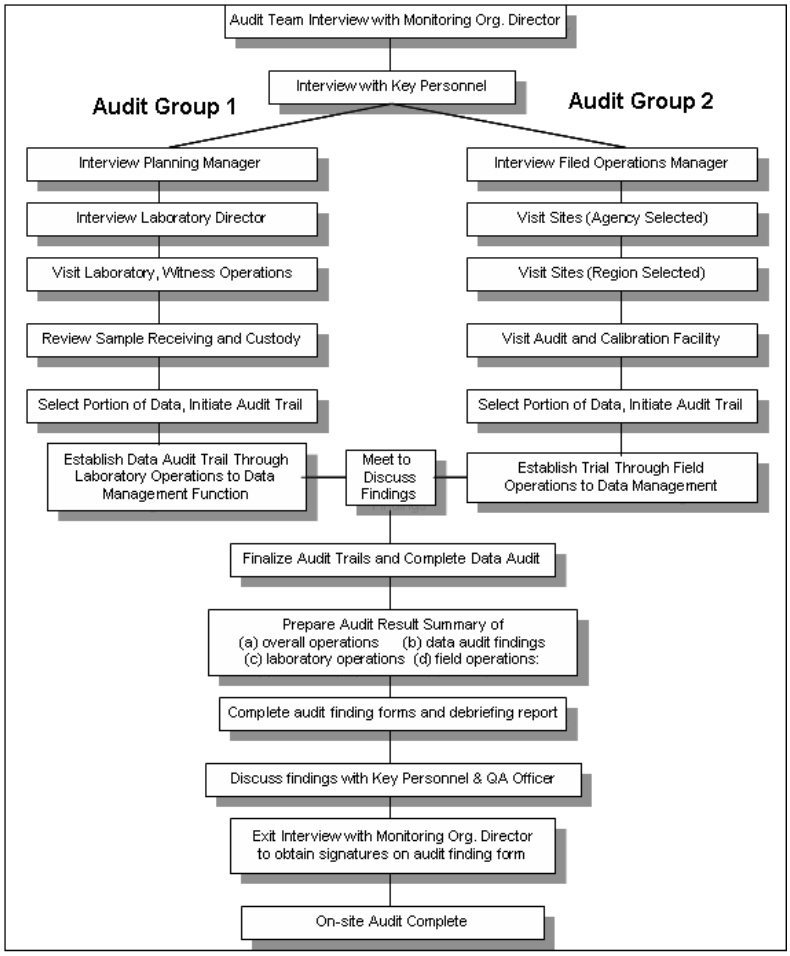


Figure 15.3 On-site audit activities

The audit team should meet initially with the audited monitoring organization'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 monitoring organization program manager or 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 can be found in Appendix H.

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 monitoring organization 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, and monitoring support functions within the organization.

The entire audit team should collaborate and prepare a brief written summary of findings, organized into the following areas: field operations, laboratory operations, quality assurance/quality control, data management, and reporting. Problems within specific areas should be discussed by the audit team and an attempt made to rank them in order of their potential impact on data quality.

Figure 15.4 is an example of an audit finding form that may be used by the audit team to delineate the more serious problems identified during the TSA. If utilized, the audit finding form is filled out for each major deficiency that requires formal corrective action. They are initiated by the audit team, and discussed at the exit briefing.

The audit is completed by having the audit team members meet once again with key personnel, the QAO, and finally with the monitoring organization's director to present their findings. 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 the monitoring organization 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.

Audit Finding

Audit Title: _____ Audit #: ____ Finding #:

Finding:

Discussion:

QA Lead Signature: Date:

Audited Agencies

Signature: Date:

Figure 15.4 Audit Finding Form

The exit briefing is also the opportunity for the monitoring organization to present any disagreements with the findings. Evidence may be presented by the audited organization that reduces the significance of the finding, in which case the finding may be removed. If the audited monitoring organization is in agreement with the finding, the audit finding form (if used) is signed by the monitoring organization's director or his/her designee during the exit meeting. If a disagreement occurs, the QA Team should record the opinions of the monitoring organization audited and set a time at some later date to address the finding at issue.

15.3.3 Post-Audit Activities

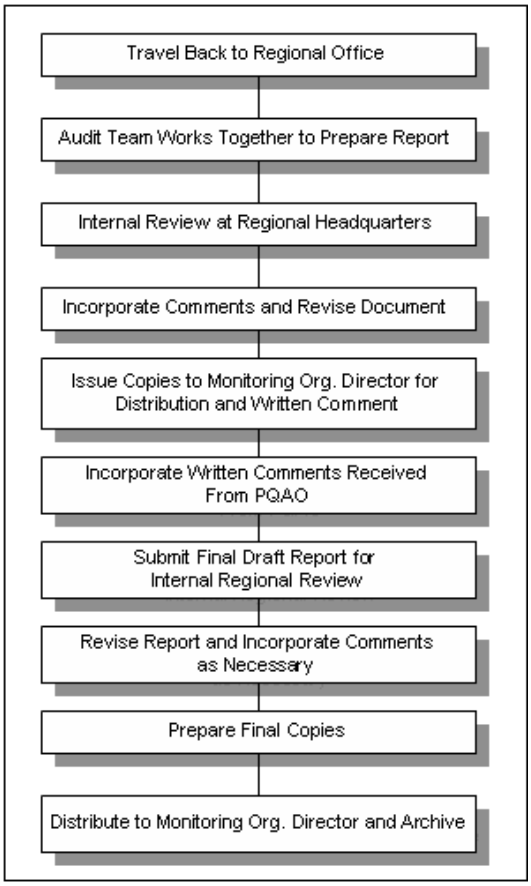


Figure 15.5 Post-audit activities

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

- audit title, 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; and
- 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 QAPP 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 draft audit report should be prepared and submitted.

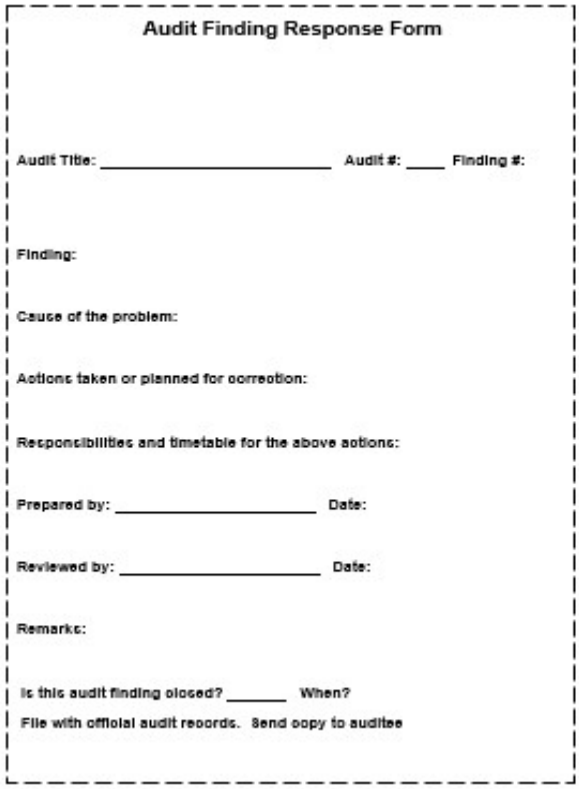
The draft TSA report is submitted to the audited monitoring organization. It is suggested that a cover letter

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 monitoring organization in its current form, and will be formally distributed without further changes.

If the monitoring organization 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 monitoring organization 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.

15.3.4 Follow-up and Corrective Action Requirements

As part of corrective action and follow-up, an audit finding response form (Figure 15.6) is generated by the audited organization for each finding submitted by the audit team. The audit finding response form is signed by the audited organization's director and sent to the organization responsible for oversight who reviews and accepts the corrective action. The audit response form should be completed by the audited organization within 30 days of acceptance of the audit report.


Audit Finding Response Form

Audit Title: _____ Audit #: ____ Finding #:

Finding:

Cause of the problem:

Actions taken or planned for correction:

Responsibilities and timetable for the above actions:

Prepared by: _____ Date:

Reviewed by: _____ Date:

Remarks:

Is this audit finding closed? _____ When?

File with official audit records. Send copy to auditee

Figure 15.6 Audit Finding Response Form

15.3.5 TSA Reporting to AQS

All 40 CFR Part 58, Appendix A-required TSAs will be reported to AQS. A QA transaction is available in AQS to allow the reporting of 5 parameters: 1) the monitoring organization audited, 2) the auditing agency, 3) the begin date of the audit, 4) the end date of the audit, and 5) the close-out date. The close-out date is defined as the date when all corrective actions for major findings identified in the audit were completed. Monitoring organizations can also use this feature to report internal audits to AQS if they so desire.

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 decisions 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 the EPA guidance document *Data Quality Assessment: A Reviewers Guide* (EPA QA/G-9R), as well as in Section 18 of this QA Handbook. The process 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, and develop plots/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.

EPA QA/G-9S, a companion document to EPA QA/G-9R, provides many appropriate statistical tests. Both can be found on the EPA Quality Staff's Website[16].

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. Currently EPA produces annual box and whisker plots of the gaseous pollutants titled: *Criteria Pollutant Quality Indicator Summary Report* that are posted on AMTIC[17] and has automated the report and posted it on the AirData website[18]. EPA also develops 3-year QA reports for $PM_{2.5}$[19]. As more QA data becomes accessible and improvements are made in reporting and assessment technologies, EPA hopes to develop a library of reports that users can run at more frequent intervals. Monitoring organizations are encouraged to implement data quality assessments for their data.

Data not meeting DQOs does not necessarily invalidate this data, but it means that those using the information for NAAQS decisions, or for other objectives, may have less certainty of making a correct decision. Monitoring organizations not meeting DQOs should make every effort to discover the reasons for the measurement uncertainties in their monitoring networks. EPA Regions or the monitoring organization QA staff may want to revise TSA schedules based on the results from data quality assessments.

[16] https://www.epa.gov/quality/agency-wide-quality-system-documents
[17] http://www3.epa.gov/ttn/amtic/qareport.html
[18] https://www.epa.gov/outdoor-air-quality-data see "Single Point Precision and Bias Report"
[19] http://www3.epa.gov/ttn/amtic/anlqa.html

16.0 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 information and requests for assistance concerning quality control and quality assurance problems. The guidance offered here is primarily intended for PQAOs that provide data to one or more of these national networks:

- SLAMS (State and Local Air Monitoring Stations)
- Tribal Monitoring Stations
- PAMS (Photochemical Air Monitoring Stations)
- PSD (Prevention of Significant Deterioration stations)
- NCore (National Core Monitoring Network)
- CSN (Chemical Speciation Network)
- NATTS (National Air Toxic Trend Stations)

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 (SPMs) 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; and,
- Suggestions for improving performance, which may include items such as fixing equipment problems, personnel training needs, and infrastructure improvements.

A report to management should not solely consist of tabulations of analyzer-by-analyzer precision and bias 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 AQS. Instead, the annual quality assurance report to management should summarize and discuss the results of such checks. These summaries from individual PQAOs can be incorporated into additional reports issued by the state, local, tribal and/or the EPA Regional Office.

This section also 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; and,
- techniques and methods for concise and effective presentation of information.

Appendix I of this Handbook 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, along with suggested reporting frequencies. An individual monitoring organization may have others to add to this list or may create reports that are combinations of those listed below. Similarly, an individual organization may prepare reports to management on a more frequent basis than what is presented in Table 16-1.

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	x	x
National Performance Evaluation Program results	Summary of PEP, NPAP, NATTS PT, and CSN audit results.	x				x
State and local organization performance audits	Summary of audit results; recommendations for action, as needed.	x				x
Technical systems 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	x
Data Certification Reports	annual summary report of all the ambient air quality data and summary reports of measurement quality data					x
Network reviews	Review results and suggestions for actions, as needed.					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 bias checks (AMP251 and 256 reports), results of systems and performance audits, laboratory and field instrument maintenance logbooks, and NPAP audits. 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	Location
State implementation plan	Types of monitors, locations, and sampling schedule.	https://www.epa.gov/air-quality-implementation-plans/sip-status-reports
Annual Network Plans	Provides for locations of networks and objectives of monitoring sites.	https://www3.epa.gov/ttn/amtic/plans.html
Quality management plans and quality assurance project plans	Data quality indicators and goals for precision, bias, completeness, timeliness.	On file at monitoring organization and in most cases EPA Regional Offices.

Information Source	Expected Information and Usefulness	Location
Quality objectives for measurement data document	Quality objectives for measurement data. Audit procedures and frequency.	Most criteria pollutants posted in CFR. Some under criteria pollutant QA site. http://www3.epa.gov/ttn/amtic/qapollutant.html
Laboratory and field instrument maintenance logbooks	Record of maintenance activity, synopsis of failures, recommendations for equipment overhaul or replacement.	Internal monitoring organization documents
Laboratory weighing room records of temperature, humidity	A record of whether or not environmental control in the weighing room is adequate to meet goals.	Internal monitoring organization documents
Audit results (NPAP, local, etc.)	Results of audit tests on ambient air pollutant measurement devices.	AQS data base
Quality control data on local information management systems or AQS	Results are generally considered valid and can be used to determine achievement of data quality objectives.	AQS data base

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. A 2008 EPA guidance document designed to assist Tribes in developing monitoring programs contains an expanded section (Section 7) that discusses many of the statistical techniques described in Table 16-3[1]. Several of these methods are available on-line in AirData[2]; 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 I of this Handbook
Control chart	Shows whether a repetitive process stays within QC limits	Figure 10.4 of this Handbook
Black box report	Visually highlights information by color coding boxes to indicate where project goals, DQOs, etc were/were not met	Executive Summary of Appendix I. Three-year $PM_{2.5}$ QA Reports on AMTIC
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 and box and whisker plots	Show a numerical value with its associated precision range.	Figure 1 of Appendix I

16.1.4 Annual Quality Assurance Report

The annual quality assurance report should consist of a number of sections that describe the quality objectives for measurement data and how those objectives have been met. An example annual quality assurance report is included in Appendix I of this Handbook. A suggested organization of the report might include:

Executive Summary of Report to Management - The executive summary should be a short section (typically one or two pages) that summarizes the annual quality assurance report to management. It

[1] Technical Guidance for the Development of Tribal Monitoring Programs
https://www.epa.gov/sites/production/files/2016-08/documents/techguidancetribalattch_0.pdf
[2] http://www.epa.gov/airdata/

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 Annual Data Certification

As described in 40 CFR part 58.15; *"the state, or where appropriate local, agency shall submit to the EPA Regional Administrator an annual air monitoring data certification letter to certify data collected by FRM, FEM, and ARM monitors at SLAMS and SPM sites that meet criteria in appendix A to this part from January 1 to December 31 of the previous year. The head official in each monitoring agency, or his or her designee, shall certify that the previous year of ambient concentration and quality assurance data are completely submitted to AQS and that the ambient concentration data are accurate to the best of her or his knowledge, taking into consideration the quality assurance findings. The annual data certification letter is due by May 1 of each year."* Along with each certification letter, the state shall submit:

- an annual summary report of all the ambient air quality data collected by FRM, FEM, and ARM monitors at SLAMS and SPM sites and

- a summary of the precision and accuracy data for all ambient air quality data collected by FRM, FEM, and ARM monitors at SLAMS and SPM sites

This certification package can be considered a report to management since the reports provide a good indication of the quality of data, are usually generated by the monitoring staff, and provided to management for review and submission to the EPA Regions. More guidance on the certification process can be found in Section 14 and on AMTIC[3]

[3] https://www3.epa.gov/ttn/amtic/qacert.html

16.1.6 Corrective Action Request

A corrective action request should be made whenever anyone in the monitoring organization notes a problem that demands either immediate or long-term action to correct a safety defect or an operational problem (either instrument malfunctions or procedural errors). A typical corrective action request form, with example information entered, is shown in Appendix I. 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 (i.e., the 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. The concepts of the corrective action requests and form apply to either hardcopy or electronic processing of this information. Laboratory/monitoring organization information management systems may be capable of implementing this process.

17.0 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, through provision of objective evidence, that *specified requirements* have been fulfilled[1]. Validation can be defined as confirmation, through provision of objective evidence, that the particular requirements for a specific *intended use* are fulfilled. So, for example, one could verify that for a monitor all 1-point QC checks were performed every two weeks (*specified requirement*) as described in standard operating procedures (*specified requirement*). However, if the checks were outside the QC limits described in the QAPP, the validation process might determine that the data could not be used for NAAQS determinations (*intended use*). 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 at some specified frequency by persons implementing the environmental data operations, as well as by personnel "independent" of the operation, such as the organization's QA personnel. 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 AQS and prior to final data quality assessments that will be discussed in Section 18.

Each of the following areas of discussion described below should be considered during the data review/verification/validation processes. Some of the discussion applies to situations in which a sample is collected 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*[2]:

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, and each site must be monitored for changes that may affect siting requirements. 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. Deviations from regulatory requirements and from specifications in the QAPP should be noted on sample documentation (e.g., chain of custody forms, field data forms, or logbooks) in a manner conducive to subsequent data entry. For example, development of a detailed set of data qualifiers (flags) makes data aggregation and assessment in information management systems much easier, can help identify how often a qualifier is used, and whether the identified deviation has an effect on data quality.

Sample Collection Procedures- Details of how a sample is collected 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 criterion. Validation activities should note potentially unacceptable departures from the QAPP. Comments or findings on deviations from written sampling plans made during field technical systems audits or reviews should be noted.

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[1] American National Standard Quality Systems of Environmental Data and Technology Programs ANSI/ASQ E4-2004 http://ansi.org/

[2] EPA Guidance to Quality Assurance Project Plans http://www.epa.gov/quality1/qs-docs/g5-final.pdf

Sample Handling- Details of how a sample is physically treated and handled during transportation to and from the field site, and through all laboratory handling stages prior to final analysis/reporting, are extremely important. Correct interpretation of the subsequent measurement results requires that deviations from the sample handling section of the QAPP/SOPs, and the actions taken to minimize or control the changes, be detailed. Data collection SOPs should indicate events that occur during sample handling that may affect the integrity of the samples. At a minimum, those responsible for reviewing/verifying/validating data should confirm that the appropriate sample containers and the preservation methods 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 (qualifiers) 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 the 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 criterion, 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- Proper calibration of instruments and equipment should be verified. The information should be reviewed to ensure that the calibrations:

- were performed before sampling began and at frequencies specified in the QAPP;
- were performed in the proper sequence (i.e., there may be a sequence of checks or other implementation activities that must take place prior to calibration);
- 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); and,
- had acceptable linearity checks and other checks to ensure that the measurement system was stable when the calibration was performed.

When calibration checks are found to be outside the acceptable limits prescribed in the QAPP, raw data sampled between this calibration and the previous calibration(s) should be handled as described in the QAPP. This could involve use of data flagging techniques for subsequent data evaluation.

Data Reduction and Processing- Data reduction/processing may be an irreversible process that involves a loss of detail in the data and may involve averaging across time (e.g., 5-minute, hourly or daily averages) or space (e.g., compositing results from samples thought to be physically equivalent). Since this summarizing process produces few values to represent a group of many data points, its validity should be well-documented in the QAPP. Data verification should include performing the data reduction

process with a subset of raw data by hand to verify that automated reduction/processing techniques are performing as required in the QAPP and SOPs.

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. In many cases these types of reports are generated on a frequent basis. A process should be developed that verifies that the reports are being properly generated. This can include hand-generating a subset of the report and reviewing and verifying the programming code used to generate the reports.

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 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; and,
- Submittal of the data into the EPA's AQS database.

More details of information management systems are included in Section 14. All systems (both manual and computer-oriented systems) require individual reviews of all data tabulations. As an individual scans these tabulations, it is nearly impossible 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.

Manual review of data tabulations also allows detection of 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 zero control chart information.

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 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.

DAS Data Review

The data review is an ongoing process that is performed by the station operators (SO) and the data processing team (DP). At a minimum a cursory review is performed daily, preferably in the morning, to provide a status of the data and instrument performance at monitoring sites. Detailed analysis can be

extremely difficult for the data processing team when reviewing the raw data without the notations, notes and calibration information that the station operators provide for the group. The typical review process for the station operator and data reviewer(s) include:

- (SO) Review of zero, span, one-point QC verification information, the hourly data, and any flags that could affect data; record any information on the daily summaries that might be vital to proper review of the data.
- (SO) Transfer strip charts information (both analog and digital), daily summaries, monthly maintenance sheets, graphic displays of meta data and site log notes to the central location for a secondary and more thorough review.
- (SO) At the central location, review the data, marking any notations of invalidations and provide electronic strip charts, meta data charts, daily summaries, site notes, and monthly maintenance sheets for ready access by the data processing staff.
- (DP) Review zero, span and one-point QC verifications, station notes, and monthly maintenance sheets for the month. Compare a defined number (e.g., 5%) of hand-reduced and/or strip chart readings to electronic data points generated by the DAS. If significant differences are observed, determine what corrective action is required.

Outliers

Outliers are "measurements that are extremely large or small relative to the rest of the data and are suspected of misrepresenting the population from which they were collected" (EPAQA/G9R). When reviewing data, some potential outliers will be obvious, such as spikes in concentrations, data remaining the same for hours, or a sudden drop in concentration (but still in the normal range of observed data). Many of these outlier checks can be automated and provide efficient real-time checks of data. Outliers do not necessarily indicate the data is invalid; they serve to alert the station operator and/or data reviewers there may be a problem. In fact, the rule of thumb for outliers should be that the data be considered valid until there is an explanation for why the data should be invalidated. At some point it may be necessary to exclude outliers from instantaneous reporting to the AIRNow network and/or AQI reporting until further investigation has occurred. EPA Guidance Documents[3] *Guidance on Environmental Data Verification and Validation* (EPA QA/G8) and *Guidance for Data Quality Assessment – A Reviewers Guide* (EPA QA/G9R) provide insight on outlier and data reviews in general.

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. If possible, use of statistical techniques to identify data anomalies and outliers (e.g., control charts) are encouraged since they provide a more consistent evaluation. Some of these techniques and checks may be incorporated into data logging systems and well as main office information management systems.

> **NOTE:** During submission of data to AQS, a number of outlier (see outlier information below) and gap checks are performed. The AQS website has documents describing these checks. When an outlier is observed, a warning is generated and sent to the monitoring organization. Monitoring organizations may ignore this warning and submit the data. However, it is recommended that this data be reviewed and compared to the validation records for this set of

[3] https://www.epa.gov/quality/agency-wide-quality-system-documents

data both to verify that the data are valid and as a test of the organizations data review system. If the outlier is considered valid, a "V" qualifier flag can added to the data indicating the validity of the value. During automated annual data certification, any outlier that does not have a "V" flag will be identified and will require the monitoring organization to review the data and either invalidate the data point or add a "V" qualifier. Therefore, EPA recommends that it is better to review and validate outliers during initial reporting rather than delay the certification process.

17.2 Data Verification Methods

Verification can be defined as confirmation, through provision of objective evidence, that *specified requirements* have been fulfilled[4]. The verification requirements for each data operation are included in the organization's QAPP and in SOPs and should include not only the verification of sampling and analysis processes but also operations such as data entry, calculations, and data reporting. 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 but are not limited to:

- Were the environmental data operations performed according to the SOPs 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 some 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.
- Have manual calculations, manual data entry, or human adjustments to software settings been checked? Automated calculations should be verified and accepted prior to use, but at some frequencies these calculations should be reviewed to ensure that they have not changed.

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. Effective data validation procedures usually are handled completely independently from the procedures of initial data collection.

[4] https://www.epa.gov/quality/agency-wide-quality-system-documents Guidance on Environmental Data Verification and Data Validation (QA/G-8)

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 SOPs are needed to ensure the validation process is consistently followed within a monitoring organization. For example, one can evaluate the difference between successive data values, since one would not normally expect very rapid changes in concentrations of a pollutant during a 5-minute or 1-hour reporting period. When the difference between two successive values exceeds a predetermined value, the data can the flagged for further investigation.

Quality control data can support data validation procedures (see Section 17.3.3). 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. Therefore, if ambient data are determined to be invalid, the associated precision, bias and accuracy readings related to the routine data should not be reported to AQS[5]. Section 17.3.4 provides additional guidance on how to handle QC data when routine data are 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.

Measurement quality objectives, based upon requirements in CFR, QAPPs and SOPs, in combination with field and laboratory technical expertise, may be used to invalidate a sample or measurement. Many organizations use flags or result qualifiers to identify potential problems with data or a sample. Flags can indicate 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 individual samples (data), or samples from a particular instrument, will be invalidated. In all cases, the sample (data) should be thoroughly reviewed by the organization and invalidated only for cause (i.e. objective evidence can be found that it does not fulfill the requirements for its intended use).

Flags may be used alone or in combination to invalidate samples. Since the possible flag combinations can be overwhelming and cannot 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 can be used to ensure that the organization evaluates and invalidates data in a consistent manner and should be documented in the QAPP and updated as needed.

Procedures for screening data for possible errors or anomalies should also be implemented. The data quality assessment document series (EPA QA/G-9R[6], EPA QA/G-9s[7]) provide several statistical screening procedures for ambient air quality data that should be applied to identify data outliers.

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[5] See QA EYE Newsletter Issue #13 Page 6 http://www3.epa.gov/ttn/amtic/files/ambient/qa/qanews13.pdf

[6] Data Quality Assessment: A Reviewer's Guide https://www.epa.gov/quality/agency-wide-quality-system-documents

[7] Data Quality Assessment: Statistical Methods for Practitioners https://www.epa.gov/quality/agency-wide-quality-system-documents

NOTE: appropriate null data code flags should replace any routine values that are invalidated when reporting data to AQS. This provides an indication to data users/ assessors to the reasons why data that was expected to be collected was missing. The actual data values and associated flags should remain in the monitoring organization's local database per the statute of limitations.

17.3.1 Automated Methods

When zero, span, or one-point QC checks exceed acceptance limits, 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 check, unless some other point in time can be identified and related to the probable cause of the excessive drift or exceedance (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 acceptable check or calibration. Based on the sophistication of the DAS (see Section 14), monitoring organizations may have other automated programs for data validation. These programs should be described in the monitoring organization's approved QAPP prior to implementation. Even though the automated technique may be considered acceptable, the raw invalidated data should be archived based on the statute of limitations discussed in Section 5.

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, 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 national performance evaluations required in 40 CFR 58, Appendix A not be used as the **sole** criteria for data invalidation because these checks are performed fairly infrequently, not at every site, and would result in a significant invalidation of data depending on how the information was used. The performance evaluations are used to provide an assessment of data comparability and bias at the PQAO level rather than an evaluation of a particular monitor. So although a performance evaluation result might lead to a question about the data quality of a particular monitor, it is expected that other quality control data would also be used in the data validation process.

17.3.3 Validation Templates

In June 1998, a workgroup was formed to develop a procedure that could be used by monitoring organizations that would provide for a consistent validation of $PM_{2.5}$ mass concentrations across the United States. The workgroup included personnel from the monitoring organizations, EPA Regional Offices, and OAQPS who were involved with assuring the quality of $PM_{2.5}$ mass; additionally, the workgroup was headed by a State and local representative. The workgroup developed a table consisting of three criteria, where each criterion had a different degree of implication about the quality of the data. The criteria included on the tables were from 40 CFR Part 50, Appendices L and N, 40 CFR Part 58, Appendix A, and Method 2.12; a few criteria were also added that were neither in CFR nor Method 2.12, but were technical elements of which the workgroup felt should be included.

To determine the appropriate classification for each criterion, the members of the workgroup considered how significantly the criterion impacted the resulting $PM_{2.5}$ mass. This was based on experience from workgroup members, experience from non-workgroup members, and feasibility of implementing the criterion.

Critical Criteria- deemed critical to maintaining the integrity of a sample (or ambient air concentration value) or group of samples. Observations that do not meet each and every criterion on the critical table should be invalidated unless there are compelling reason and justification for not doing so. Basically, the sample or group of samples for which one or more of these criteria are not met is invalid until proven otherwise. In most cases the requirement, the implementation frequency of the criteria, and the acceptance criteria are found in CFR and are therefore regulatory in nature. The sample or group of samples for which one or more of these criteria are not met is invalid until proven otherwise. In many cases, precedent has been set on invalidating data that do not meet CFR criteria. For example, the $PM_{2.5}$ sampler must maintain a volumetric flow rate of approximately 16.67 LPM in order for its inertial separators to appropriately fractionate the collected ambient air particles. With that in mind, the criterion that the average flow rate for the $PM_{2.5}$ sampling period must be maintained to within ±5% of 16.67 LPM is considered a critical criterion. A deviation from a requirement listed in CFR that includes an acceptance criterion is cause for data invalidation. Any regulatory requirement that identifies a frequency and an acceptance criterion is considered critical.

Operational Criteria - important for maintaining and evaluating the quality of the data collection system. Violation of a criterion or a number of criteria may be cause for invalidation. The decision maker should consider other quality control information that may or may not indicate the data are acceptable for the parameter being controlled. Therefore, the sample or group of samples for which one or more of these criteria are not met is suspect unless other quality control information demonstrates otherwise and is documented. The reason for not meeting the criteria should be investigated, mitigated or justified. An example criterion is that the $PM_{2.5}$ field filter blanks should not change weight by more than 30µg between initial and final weighings.

Systematic Criteria - include those criteria which are important for the correct interpretation of the data but do not usually impact the validity of a sample or group of samples. An example criterion is that at least 75% of the scheduled samples for each quarter should be successfully collected and validated. The data quality objectives are also included in this table. If the data quality objectives are not met, this does not invalidate any of the samples but it may impact the confidence in the attainment/non-attainment decision.

> **NOTE:** Please note the designation of quality control checks as Operational or Systematic do not imply that these quality control checks need not be performed. Not performing an operational or systematic quality control check that is required by regulation (in CFR) can be a basis for invalidation of all associated data. Any time a CFR requirement is identified in the Requirement, Frequency or Acceptance Criteria column it will be identified by bold and italics font. Many monitoring organization/PQAOs are using the validation templates and have included them in QAPPs. However, it must be mentioned that diligence must be paid to its use. Data quality findings through data reviews and technical systems audits have identified multiple and concurrent non-compliance with operational criteria that monitoring organization considered valid without any documentation to prove the data validity. The validation templates were meant to be applied to small data sets (single values or a few weeks of information) and should not be construed to allow a criterion to be in non-conformance simple

because it is operational or systematic.

The data validation templates will evolve as new information is discovered about the impact of the various criteria on the error in the resulting concentration estimate. In recent years there has been a number of circumstances where critical criteria and in some cases operational criteria that were in regulation (had a frequency and acceptance criteria) where not met. In these cases, EPA has been consistent in their application of invalidating data not meeting regulations. Interactions of the criteria, whether synergistic or antagonistic, should also be incorporated when the impact of these interactions becomes quantified. Due to the potential misuse of invalid data, data that are invalidated should not be uploaded to AQS, but should be retained on the monitoring organization's local database. This data will be invaluable to the evolution of the validation template.

Appendix D of this Handbook provides the AMTIC[8] web address for the validation templates for each criteria pollutant. Since technology and regulations may change faster than development and revisions to the Handbook, the validation templates will be posted on AMTIC so that changes to the templates can be made more easily and efficiently. EPA will also provide a running tally of the changes to the validation template so that over time it will be easier for the user to see any edits or changes to the template.

NOTE: Although adherence to regulations are required, strict adherence to the validation templates is not required. They are meant to be a guide based upon current knowledge and best practices and may be a starting point for the monitoring organization's specific validation requirement. Monitoring organizations should discuss deviations from the validation templates with their respective EPA Regions to ensure the deviation under consideration is not considered significant.

17.3.4 Reporting QC Data Relative to Data Validation

The intent of the QC data that are reported to the AQS is to provide an estimate of precision and bias of the routine data collected during a particular time period. For example, the 1-point QC check is performed minimally every two weeks for the gaseous pollutants and so the data from the check represents that the monitor was within acceptance specifications for that time period. Upon failure of the QC checks and subsequent invalidation of the data (should that occur), it is expected that null value codes would replace the routine data and that the QC check would not be reported to AQS. Since the routine data would not be available, it would not be appropriate to provide a QC value that would be used in overall estimates of precision and bias of that site. The estimate of precision and bias for that site should represent the **valid** routine data being reported for the site.

It is suggested that only those QC checks that are performed on each monitor/sampler are subject to removal and only for the checks within the same time period that the routine data were invalidated. As an example, if the Annual PE for ozone was performed in April 2012 and the ozone data for December 2012 were invalidated, the April 2012 PE could remain in AQS and only the 1-point QC checks for December would be removed. Not all Appendix A QC checks fit nicely into this paradigm. For example:

Collocated data- Since they represent a PQAO and not an individual site it becomes more of a dilemma.

[8] http://www.epa.gov/ttn/amtic/qalist.html

However, if routine data from a collocated site were invalidated due to a finding based on imprecision of the collocated data (faulty collocated sampler), then one would not want to have these data represent the other sites in the PQAO.

NPAP and PEP data - Similar to the collocated data, this data represents the PQAO and is not often used to invalidate data. However, there are cases where NPAP data have been used in concert with other data quality information that led to the invalidation of routine data and, in that case, it would not be appropriate to report the NPAP results to AQS.

Other concerns might arise in connection with the annual PEs or audits mentioned above. Consistent with many organizations' QAPPs, data will not be invalidated on the basis of an audit alone. Many agencies will verify, such as by independent tests, the results of a "failed" audit. It might not be practical in all cases to verify an audit result, immediately recalibrate the "failed" channel, and then schedule a second audit following the recalibration. Accordingly, excluding the audit result that discovered a problem in the first place could cause the responsible organization either to incur additional audit costs or, alternatively, be "penalized" for appearing to fail to meet the required number of audits. Many organizations would be concerned about having a less than complete audit count appear in the AMP600 at the time of annual data certification.

As suggested above, monitoring organizations should keep in mind the objective of reporting the results of QA and QC checks to AQS: representing the precision and bias of the reported raw data. The analysts who report these data should be mindful that precision and bias calculations can apply at the monitor level or at the PQAO level. Often, a result that falls outside criteria indicates an out-of-control situation that is subsequently corrected such as by invalidating data and recalibrating. Under other circumstances, after-the-fact review of QC checks with poor, but "passing," results might reveal a trend consistent with a problem that was only discovered by some other means.

Because of concerns such as these, it is important to consider these recommendations in the context of corrective action. It is recommended that QAPPs include wording that addresses when to retain and when to exclude QA and QC data from AQS and when to conduct replacement QA/QC checks. However, it is impossible to foresee every circumstance that might lead to a poor QA/QC result and, in some cases, it might not be obvious whether to report or exclude a result. In these cases, decisions may fall to the responsible QA officers or managers. Discussions between the EPA Region and monitoring organizations might also need to occur to determine the best course of action.

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, to 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 monitoring organizations 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 are adequate for their 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. These procedures can also be used for data that do not have formal DQOs, but some idea of the decisions that will be made with the data are needed. Guidance on the DQA process can be found in the document titled *Data Quality Assessment: A Reviewer's Guide (EPA QA/G-9R).* It has a companion document, *Data Quality Assessment: Statistical Tools for Practitioners (EPA QA/G-9S*), that focuses on evaluating data for fitness in decision-making and also provides many graphical and statistical tools. Both documents can be found on the EPA Quality Staffs website[1]

As stated in EPA QA/G-9R, "*Data quality, as a concept, is meaningful only when it relates to the intended use of the data*". By using the DQA Process, one can answer four fundamental questions:

1. Can the decision (or estimate) be made with the desired level of certainty, given the quality of the data set?
2. How well did the sampling design perform?
3. If the same sampling design strategy is used again for a similar study, would the data be expected to support the same intended use with the desired level of uncertainty?
4. Is it likely that sufficient samples were taken to enable the reviewer to see an effect if it was really present?

The DQA is a key part of the assessment phase of the data life cycle (Figure 18.1), which is very similar to the ambient air QA life cycle described in Section 1. 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.

It is realized that some monitoring organizations may not have the statistical support available to use the formal DQA process described below. The information below is intended to provide a good example of the steps that would be followed for a formal DQA for those capable and interested in the approach. EPA, through the development of the criteria pollutant DQOs and the assessments it produces through 3-year QA reports, AQS AMP reports, and annual box and whisker plots, attempts to provide information to assist monitoring organizations in their data quality assessments. In addition, there are many software packages available that can generate the statistics mentioned in the following DQA steps and there are a number of internet sites that can be searched to inform one on how to use these statistics. Some additional guidance will be provided after the five-step process that can be used to help evaluate data.

[1] https://www.epa.gov/quality/agency-wide-quality-system-documents

18.1 Five Steps of the DQA Process

As described in *EPA QA/G-9R* and *EPA QA/G-9S*, 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[2] for a fictitious PQAO called Palookaville. The model QAPP was developed to help monitoring organizations develop QAPPs based upon the R-5 QAPP requirements. Most of the information that follows will be provided verbatim from the Model QAPP. However, notes will be added where updates, relative to the date of this Handbook, are needed.

The DQA discussed below is based on a 3-year assessment. The $PM_{2.5}$ DQOs were developed with goals for a 3-year precision estimate of 10 percent coefficient of variation and a 3-year bias estimate of $\pm$ 10 percent. Some steps below may seem inefficient since monitoring organizations evaluate QC data on a more frequent basis than every three years. However, the example below is used relative to the achievement of the 3-year $PM_{2.5}$ DQO.

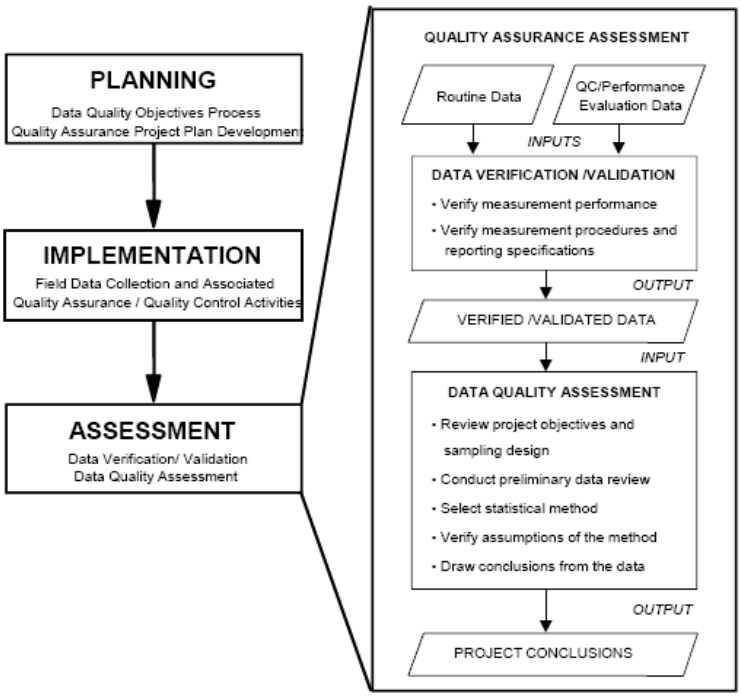

Figure 18.1 DQA in the context of data life cycle.

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;

[2] http://www3.epa.gov/ttn/amtic/pmqa.html

for estimation problems, define an acceptable confidence probability interval width). Review the sampling design and data collection documentation for consistency with the DQOs observing any potential discrepancies.

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 12 µg/m^3 and 3-year average of annual 98th percentiles of the $PM_{2.5}$ concentrations less than or equal to 35 µg/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.

> **NOTE:** CFR now requires an annual air monitoring network plan[3] that may be helpful in the evaluation of this step.

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

A preliminary data review will be performed to uncover potential limitations of 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[4]. 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 prominent summary statistics for each of its primary and QA samplers. These 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. For example, Palookaville may evaluate the

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[3] Monitoring plans can be found on AMTIC at: https://www3.epa.gov/ttn/amtic/plans.html
[4] At the writing of this Handbook, the AQS system produces the AMP256 Data Quality Indicator report, which is the primary report for the assessment of quality assurance data for criteria pollutants.

influence of a potential outlier by evaluating the change in the summary statistics resulting from exclusion of the outlier.

Palookaville will generate graphics to present the results from the summary statistics and show the spatial continuity over the sample areas. 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 performance and acceptance criteria associated with 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:

$$H_0 : X \leq 12\ \mu g / m^3 \ \text{and}\ Y \leq 35\ \mu g / m^3$$
$$H_A : X > 12\ \mu g / m^3 \ \text{or}\ Y > 35\ \mu g / m^3$$

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 12.05 $\mu g/m^3$ or when the observed three-year average of the annual 98th percentiles exceeds 35.5 $\mu g/m^3$. If the bias of the sampler is ± 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. The 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 concentration 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. Instead, Palookaville will evaluate the reasonableness of the normality assumption by reviewing a normal probability plot, and calculating the Shapiro-Wilk W Test statistic (if sample size less than 50) or calculating the Kolmogorov-Smirnoff Test statistic (if sample size greater than 50). All three techniques are provided by standard statistical packages. 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 (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%. 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 3-year level of aggregation, the sampler bias is within $\pm$ 10% and precision is < 10%. The data from the collocated samplers will be used to calculate quarterly, annual, and 3-year bias and precision estimates even though it is only the 3-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 closer to the "true" value. The following paragraphs contain the algorithms for calculating precision and bias. These are similar, but differ slightly, from the equations in 40 CFR Part 58, Appendix A.

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, some ground work is necessary. 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 quarter's 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	$w_q = 12\text{-}(Q\text{-}1)$ 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, $w_q = 11/(Q\text{-}1)$ 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.*

$$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} \times 100\,\%$$

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*

$$\hat{D}_j = \frac{\sum_{q=1}^{n_q} w_q D_{j,q}}{\sum_{q=1}^{n_q} w_q} \qquad \textit{Equation 18-1}$$

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, a non-parametric test will be used (Wilcoxon Signed Rank Test), which is described in EPA QA/G-9S[2]. 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, cv_i,*

$$cv_i = \frac{|d_i|}{\sqrt{2}}$$

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*

$$\hat{CV}_j = \sqrt{\frac{\sum_{q=1}^{n_q} \left(w_q CV_{j,q}^{\,2}\right)}{\sum_{q=1}^{n_q} w_q}} \qquad \textit{Equation 18-2}$$

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 in Table 24-2 (reference to Model QAPP).

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 12 $\mu g/m^3$ and the observed three-year average 98th percentile is less than 35 $\mu g/m^3$, 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 investigated.

What if the DQOs Are Not Met?

DQOs provide a goal on which to build a quality system. As the DQO process is developed, the EPA identifies what are expected to be reasonable and achievable measurement quality objectives that, if met, can be assumed that the DQOs will be achieved as well. The DQA process is implemented to confirm the achievement of the DQOs. However, achieving the DQOs does not equate to one hundred percent certainty that every NAAQS decision (attainment, non-attainment) will be a correct decision. Even when a DQO is achieved, there is still a chance of making an incorrect decision as the data (e.g., design value)

get closer to the action limit (NAAQS). Similarly, if the DQOs are not met it does not mean that the pollutant data cannot be used for NAAQS decisions; it means that the decision makers will have less confidence that they will make the correct decision, especially around the action limit. In either case (achieving or not achieving the DQOs) the data is used as it has been measured and reported and is not corrected in any manner for this uncertainty. Based on this understanding of uncertainty, EPA listed the DQOs as goals in CFR. Data quality indicator reports demonstrate that these goals are being met for the majority of the monitoring organizations so they are considered achievable. However, if DQOs are developed and through assessments EPA finds that the goals cannot be met, then either the DQOs must be revised or new technologies (sampling or analytical methods) must be developed to achieve the DQOs. At the monitoring organization level, if the DQA shows that DQOs are not achieved, then the organization should use that information to determine whether underlying systematic issues need to be addressed and corrected. For example, if the organization is utilizing older equipment or outdated monitoring technology to support its network operations, then exceedance of the DQOs may indicate that purchasing new, updated equipment is warranted.

DQA Tools

Over the years EPA has developed DQOs for each criteria pollutant as the criteria pollutant moved through the NAAQS review process. In addition, monitoring organizations collect enough types of QA/QC data to estimate the quality of their data and should be able to express the confidence in that information. The following reports and tools can help monitoring organizations assess the quality of their information.

AMP256 Report –

At a minimum the quality control information described in 40 CFR Part 58, Appendix A, that is submitted to AQS can be used to perform assessments of measurement uncertainty. The AMP256 report is the most important QA report in AQS for the criteria pollutants. It provides an assessment of each quality control sample based on the statistical criteria set forth in 40 CFR Part 58, Appendix A. It aggregates data by PQAO and, depending on the begin data and end date of the selected report, it will summarize data by year as well as 3-year intervals. It will assess quality control data completeness as well as precision and bias (depending on the type of quality control sample). A user ID is required to access AQS and data is required to be loaded in AQS in order to run reports. This can be problematic based on the lag time of information that is reported to AQS.

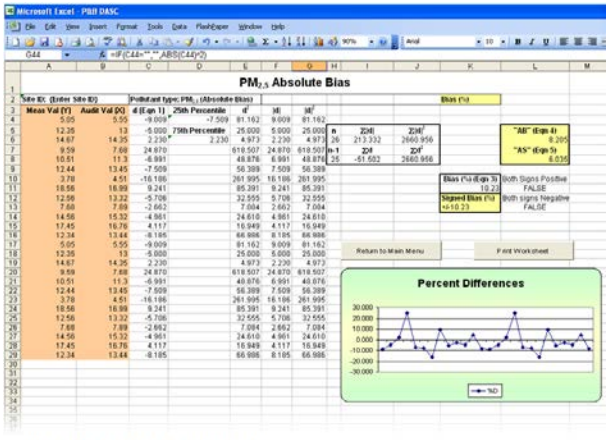

Figure 18.2 Example DASC Tool

Data Assessment Statistical Calculator (DASC) Tool –

In order to provide monitoring organizations access to CFR statistics, prior to submission to AQS, EPA developed the DASC Tool. This tool, developed in Microsoft Excel, provides for local entry of QC data and uses the same statistics provided in 40 CFR Part 58, Appendix A. The software and a guidance document for its use can be found on AMTIC[5]

[5] Data Assessment Statistical Calculator https://www3.epa.gov/ttn/amtic/qareport.html

Annual Box and Whisker Plots

The AMP256 and DASC tools are very useful, but EPA was also looking for more graphical ways to display precision and bias data in order to assist monitoring organizations in identifying monitoring sites in need of corrective action. Figure 18.3 provides an example of the report (new report on Air Data). The plots are created using the 1-point QC checks for the gaseous pollutants or each site within the PQAO, and include the same precision and bias information that is generated in the AMP256 and well as the number of observations used in the assessment. In addition, the graphical display can identify sites that are biased or are variable. Information on how to assess the box and whisker information, as well as the annual reports, up until 2014 are found on AMTIC[6]. In 2016 the plots were automated and can be found at Air Data[7] where a monitoring organization can run the plots any time.

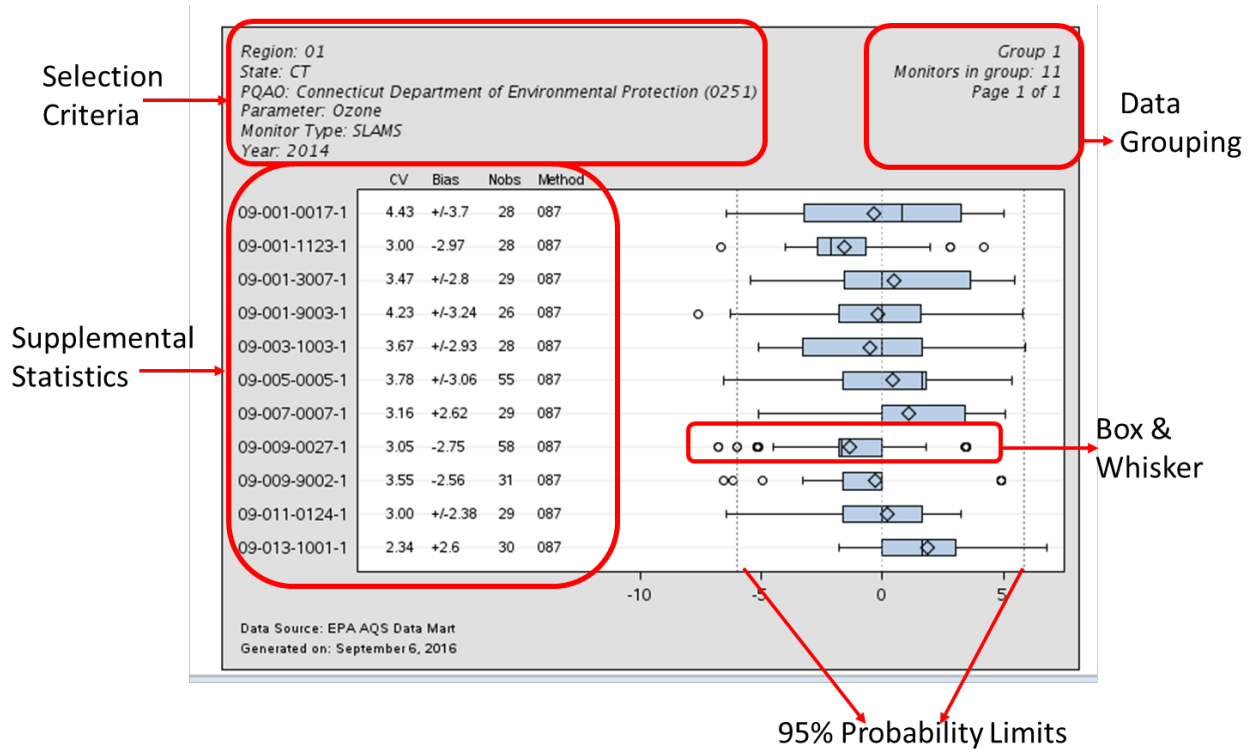

Figure 18.3. Components of Box and Whisker Plots

[6] Criteria Pollutant Quality Indicator Summary Report for AQS Data https://www3.epa.gov/ttn/amtic/qareport.html
[7] https://www.epa.gov/outdoor-air-quality-data See "Single Point Precision and Bias Report"

Appendix A

National Air Quality Monitoring Program Fact Sheets

The following information provides a fact sheet on a number of national ambient air monitoring networks including:

- **State or Local Air Monitoring Stations (SLAMS) Network**
- **National Core (NCore) Network**
- **Photochemical Assessment Monitoring Stations (PAMS)**
- **$PM_{2.5}$ Chemical Speciation Network (CSN)**
- **National Air Toxics Trends Network Stations (NATTS)**
- **Interagency Monitoring of Protected Visual Environments (IMPROVE)**
- **Clean Air Status and Trends Network (CASTNET)**
- **National Atmospheric Deposition Network (NADP)**

Only the SLAMS, NCore, PAMS, CSN and NATTS pertain to the information covered in the Handbook. The other networks described are for the benefit of the reader.

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State or Local Air Monitoring Stations (SLAMS) Network

Background

The SLAMS make up the ambient air quality monitoring sites that are operated by State or local agencies for the primary purpose of comparison to the National Ambient Air Quality Standards (NAAQS), but may serve other purposes such as:

- provide air pollution data to the general public in a timely manner;
- support compliance with air quality standards and emissions strategy development; and
- support air pollution research studies.

The SLAMS network includes stations classified as NCore, PAMS, and Speciation, and formerly categorized as NAMS, and does not include Special Purpose Monitors (SPM) and other monitors used for non-regulatory or industrial monitoring purposes.

In order to support the objectives, the monitoring networks are designed with a variety of monitoring sites that generally fall into the following categories which are used to determine:

1. the highest concentrations expected to occur in the area covered by the network;
2. typical concentrations in areas of high population density;
3. the impact on ambient pollution levels of significant sources or source categories;
4. the general background concentration levels;
5. the extent of regional pollutant transport among populated areas, and in support of secondary standards; and
6. air pollution impacts on visibility, vegetation damage, or other welfare- based impacts.

The monitoring aspects of the SLAMS program are found in the Code of Federal Regulations, Title 40, Parts 50, 53 and 58.

SLAMS must use approved Federal reference method (FRM), Federal equivalent method (FEM), or Approved Regional Method (ARM) monitors for ambient pollutant levels being compared to the NAAQS.

Reference Category	References	Comments
Program References	40 CFR Part 50, 53 and 58 https://www.epa.gov/amtic	
Pollutants Measured	O_3, CO, SO_2, NO_2 $PM_{2.5}$, PM_{10}, Pb	
Methods References	40 CFR Part 50 and 58 Appendix C https://www.epa.gov/amtic/amtic-air-monitoring-methods	Must be FRM, FEM, or ARM for NAAQS comparisons. Website lists designated methods
Network Design References	40 CFR Part 58 Appendix D, E	
Siting Criteria	40 CFR Part 58 Appendix E	
Quality System References	40 CFR Part 58 Appendix A https://www3.epa.gov/ttn/amtic/qalist.html https://www3.epa.gov/ttn/amtic/met.html	 Website for QA Handbook Vol II Website for QA Handbook Vol IV
Data Management References	https://www.epa.gov/aqs	Air Quality System

National Core (NCore) Network

Background

NCore is a multi pollutant network that integrates several advanced measurement systems for particles, pollutant gases and meteorology. Most NCore stations have been operating since the formal start of the network on January 1, 2011. The NCore Network addresses the following objectives:

- Timely reporting of data to public by supporting AIRNow, air quality forecasting, and other public reporting mechanisms;
- Support for development of emission strategies through air quality model evaluation and other observational methods;
- Accountability of emission strategy progress through tracking long-term trends of criteria and non-criteria pollutants and their precursors;
- Support for long-term health assessments that contribute to ongoing reviews of the NAAQS;
- Compliance through establishing nonattainment/attainment areas through comparison with the NAAQS;
- Support to scientific studies ranging across technological, health, and atmospheric process disciplines; and
- Support to ecosystem assessments recognizing that national air quality networks benefit ecosystem assessments and, in turn, benefit from data specifically designed to address ecosystem analyses.

The objective is to locate sites in broadly representative urban (about 55 sites) and rural (about 20 sites) locations throughout the country to help characterize regional and urban patterns of air pollution.

In many cases, states will collocate these new stations with STN sites measuring speciated $PM_{2.5}$ components, PAMS sites already measuring O_3 precursors, and/or NATTS sites measuring air toxics. By combining these monitoring programs at a single location, EPA and its partners will maximize the multi-pollutant information available. This greatly enhances the foundation for future health studies, NAAQS revisions, validation of air quality models, assessment of emission reduction programs, and studies of ecosystem impacts of air pollution.

Reference Category	References	Comments
Program References	https://www3.epa.gov/ttn/amtic/ncore.html	
Pollutants Measured	SO_2, CO, NO and NO_y, and O_3, $PM_{2.5}$, $PM_{2.5}$ speciation, $PM_{10-2.5}$, basic meteorological parameters https://www3.epa.gov/ttn/amtic/ncore.html	
Methods References	https://www3.epa.gov/ttn/amtic/ncoreguidance.html	
Network Design References	https://www3.epa.gov/ttn/amtic/ncorenetworks.html	
Siting Criteria	https://www3.epa.gov/ttn/amtic/ncoreguidance.html	
Quality System References	https://www3.epa.gov/ttn/amtic/ncoreguidance.html	
Data Management References	https://www3.epa.gov/ttn/amtic/ncoreguidance.html	

Photochemical Assessment Monitoring Stations (PAMS)

Background

On February 12, 1993, the U.S. Environmental Protection Agency (EPA) revised ambient air quality surveillance regulations in Title 40 Part 58 of the Code of Federal Regulations (40 CFR Part 58) to include provisions for enhanced monitoring of ozone (O3), oxides of nitrogen (NOx), volatile organic compounds (VOCs), and selected carbonyl compounds, as well as monitoring of meteorological parameters. On October 1, 2015, EPA made significant changes to the PAMS monitoring requirements and applicability (40 CFR part 58 Appendix D, section 5.0) to better serve both national and local objectives. The EPA finalized a two part network design. The first part of the design includes a network of fixed sites ("required PAMS sites") intended to support O3 model development and evaluation and the tracking of trends of important O3 precursor concentrations. These required PAMS sites are to be located at NCore sites located in CBSAs with a population of one million or more. The second part of the network design requires states with moderate O3 non-attainment areas to develop and implement Enhanced Monitoring Plans (EMPs) which were intended to allow monitoring agencies the needed flexibility to implement additional monitoring capabilities to suit the needs of their area.

NOTE: As of the publication date of this Handbook, the PAMS Program was undergoing revisions to the implementation of the program. Those interested in more current guidance on the PAMS program should visit the AMTIC website for more up-to-date information.

Reference Category	References	Comments
Program References	https://www3.epa.gov/ttn/amtic/pamsmain.html	
Pollutants Measured	Ozone, Nitrogen Oxides, VOCs, surface meteorological https://www3.epa.gov/ttn/amtic/pamsreeng.html	
Methods References	https://www3.epa.gov/ttn/amtic/pamsguidance.html	
Network Design References	https://www3.epa.gov/ttn/amtic/pamssites.html	
Siting Criteria	https://www3.epa.gov/ttn/amtic/pamsmain.html https://www3.epa.gov/ttn/amtic/pamssites.html	
Quality System References	https://www3.epa.gov/ttn/amtic/pamsguidance.html	
Data Management References	https://www3.epa.gov/ttn/amtic/pamsdata.html	

$PM_{2.5}$ Chemical Speciation Network

Background

As part of the $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS) review completed in 1997, EPA established a $PM_{2.5}$ Chemical Speciation Network (CSN) consisting of Speciation Trends Network (STN) sites and supplemental speciation sites. The CSN is a component of the National $PM_{2.5}$ Monitoring Network. Although the CSN is intended to complement the activities of the much larger gravimetric $PM_{2.5}$ measurements network component (whose goal is to establish if the NAAQS are being attained), CSN data is not used for attainment or nonattainment decisions. CSN data is used for multiple objectives, which include:

- The assessment of trends;
- The development of effective State Implementation Plans (SIPs) and determination of regulatory compliance;
- The development of emission control strategies and tracking progress of control programs;
- Aiding in the interpretation of health studies by linking effects to $PM_{2.5}$ constituents;
- Characterizing annual and seasonal spatial variation of aerosols;
- Comparison to chemical speciation data collected from the IMPROVE network.

As of 2016, the $PM_{2.5}$ Chemical Speciation Network includes about 50 STN sites and about 100 State and Local Air Monitoring Stations (SLAMS) supplemental sites. All STN sites operate on a one-in-three day sample collection schedule. The majority of the SLAMS supplemental sites operate on a one-in-six day sample collection schedule. CSN sites collect aerosol samples over 24 hours on filters that are analyzed for a number of trace elements, major ions (sulfate, nitrate, ammonium, sodium, chloride and potassium), and organic and elemental carbon.

CSN data users include those at EPA seeking to determine concentration trends of $PM_{2.5}$ chemical species over a period of 3 or more years and decision-makers at tribal, state and local levels who use the data as input to models and for development of emission control strategies and determination of their long-term effectiveness. Other users include public health officials and epidemiological researchers.

Reference Category	References	Comments
Program References	https://www3.epa.gov/ttn/amtic/speciepg.html	
Pollutants Measured	Trace elements, ions, and organic and element carbon https://www3.epa.gov/ttn/amtic/specgen.html	
Methods References	https://www3.epa.gov/ttn/amtic/spectraining.html https://www3.epa.gov/ttn/amtic/specsop.html	
Network Design References	https://www3.epa.gov/ttn/amtic/specgen.html	
Siting Criteria	https://www3.epa.gov/ttn/amtic/specgen.html	
Quality System References	https://www3.epa.gov/ttn/amtic/specguid.html	
Data Management References	https://www3.epa.gov/ttn/amtic/specdat.html https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-32	

National Air Toxics Trends Network Stations (NATTS)

Background

The National Air Toxics Trends Network Stations (NATTS) has been developed to fulfill the need for long-term HAP monitoring data of consistent quality. Among the principle objectives are assessing trends and emission reduction program effectiveness, assessing and verifying air quality models (e.g., exposure assessments, emission control strategy development, etc.), and as direct input to source-receptor models. The current network configuration includes 27 sites (20 urban, 7 rural) across the United States; thirteen sites were established in 2003, ten sites in 2004, and two sites each in 2007 and 2008. There are typically over 100 pollutants monitored at each NATTS (though only 19 of those are required; included are VOCs, carbonyls, PM10 metals, hexavalent chromium, and PAHs. Specifically, it is anticipated that the NATTS data will be used for:

- tracking trends in ambient levels to facilitate tracking progress toward emission and risk reduction goals, which is the major objective of this program;
- directly evaluating public exposure & environmental impacts in the vicinity of monitors;
- providing quality assured data AT for risk characterization;
- assessing the effectiveness of specific emission reduction activities; and
- evaluating and subsequently improving air toxics emission inventories and model performance.

Currently the NATTS program is made up of 27 monitoring sites; representing urban (20) communities and rural (7) communities.

Reference Category	References	Comments
Program References	https://www3.epa.gov/ttn/amtic/natts.html	
Pollutants Measured	33 HAPS which include metals, VOCs and carbonyls https://www3.epa.gov/ttn/amtic/airtox.html	
Methods References	http://www.epa.gov/ttn/amtic/airtox.html http://www.epa.gov/ttn/amtic/files/ambient/airtox/nattsworkplantemplate.pdf	
Network Design References	https://www3.epa.gov/ttn/amtic/airtoxqa.html	National Air Toxics Trends Stations – Quality Management Plan –final 09/09/05
Siting Criteria	https://www3.epa.gov/ttn/amtic/natts.html	40 CFR part 58 Appendix E, PAMS Probe and Path Siting Criteria
Quality System References	https://www3.epa.gov/ttn/amtic/airtoxqa.html	
Data Management References	https://www3.epa.gov/ttn/amtic/toxdat.html	

Interagency Monitoring of Protected Visual Environments (IMPROVE)

Background

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program is a cooperative measurement effort governed by a steering committee composed of representatives from federal and regional-state organizations. The IMPROVE monitoring program was established in 1985 to aid the creation of Federal and State Implementation Plans for the protection of visibility in Class I areas (156 national parks and wilderness areas) as stipulated in the 1977 amendments to the Clean Air Act.
The objectives of IMPROVE are:

1. to establish current visibility and aerosol conditions in mandatory class I areas;
2. to identify chemical species and emission sources responsible for existing man-made visibility impairment;
3. to document long-term trends for assessing progress towards the national visibility goal;
4. and with the enactment of the Regional Haze Rule, to provided regional haze monitoring representing all visibility-protected federal class I areas where practical.

IMPROVE has also been a key participant in visibility-related research, including the advancement of monitoring instrumentation, analysis techniques, visibility modeling, policy formulation and source attribution field studies. In addition to 110 IMPROVE sites at visibility-protected areas, IMPROVE Protocol sites are operated identically at locations to serve the needs of state, tribes and federal agencies.

Reference Category	References	Comments
Program References	http://vista.cira.colostate.edu/improve/	
Pollutants Measured	PM_{10} & $PM_{2.5}$ mass concentration, and $PM_{2.5}$ elements heavier than sodium, anions, organic and elemental carbon concentrations. Optical & met. parameters at select sites	All sites have aerosol speciation monitoring by one day in three 24-hour duration sampling
Methods References	http://vista.cira.colostate.edu/Improve/sops/	
Network Design References	http://vista.cira.colostate.edu/Improve/improve-program/	
Siting Criteria	http://vista.cira.colostate.edu/Improve/monitoring-site-browser/	
Quality System References	http://vista.cira.colostate.edu/Improve/quality-assurance/	
Data Management References	http://vista.cira.colostate.edu/Improve/improve-data/	

Clean Air Status and Trends Network (CASTNET)

Background

The Clean Air Status and Trends Network (CASTNET) is a national air quality monitoring network designed to provide data to assess trends in air quality, atmospheric deposition, and ecological effects due to changes in air pollutant emissions. CASTNET began collecting measurements in 1991 with the incorporation of 50 sites from the National Dry Deposition Network, which had been in operation since 1987. CASTNET provides long-term monitoring of air quality in rural areas to determine trends in regional atmospheric nitrogen, sulfur, and ozone concentrations and deposition fluxes of sulfur and nitrogen pollutants in order to evaluate the effectiveness of national and regional air pollution control programs. CASTNET operates more than 80 regional sites throughout the contiguous United States, Alaska, and Canada. Sites are located in areas where urban influences are minimal. Ozone measurements became CFR 40 Part 58, Appendix A compliant in 2011. Meteorological measurements are made at approximately 30 sites, and are available for all sites prior 2010. Modeled dry deposition velocities are also provided.

The main objectives of the network are to:

1) track the effectiveness of national and regional scale emission control programs;
2) report high quality, publicly available data on the temporal and geographic patterns of air quality and atmospheric deposition trends; and
3) provide the necessary information for understanding the environmental effects in sensitive terrestrial and aquatic receptor areas associated with atmospheric loadings of pollutants.

Reference Category	References	Comments
Program References	CASTNET Main Webpage https://www.epa.gov/castnet/ CASTNET Annual Report https://java.epa.gov/castnet/documents.do	
Pollutants Measured	sulfate, nitrate, ammonium, sulfur dioxide, nitric acid, base cations, ozone CASTNET Factsheet https://java.epa.gov/castnet/documents.do	
Methods References	CASTNET Quality Assurance Project Plan (QAPP) Main Body https://java.epa.gov/castnet/documents.do	
Network Design References	CASTNET QAPP Main Body https://java.epa.gov/castnet/documents.do	
Siting Criteria	CASTNET QAPP Main Body https://java.epa.gov/castnet/documents.do	
Quality System References	CASTNET QAPP Main Body https://java.epa.gov/castnet/documents.do	
Data Management References	CASTNET QAPP Appendix 6: CASTNET Data Operations Standard Operating Procedures https://java.epa.gov/castnet/documents.do	

National Atmospheric Deposition Network (NADP)

Background

The National Atmospheric Deposition Program (NADP) provides quality-assured data and information in support of research on the exposure of managed and natural ecosystems and cultural resources to acidic compounds, nutrients, base cations, and mercury in precipitation. The NADP also provides data on ambient concentrations of speciated mercury and ammonia gases. NADP data serve science and education and support informed decisions on air quality issues related to precipitation and atmospheric chemistry.

The NADP operates three precipitation chemistry networks: the 250-station National Trends Network (NTN), 6-station Atmospheric Integrated Research Monitoring Network (AIRMoN), and 115-station Mercury Deposition Network (MDN) and two ambient monitoring networks: the 20-station Atmospheric Mercury Network (AMNet) and the 98-station Ammonia Monitoring Network. The NTN provides the only long-term nationwide record of the wet deposition of acids, nutrients, and base cations. NTN stations collect one-week precipitation samples in 48 states, Puerto Rico, the Virgin Islands, and Quebec Province, Canada. Complementing the NTN is the 6-station AIRMoN. The daily precipitation samples collected at AIRMoN stations support continued research of atmospheric transport and removal of air pollutants and the development of computer simulations of these processes. The MDN offers the only regional measurements of mercury (Hg) in North American precipitation. MDN data are used to quantify Hg deposition to water bodies that have fish and wildlife consumption advisories due to this toxic chemical. The AMNet compliments the MDN by measuring speciated hourly samples of ambient Hg gases. AMNet measurements are made using a Tekran instrument which analyzes ambient samples for elemental, gaseous and particulate bound Hg fractions. The AMoN is the only national monitoring network measuring ambient ammonia (NH3) concentrations. Bi-weekly measurements of NH3 compliment the NTN and CASTNET networks by filling a gap in the total nitrogen budget. Work continues on developing routine model estimates for Hg and NH3 bi-directional dry deposition velocities.

In addition to these long-term monitoring networks, the NADP is responsive to emerging issues requiring new or expanded measurements. Its measurement system is efficient, its data meet pre-defined data quality objectives, and its reports and products are designed to meet user needs.

Reference Category	References	Comments
Program References	NADP http://nadp.isws.illinois.edu/ NTN http://nadp.isws.illinois.edu/NTN/ AIRMoN http://nadp.isws.illinois.edu/AIRMoN/ MDN http://nadp.isws.illinois.edu/MDN/ AMNet http://nadp.isws.illinois.edu/amn/ AMoN http://nadp.isws.illinois.edu/AMoN/	
Pollutants Measured	In precipitation: sulfate, nitrate, chloride, ammonium, calcium, magnesium, sodium, potassium, pH, mercury Ambient concentrations: speciated mercury, ammonia	
Methods References	http://nadp.isws.illinois.edu/NADP/networks.aspx	
Network Design References	http://nadp.isws.illinois.edu/NADP/networks.aspx	
Siting Criteria	http://nadp.isws.illinois.edu/NADP/networks.aspx	
Quality System References	http://nadp.isws.illinois.edu/lib/qaPlans.aspx http://nadp.isws.illinois.edu/lib/qaReports.aspx	
Data Management References	http://nadp.isws.illinois.edu/lib/qaplans/NADP_Network_Quality_Assurance_Plan.pdf	

Appendix B

Ambient Air Monitoring Quality Assurance Information and Web Addresses

The following information provides key guidance documents and reports that can be found on various sites within the Ambient Monitoring Technical Information Center (AMTIC) Website. The following identifiers are used to describe national ambient air monitoring programs

SLAMS-	**State or Local Air Monitoring Stations Network**
NCore-	**National Core Network**
PAMS -	**Photochemical Assessment Monitoring Stations**
CSN	**$PM_{2.5}$ Chemical Speciation Network**
NATTS-	**National Toxics Trends Network**
SLAMS-NPAP-	**National Performance Audit Program**
SLAMS-PEP-	**National PM2.5 Performance Evaluation Program**

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Ambient Air Quality Assurance Information				
Identifier	**Title**	**EPA Number**	**Pub Date Year**	**URL**
	GUIDANCE DOCUMENTS			
CSN	Particulate Matter (PM2.5) Speciation Guidance Document		1999	http://www.epa.gov/ttn/amtic/files/ambient/pm25/spec/specfinl.pdf
NATTS	NATTS Technical Assistance Document (TAD)		2016	https://www3.epa.gov/ttn/amtic/airtox.html
NCore	NCore Technical Assistance Document (TAD)		2005	http://www.epa.gov/ttn/amtic/files/ambient/monitorstrat/precursor/tadversion4.pdf
NCore	QA Handbook for Air Pollution Measurement Systems Volume IV Meteorlogical Measurment Systems	EPA-454/B-08-002	2008	http://www.epa.gov/ttn/amtic/files/ambient/met/Volume%20IV_Meteorological_Measurements.pdf
PAMS	Technical Assistance Document (TAD) for Sampling and Analysis of Ozone Precursors;	EPA/600-R-98/161	1998	http://www.epa.gov/ttn/amtic/files/ambient/pams/newtad.pdf
SLAMS	QA Handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program	EPA-454/B-13-003	2017	http://www.epa.gov/ttn/amtic/qalist.html
SLAMS	Guideline on the Meaning and the Use of Precision and Bias Data Required by 40 CFR Part 58 Appendix A	EPA-454/B-07-001	2007	https://www3.epa.gov/ttn/amtic/files/ambient/qaqc/PBGuidance101007.pdf
SLAMS	Transfer Standards for the Calibration of Air Monitoring Analyzers for Ozone	EPA-454/B-13-004	2013	http://www.epa.gov/ttn/amtic/files/ambient/qaqc/OzoneTransferStandardGuidance.pdf
	QA REPORTS			
CSN	PM 2.5 Speciation Lab Audit Reports and Assessments		Various Years	http://www3.epa.gov/ttn/amtic/pmspec.html
NATTS	National Air Toxics Trends Stations Quality Assurance Annual Reports and Proficiency Reports		Various Years	http://www3.epa.gov/ttn/amtic/airtoxqa.html
SLAMS	Annual Precision, Bias and Completeness Reports for Criteria Pollutants		Various Years	http://www3.epa.gov/ttn/amtic/parslist.html
PAMS	PAMS Data Analysis and Reports		Various Years	http://www3.epa.gov/ttn/amtic/pamsdata.html
SLAMS-PM2.5	3-Year and Annual QA Reports		Various Years	http://www3.epa.gov/ttn/amtic/anlqa.html
SLAMS AA-PGVP	Annual Reports		Various Years	http://www3.epa.gov/ttn/amtic/aapgvp.html
SLAMS-PEP	Laboratory Comparison Study of Gravimetric Laboratories		Various Years	http://www3.epa.gov/ttn/amtic/pmpep.html
	Methods			
CSN	Speciation Field Guidance Documents		Various Years	http://www3.epa.gov/ttn/amtic/specguid.html
NATTS	Air Toxics Methods- Various Methods		2007	http://www3.epa.gov/ttn/amtic/airtox.html
SLAMS	Reference and Equivalent Methods-Criteria Polluntants		Various Years	https://www3.epa.gov/ttn/amtic/criteria.html
NCore	NCore Training Videos		Various Years	http://www3.epa.gov/ttn/amtic/qalist.html
SLAMS-NPAP	DRAFT SOP for Through-the-Probe Performance Evaluations of Ambient Air Quality Monitoring of Criteria Air Pollutants		2011	http://www.epa.gov/ttn/amtic/npapsop.html
SLAMS-PEP	Method Compendium "Field Standard Operating Procedures for the $PM_{2.5}$ Performance Evaluation Program"		2009	https://www3.epa.gov/ttn/amtic/pmpep.html
SLAMS-PEP	Method Compendium "$PM_{2.5}$ Mass Weighing Laboratory Standard Operating Procedures for the Performance Evaluation Program		1998	http://www.epa.gov/ttn/amtic/files/ambient/pm25/qa/peplsop.pdf
SLAMS-PM2.5	2.12 "Monitoring $PM_{2.5}$ in Ambient Air Using Designated Reference or Class I Equivalent Methods"	EPA-454/B-16-001	2016	https://www3.epa.gov/ttn/amtic/qapollutant.html
SLAM-Pb	Approved Equivalent Methods		Various Years	http://www.epa.gov/ttn/amtic/pb-monitoring.html

Ambient Air Quality Assurance Information				
Identifier	**Title**	**EPA Number**	**Pub Date Year**	**URL**
SLAM-Pb	RTI Procedure for the development of Pb Analysis Audits (TSP)		2010	http://www.epa.gov/ttn/amtic/files/ambient/pb/rtipbauditstrip2010.pdf
SLAM-Pb	RTI Procedure for the development of Pb Analysis Audits (Teflon for ICP-MS)		2012	http://www.epa.gov/ttn/amtic/files/ambient/pb/rtipbauditsopteflon.pdf
SLAMS-Pb	MO Procedure for the development of Pb Analysis Audits (TSP)		2009	http://www.epa.gov/ttn/amtic/files/ambient/pb/MOAuditStripMethod.pdf
	IMPLEMENTATION PLANS and QAPPs			
CSN	Speciation Laboratory Standard Operating Procedures		Various Years	http://www.epa.gov/ttn/amtic/specsop.html
CSN	Quality Chemical Speciation Network QAPP for NCore and Supplemental Sites	EPA-454/B-12-003	2012	http://www.epa.gov/ttn/amtic/files/ambient/pm25/spec/CSN_QAPP_v120_05-2012.pdf
	Addendum to June 2012 Quality Assurance Project Plan for the PM2.5 Chemical Speciation Sampling at Trends, NCore,	EPA-454/B-12-003	2015	https://www3.epa.gov/ttn/amtic/specguid.html
CSN	Quality Management Plan for the $PM_{2.5}$ Speciation Trends Network	EPA-454/R-01-009	2001	http://www.epa.gov/ttn/amtic/files/ambient/pm25/spec/finlqmp.pdf
NATTS	Model Quality Assurance Project Plan for the National Air Toxics Trends Stations - updated version 1.1		2007	http://www.epa.gov/ttn/amtic/files/ambient/airtox/NATTS_Model_QAPP.pdf
NATTS	Model QAPP for Local-Scale Monitoring Projects	EPA-454/R-01-007	2006	http://www.epa.gov/ttn/amtic/files/ambient/airtox/pilotqapp.pdf
NATTS	National Air Toxics Trends Stations - Quality Management Plan Final		2005	http://www.epa.gov/ttn/amtic/files/ambient/airtox/nattsqmp.pdf
PAMS	PAMS Implementation Manual	EPA-454/B-93-051	1994	http://www.epa.gov/ttn/amtic/files/ambient/pams/b93-051a.pdf
PAMS	PAMS Required Sites Quality Assurance Implementation Plan		2016	https://www3.epa.gov/ttn/amtic/pamsguidance.html
SLAMS PM2.5	$PM_{2.5}$ Model QA Project Plan (QAPP)	EPA-454/R-98-005	1998	http://www.epa.gov/ttn/amtic/files/ambient/pm25/qa/totdoc.pdf
SLAMS PM2.5	PM2.5 FRM Network Federal Performance Evaluation Program Quality Assurance Project Plan (QAPP)		2009	https://www3.epa.gov/ttn/amtic/pmpep.html
SLAMS PM2.5	$PM_{2.5}$ Performance Evaluation Program Implementation Plan		1998	http://www.epa.gov/ttn/amtic/files/ambient/pm25/qa/pep-ip.pdf
AA-PGVP	Ambient Air Protocal Gas Verification Program QAPP		2010	http://www.epa.gov/ttn/amtic/files/ambient/qaqc/pgvp-qapp-march2010v2.pdf
AA-PGVP	Ambient Air Protocal Gas Verification Program Implementation Plan		2010	http://www.epa.gov/ttn/amtic/files/ambient/qaqc/aapgvpimpplan.pdf
	WHITE PAPERS/IMPORTANT MEMOS			
CSN	Current List of CSN Sites as of November 2016		2016	http://www3.epa.gov/ttn/amtic/specgen.html
CSN	Modification of Carbon Procedures in the Speciation Network; Overview and Frequently Asked Questions		2006	http://www.epa.gov/ttn/amtic/files/ambient/pm25/spec/faqcarbon.pdf
SLAMS	Training and Conferences		Various Years	https://www3.epa.gov/ttn/amtic/training.html
SLAMS	QA Newsletters		Various Years	http://www3.epa.gov/ttn/amtic/qanews.html

Appendix C

Using the Graded Approach for the Development of QMPs and QAPPs in Ambient Air Quality Monitoring Programs

NOTE: As of the date of this Handbook publication the EPA Quality Staff is revising some of the requirements for QAPPs and QMPs. Please visit the Quality Staffs website for updates on these documents (http://www.epa.gov/quality1/)

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Using the Graded Approach for the Development of QMPs and QAPPs in Ambient Air Quality Monitoring Programs

EPA policy requires that all organizations funded by EPA for environmental data operations (EDOs) develop quality management plans (QMPs) and quality assurance project plans (QAPPs). In addition, EPA has provided flexibility to EPA organizations on how they implement this policy, allowing for use of a graded approach. The following proposal explains the graded approach for data collection activities related to ambient air monitoring. OAQPS proposes a graded approach for the development of QAPPs and QMPs.

The Graded Approach

The QMP describes the quality system in terms of the organizational structure, functional responsibilities of management and staff, lines of authority, and required interfaces for those planning, implementing, and assessing activities involving EDOs. Each program should provide appropriate documentation of their quality system. Here are a few ways that this could be handled.

Concept - Small organizations may have limited ability to develop and implement a quality system. EPA should provide options for those who are capable of making progress towards developing a quality system. If it is clear that the EDO goals are understood and that progress in quality system development is being made, a non-optimal quality system structure, for the interim, is acceptable. The concept is to work with the small organization to view the QMP as a long-term strategic plan with an open ended approach to quality system development that will involve continuous improvement. The graded approach to QMP development is described below and is based on the size of the organization and experience in working with EPA and the associated QA requirements.

1. Small organization that just received its first EPA grant or using a grant for a discrete, small, project-level EDO. Such organizations could incorporate a description of its quality system into its QAPP.
2. Small organization implementing EDOs with EPA at more frequent intervals or implementing long-term monitoring programs with EPA funds. If such an organization demonstrates capability of developing and implementing a stand-alone quality system, it is suggested that an appropriate separate QMP be written.
3. Medium or large organization. Develop QMP to describe its quality system and QAPPs for specific EDOs. Approval of the recipient's QMP by the EPA Project Officer and the EPA Quality Assurance Manager may allow delegation of the authority to review and approve Quality Assurance Project Plans (QAPPs) to the grant recipient based on acceptable procedures documented in the QMP.

Quality Assurance Project Plans

The QAPP is a formal document describing, in comprehensive detail, the necessary QA/QC and other technical activities that must be implemented to ensure that the results of work performed will satisfy the stated performance criteria, which may be in the form of a data quality objective (DQO). The quality assurance policy of the EPA requires every EDO to have written and approved quality assurance project plans (QAPPs) prior to the start of the EDO. It is the responsibility of the EPA Project Officer (person responsible for the technical work on the project) to adhere to this policy. If the Project Officer gives permission to proceed without an approved QAPP, he/she assumes all responsibility. If a grantee's QMP is approved by EPA and provides for delegation of QAPP approval to the grantee, the grantee is responsible to ensuring approval of the QAPP prior to the start of the EDO.

The Ambient Air Monitoring Program recommends a four-tiered project category approach to the Ambient Air QA Program in order to effectively focus QA. Category I involves the most stringent QA approach, utilizing all QAPP elements as described in EPA R5[a] (see Table 2), whereas category IV is the least stringent, utilizing fewer elements. In addition, the amount of detail or specificity required for each element will be less as one moves from category I to IV. Table 1 provides information that helps to define the categories of QAPPs based upon the data collection objective. Each type of ambient air monitoring program EDO will be associated with one of these categories. The comment area of the table will identify whether QMPs and QAPPs can be combined and the type of data quality objectives (DQOs) required (see below). Table 2 identifies which of the 24 QAPP elements are required for each category of QAPP. Based upon a specific project, the QAPP approving authority may add/delete elements for a particular category as it relates to the project but in general, this table will be applicable based on the category of QAPP.

Flexibility on the systematic planning process and DQO development

Table 1 describes 4 QAPP/QMP categories which require some type of statement about the program or project objectives. Three of the categories use the term data quality objectives (DQOs), but there should be flexibility with the systematic planning process on how these DQOs are developed based on the particular category. For example, a category 1 project would have formal DQOs. Examples of category I projects, such as the State and Local Monitoring Stations (SLAMS), have DQOs developed by OAQPS. Category II QAPPS may have formal DQOs developed if there are national implications to the data (i.e., Speciation Trends Network) or less formal DQOs if developed by organizations implementing important projects that are more local in scope. Categories 3 and 4 would require less formal DQOs to a point that only project goals (category 4) may be necessary.

[a] EPA Requirements for QA Project Plans (QA/R-5) http://www.epa.gov/quality/qa_docs.html

Standard Operating Procedures- (SOP)

SOPs are an integral part of the QAPP development and approval process and- usually address key information required by the QAPP elements. Therefore, SOPs can be referenced in QAPP elements as long as the SOPs are available for review or are part of the QAPP.

Table 1. Ambient Air Monitoring Program QAPP/QMP categories

Categories	Programs	QAPP/QMP Comments	DQO
Category 1 Projects include EDOs that directly support rulemaking, enforcement, regulatory, or policy decisions. They also include research projects of significant national interest, such as those typically monitored by the Administrator. Category I projects require the most detailed and rigorous QA and QC for legal and scientific defensibility. Category I projects are typically stand-alone; that is, the results from such projects are sufficient to make the needed decision without input from other projects.	SLAMS PSD NCore IMPROVE CastNet	Most agencies implementing Ambient Air Monitoring Networks will have separate QMPs and QAPPs. However, a Region has the discretion to approve QMP/QAPP combination for small monitoring organizations (i.e., Tribes)	Formal DQOs
Category 2 Projects include EDOs that complement other projects in support of rulemaking, regulatory, or policy decisions. Such projects are of sufficient scope and substance that their results could be combined with those from other projects of similar scope to provide necessary information for decisions. Category II projects may also include certain high visibility projects as defined by EPA management	Speciation Trends Toxics Mon.	Most agencies implementing Ambient Air Monitoring Networks will have separate QMPs and QAPPs. However, a Region has the discretion to approve QMP/QAPP combination for small monitoring organizations (i.e., Tribes)	Formal DQOs for national objective, Flexible DQOs for localized objectives
Category 3 Projects include EDOs performed as interim steps in a larger group of operations. Such projects include those producing results that are used to evaluate and select options for interim decisions or to perform feasibility studies or preliminary assessments of unexplored areas for possible future work.	SPM One time Studies Local Scale Air Toxics Grants	EDOs of short duration. QMP and QAPP can be combined.	Flexible DQOs
Category 4 Projects involving EDOs to study basic phenomena or issues, including proof of concepts, screening for particular analytical species, etc. Such projects generally do not require extensive detailed QA/QC activities and documentation	Education/Outreach		Project Objectives or Goals

Table 2 QAPP Elements

QAPP Element		Category Applicability
A1	Title and Approval Sheet	I, II, III, IV
A2	Table of Contents	I, II, III
A3	Distribution List	I,
A4	Project/Task Organization	I, II, III
A5	Problem Definition/Background	I, II, III
A6	Project/Task Description	I, II, III, IV
A7	Quality Objectives and Criteria for Measurement Data	I, II, III, IV
A8	Special Training Requirements/Certification	I
A9	Documentation and Records	I, II, III
B1	Sample Process (Network) Design	I, II, III, IV
B2	Sampling Methods Requirements	I, II, III,
B3	Sample Handling and Custody Requirements	I, II, III
B4	Analytical Methods Requirements	I, II, III, IV
B5	Quality Control Requirements	I, II, III, IV
B6	Instrument/Equipment Testing, Inspection & Maintenance	I, II, III
B7	Instrument Calibration and Frequency	I, II, III
B8	Inspection/Acceptance Requirements for Supplies and Con.	I,
B9	Data Acquisition Requirements for Non-direct Measurements	I, II, III
B10	Data Management	I, II
C1	Assessments and Response Actions	I, II,
C2	Reports to Management	I, II,
D1	Data Review, Validation, and Verification Requirements	I, II, III
D2	Validation and Verification Methods	I, II
D3	Reconciliation and User Requirements	I, II,

Appendix D

Measurement Quality Objectives and Validation Templates

Please go to the AMTIC Website to find the Measurement Quality Objectives and Validation Templates

https://www3.epa.gov/ttn/amtic/qalist.html

Since the templates may change or be revised more frequently then this guidance document, EPA felt it would be better to include the templates on AMTIC.

In addition, EPA will also maintain a table of revisions on AMTIC so monitoring organizations can easily identify what changes have been made since the templates were posted.

Appendix E
Characteristics of Spatial Scales Related to Each Pollutant

The following tables provide information in order to match the spatial scale represented by the monitor with the monitoring objectives.

NOTE: This information can also be found in 40 CFR Part 58, Appendix D and since there is a possibility that spatial scales have been updated, users should also review CFR.
http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl

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Pollutant	Spatial Scale	Characteristics NOTE: This information can also be found in 40 CFR Part 58, Appendix D and since there is a possibility that spatial scales have been updated, users should also review CFR.
NCore	Urban	Generally located at urban or neighborhood scale to provide representative concentrations of exposure expected throughout the metropolitan area; however, a middle-scale site may be acceptable in cases where the site can represent many such locations throughout a metropolitan area.
	Rural	Rural NCore stations are to be located to the maximum extent practicable at a regional or larger scale away from any large local emission source, so that they represent ambient concentrations over an extensive area.
PM_{10}	Micro	This scale would typify areas such as downtown street canyons, traffic corridors, and fence line stationary source monitoring locations where the general public could be exposed to maximum PM10 concentrations. Microscale particulate matter sites should be located near inhabited buildings or locations where the general public can be expected to be exposed to the concentration measured. Emissions from stationary sources such as primary and secondary smelters, power plants, and other large industrial processes may, under certain plume conditions, likewise result in high ground level concentrations at the microscale. In the latter case, the microscale would represent an area impacted by the plume with dimensions extending up to approximately 100 meters. Data collected at microscale sites provide information for evaluating and developing hot spot control measures.
	Middle	Much of the short-term public exposure to coarse fraction particles (PM10) is on this scale and on the neighborhood scale. People moving through downtown areas or living near major roadways or stationary sources, may encounter particulate pollution that would be adequately characterized by measurements of this spatial scale. Middle scale PM10 measurements can be appropriate for the evaluation of possible short-term exposure public health effects. In many situations, monitoring sites that are representative of micro-scale or middle-scale impacts are not unique and are representative of many similar situations. This can occur along traffic corridors or other locations in a residential district. In this case, one location is representative of a neighborhood of small scale sites and is appropriate for evaluation of long-term or chronic effects. 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 seldomly swept parking lots associated with these sources could be an important source in addition to the vehicular emissions themselves.
	Neighborhood	Measurements in this category represent conditions throughout some reasonably homogeneous urban subregion with dimensions of a few kilometers and of generally more regular shape than the middle scale. Homogeneity refers to the particulate matter concentrations, as well as the land use and land surface characteristics. In some cases, a location carefully chosen to provide neighborhood scale data would represent not only the immediate neighborhood but also neighborhoods of the same type in other parts of the city. Neighborhood scale PM10 sites provide information about trends and compliance with standards because they often represent conditions in areas where people commonly live and work for extended periods. Neighborhood scale data could provide valuable information for developing, testing, and revising models that describe the largerscale concentration patterns, especially those models relying on spatially smoothed emission fields for inputs. The neighborhood scale measurements could also be used for neighborhood comparisons within or between cities.

Pollutant	Spatial Scale	Characteristics NOTE: This information can also be found in 40 CFR Part 58, Appendix D and since there is a possibility that spatial scales have been updated, users should also review CFR.
SO_2	Micro	This scale would typify areas in close proximity to SO_2 point and area sources. Emissions from stationary point and area sources, and non-road sources may, under certain plume conditions, result in high ground level concentrations at the microscale. The microscale typically represents an area impacted by the plume with dimensions extending up to approximately 100 meters.
	Middle	This scale generally represents air quality levels in areas up to several city blocks in size with dimensions on the order of approximately 100 meters to 500 meters. The middle scale may include locations of expected maximum short-term concentrations due to proximity to major SO_2 point, area, and/or non-road sources.
	Neighborhood	The neighborhood scale would characterize air quality conditions throughout some relatively uniform land use areas with dimensions in the 0.5 to 4.0 kilometer range. Emissions from stationary point and area sources may, under certain plume conditions, result in high SO_2 concentrations at the neighborhood scale. Where a neighborhood site is located away from immediate SO_2 sources, the site may be useful in representing typical air quality values for a larger residential area, and therefore suitable for population exposure and trends analyses
	Urban	Measurements in this scale would be used to estimate concentrations over large portions of an urban area with dimensions from 4 to 50 kilometers. Such measurements would be useful for assessing trends in area-wide air quality, and hence, the effectiveness of large scale air pollution control strategies. Urban scale sites may also support other monitoring objectives of the SO_2 monitoring network such as identifying trends, and when monitors are sited upwind of local sources, background concentrations.
CO	Micro	This scale applies when air quality measurements are to be used to represent distributions within street canyons, over sidewalks, and near major roadways. In the case with carbon monoxide, microscale measurements in one location can often be considered as representative of other similar locations in a city.
	Middle	Middle scale measurements are intended to represent areas with dimensions from 100 meters to 0.5 kilometer. In certain cases, middle scale measurements may apply to areas that have a total length of several kilometers, such as ‘‘line’’ emission source areas. This type of emission sources areas would include air quality along a commercially developed street or shopping plaza, freeway corridors, parking lots and feeder streets
	Neighborhood	Neighborhood scale measurements are intended to represent areas with dimensions from 0.5 kilometers to 4 kilometers. Measurements of CO in this category would represent conditions throughout some reasonably urban sub-regions. In some cases, neighborhood scale data may represent not only the immediate neighborhood spatial area, but also other similar such areas across the larger urban area. Neighborhood scale measurements provide relative area-wide concentration data which are useful for providing relative urban background concentrations, supporting health and scientific research, and for use in modeling.

Pollutant	Spatial Scale	Characteristics NOTE: This information can also be found in 40 CFR Part 58, Appendix D and since there is a possibility that spatial scales have been updated, users should also review CFR.
O_3	Neighborhood	Measurements in this category represent conditions throughout some reasonably homogeneous urban subregion, with dimensions of a few kilometers. Homogeneity refers to pollutant concentrations. Neighborhood scale data will provide valuable information for developing, testing, and revising concepts and models that describe urban/regional concentration patterns. These data will be useful to the understanding and definition of processes that take periods of hours to occur and hence involve considerable mixing and transport. Under stagnation conditions, a site located in the neighborhood scale may also experience peak concentration levels within a metropolitan area.
	Urban	Measurement in this scale will be 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 sites would also be used to measure high concentrations downwind of the area having the highest precursor emissions.
	Regional	This scale of measurement will be 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 O3 that is transported to and from a metropolitan area, as well as background concentrations. In some situations, particularly when considering very large metropolitan areas with complex source mixtures, regional scale sites can be the maximum concentration location.
NO_2	Microscale	This scale represents areas in close proximity to major roadways or point and area sources. Emissions from roadways result in high ground level NO_2 concentrations at the microscale, where concentration gradients generally exhibit a marked decrease with increasing downwind distance from major roads. As noted in appendix E of this part, near-road NO_2 monitoring stations are required to be within 50 meters of target road segments in order to measure expected peak concentrations. Emissions from stationary point and area sources, and non-road sources may, under certain plume conditions, result in high ground level concentrations at the microscale. The microscale typically represents an area impacted by the plume with dimensions extending up to approximately 100 meters.
	Middle	Dimensions from about 100 meters to 500 meters. The middle scale may include locations of expected maximum hourly concentrations due to proximity to major NO_2 point, area, and/or non-road sources.
	Neighborhood	The neighborhood scale represents air quality conditions throughout some relatively uniform land use areas with dimensions in the 0.5 to 4.0 kilometer range.
	Urban	Measurements in this scale would be used to estimate concentrations over large portions of an urban area with dimensions from 4 to 50 kilometers. Such measurements would be useful for assessing trends in area-wide air quality, and hence, the effectiveness of large scale air pollution control strategies

Pollutant	Spatial Scale	Characteristics NOTE: This information can also be found in 40 CFR Part 58, Appendix D and since there is a possibility that spatial scales have been updated, users should also review CFR.
PM2.5	Microscale	Areas such as downtown street canyons and traffic corridors where the general public would be exposed to maximum concentrations from mobile sources. In some circumstances, the microscale is appropriate for particulate sites; community-oriented SLAMS sites measured at the microscale level should, however, be limited to urban sites that are representative of long-term human exposure and of many such microenvironments in the area. In general, microscale particulate matter sites should be located near inhabited buildings or locations where the general public can be expected to be exposed to the concentration measured. Emissions from stationary sources such as primary and secondary smelters, power plants, and other large industrial processes may, under certain plume conditions, likewise result in high ground level concentrations at the microscale. In the latter case, the microscale would represent an area impacted by the plume with dimensions extending up to approximately 100 meters. Data collected at microscale sites provide information for evaluating and developing hot spot control measures.
	Middle	People moving through downtown areas, or living near major roadways, encounter particle concentrations that would be adequately characterized by this spatial scale. Thus, measurements of this type would be appropriate for the evaluation of possible short-term exposure public health effects of particulate matter pollution. In many situations, monitoring sites that are representative of microscale or middle-scale impacts are not unique and are representative of many similar situations. This can occur along traffic corridors or other locations in a residential district. In this case, one location is representative of a number of small scale sites and is appropriate for evaluation of long-term or chronic effects. 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 sub-region with dimensions of a few kilometers and of generally more regular shape than the middle scale. Homogeneity refers to the particulate matter concentrations, as well as the land use and land surface characteristics. Much of the PM2.5 exposures are expected to be associated with this scale of measurement. In some cases, a location carefully chosen to provide neighborhood scale data would represent the immediate neighborhood as well as neighborhoods of the same type in other parts of the city. PM2.5 sites of this kind provide good information about trends and compliance with standards because they often represent conditions in areas where people commonly live and work for periods comparable to those specified in the NAAQS. In general, most PM2.5 monitoring in urban areas should have this scale.
	Urban	This class of measurement would be used to characterize the particulate matter concentration over an entire metropolitan or rural area ranging in size from 4 to 50 kilometers. Such measurements would be useful for assessing trends in area-wide air quality, and hence, the effectiveness of large scale air pollution control strategies. Community-oriented PM2.5 sites may have this scale.
	Regional	These measurements would characterize conditions over areas with dimensions of as much as hundreds of kilometers. As noted earlier, 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. Data characteristics of this scale would provide information about larger scale processes of particulate matter emissions, losses and transport. $PM_{2.5}$ transport contributes to elevated particulate concentrations and may affect multiple urban and State entities with large populations such as in the eastern United States. Development of effective pollution control strategies requires an understanding at regional geographical scales of the emission sources and atmospheric processes that are responsible for elevated $PM_{2.5}$ levels and may also be associated with elevated O_3 and regional haze.

Pollutant	Spatial Scale	Characteristics NOTE: This information can also be found in 40 CFR Part 58, Appendix D and since there is a possibility that spatial scales have been updated, users should also review CFR.
Pb	Micro	This scale would typify areas in close proximity to lead point sources. Emissions from point sources such as primary and secondary lead smelters, and primary copper smelters may under fumigation conditions likewise result in high ground level concentrations at the microscale. In the latter case, the microscale would represent an area impacted by the plume with dimensions extending up to approximately 100 meters. Pb monitors in areas where the public has access, and particularly children have access, are desirable because of the higher sensitivity of children to exposures of elevated Pb concentrations.
	Middle	This scale generally 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. The middle scale may for example, include schools and playgrounds in center city areas which are close to major Pb point sources. Pb monitors in such areas are desirable because of the higher sensitivity of children to exposures of elevated Pb concentrations. Emissions from point sources frequently impact on areas at which single sites may be located to measure concentrations representing middle spatial scales.
	Neighborhood	The neighborhood scale would characterize air quality conditions throughout some relatively uniform land use areas with dimensions in the 0.5 to 4.0 kilometer range. Sites of this scale would provide monitoring data in areas representing conditions where children live and play. Monitoring in such areas is important since this segment of the population is more susceptible to the effects of Pb. Where a neighborhood site is located away from immediate Pb sources, the site may be very useful in representing typical air quality values for a larger residential area, and therefore suitable for population exposure and trends analyses.

Pollutant	Spatial Scale	Characteristics NOTE: This information can also be found in 40 CFR Part 58, Appendix D and since there is a possibility that spatial scales have been updated, users should also review CFR.
PAMs		The PAMS program provides more comprehensive data on O_3 air pollution in areas classified as serious, severe, or extreme nonattainment for O_3 than would otherwise be achieved through the NCore and SLAMS sites. More specifically, the PAMS program includes measurements for O_3 , oxides of nitrogen, VOC, and meteorology. PAMS design criteria are site specific. Concurrent measurements of O_3 , oxides of nitrogen, speciated VOC, CO, and meteorology are obtained at PAMS sites. Design criteria for the PAMS network are based on locations relative to O_3 precursor source areas and predominant wind directions associated with high O_3 events. Specific monitoring objectives are associated with each location. The overall design should enable characterization of precursor emission sources within the area, transport of O_3 and its precursors, and the photochemical processes related to O_3 nonattainment. Specific objectives that must be addressed include assessing ambient trends in O_3 , oxides of nitrogen, VOC species, and determining spatial and diurnal variability of O_3 , oxides of nitrogen, and VOC species. Specific monitoring objectives associated with each of these sites may result in four distinct site types. Detailed guidance for the locating of these sites may be found in reference 9 of this appendix. (a) Type 1 sites are established to characterize upwind background and transported O_3 and its precursor concentrations entering the area and will identify those areas which are subjected to transport. (b) Type 2 sites are established to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions are expected to impact and are suited for the monitoring of urban air toxic pollutants. (c) Type 3 sites are intended to monitor maximum O_3 concentrations occurring downwind from the area of maximum precursor emissions. (d) Type 4 sites are established to characterize the downwind transported O_3 and its precursor concentrations exiting the area and will identify those areas which are potentially contributing to overwhelming transport in other areas. Minimum Monitoring Network Requirements. A Type 2 site is required for each area. Overall, only two sites are required for each area, providing all chemical measurements are made. For example, if a design includes two Type 2 sites, then a third site will be necessary to capture the NO_y measurement. The minimum required number and type of monitoring sites and sampling requirements are listed in Table D-6 of this appendix. Any alternative plans may be put in place in lieu of these requirements, if approved by the Administrator.

Pollutant	Spatial Scale	Characteristics NOTE: This information can also be found in 40 CFR Part 58, Appendix D and since there is a possibility that spatial scales have been updated, users should also review CFR.
$PM_{10-2.5}$		The only required monitors for $PM_{10-2.5}$ are those required at NCore Stations. Although microscale monitoring may be appropriate in some circumstances, middle and neighborhood scale measurements are the most important station classifications for $PM_{10-2.5}$
	Micro	This scale would typify relatively small areas immediately adjacent to: Industrial sources; locations experiencing ongoing construction, redevelopment, and soil disturbance; and heavily traveled roadways. Data collected at microscale stations would characterize exposure over areas of limited spatial extent and population exposure, and may provide information useful for evaluating and developing source oriented control measures.
	Middle	People living or working near major roadways or industrial districts encounter particle concentrations that would be adequately characterized by this spatial scale. Thus, measurements of this type would be appropriate for the evaluation of public health effects of coarse particle exposure. Monitors located in populated areas that are nearly adjacent to large industrial point sources of coarse particles provide suitable locations for assessing maximum population exposure levels and identifying areas of potentially poor air quality. Similarly, monitors located in populated areas that border dense networks of heavily-traveled traffic are appropriate for assessing the impacts of resuspended road dust. This scale also includes the characteristic concentrations for other areas with dimensions of a few hundred meters such as school grounds and parks that are nearly adjacent to major roadways and industrial point sources, locations exhibiting mixed residential and commercial development, and downtown areas featuring office buildings, shopping centers, and stadiums.
	Neighborhood	Measurements in this category would represent conditions throughout some reasonably homogeneous urban sub-region with dimensions of a few kilometers and of generally more regular shape than the middle scale. Homogeneity refers to the particulate matter concentrations, as well as the land use and land surface characteristics. This category includes suburban neighborhoods dominated by residences that are somewhat distant from major roadways and industrial districts but still impacted by urban sources, and areas of diverse land use where residences are interspersed with commercial and industrial neighborhoods. In some cases, a location carefully chosen to provide neighborhood scale data would represent the immediate neighborhood as well as neighborhoods of the same type in other parts of the city. The comparison of data from middle scale and neighborhood scale sites would provide valuable information for determining the variation of PM10–2.5 levels across urban areas and assessing the spatial extent of elevated concentrations caused by major industrial point sources and heavily traveled roadways. Neighborhood scale sites would provide concentration data that are relevant to informing a large segment of the population of their exposure levels on a given day.
$PM_{2.5}$ Speciation	NA	Each State shall continue to conduct chemical speciation monitoring and analyses at sites designated to be part of the PM2.5 Chemical Speciation Trends Network (CSN). The selection and modification of these CSN sites must be approved by the Administrator.

Appendix F

Sample Manifold Design for Precursor Gas Monitoring

The following information is extracted from the document titled: *Version 4 of the Technical Assistance Document for Precursor Gas Measurements in the NCore Multi-Pollutant Monitoring Network* which can be found on the AMTIC website at:
https://www3.epa.gov/ttnamti1/ncore/guidance/tadversion4.pdf

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Sample Manifold Design for Precursor Gas Monitoring

Many important variables affect sampling manifold design for ambient precursor gas monitoring: residence time of sample gases, materials of construction, diameter, length, flow rate, and pressure drop. Considerations for these parameters are discussed below.

Residence Time Determination: The residence time of air pollutants within the sampling system (defined as extending from the entrance of the sample inlet above the instrument shelter to the bulkhead of the precursor gas analyzer) is critical. Residence time is defined as the amount of time that it takes for a sample of air to travel through the sampling system. This issue is discussed in detail for NO_y monitoring in Section 4.2, and recommendations in Section 4 for the arrangement of the molybdenum converter and inlet system should be followed. However, residence time is also an issue for other precursor gases, and should be considered in designing sample manifolds for those species. For example, Code of Federal Regulations (CFR), Title 40 Part 58, Appendix E.9 states, "Ozone in the presence of NO will show significant losses even in the most inert probe material when the residence time exceeds 20 seconds. Other studies indicate that 10-second or less residence time is easily achievable."[1] Although 20-second residence time is the maximum allowed as specified in 40 CFR 58, Appendix E, it is recommended that the residence time within the sampling system be less than 10 seconds. If the volume of the sampling system does not allow this to occur, then a blower motor or other device (such as a vacuum pump) can be used to increase flow rate and decrease the residence time. The residence time for a sample manifold system is determined in the following way. First the total volume of the cane (inlet), manifold, and sample lines must be determined using the following equation:

$$Total\ Volume = Cv + Mv + Lv \qquad \textit{Equation 1}$$

Where:

Cv = Volume of the sample cane or inlet and extensions
Mv = Volume of the sample manifold and moisture trap
Lv = Volume of the instrument lines from the manifold to the instrument bulkhead

The volume of each component of the sampling system must be measured individually. To measure the volume of the components (assuming they are cylindrical in shape), use the following equation:

$$V = \pi * (d/2)^2 * L \qquad \textit{Equation 2}$$

Where:
V = volume of the component, cm^3
π = 3.14
L = Length of the component, cm
d = inside diameter of the component, cm

Once the total volume is determined, divide the total volume by the total sample flow rate of all instruments to calculate the residence time in the inlet. If the residence time is greater than 20 seconds, attach a blower or vacuum pump to increase the flow rate and decrease the residence time.

Laminar Flow Manifolds: In the past, vertical laminar flow manifolds were a popular design. By the proper selection of a large diameter vertical inlet probe and by maintaining a laminar flow throughout, it was assumed that the sample air would not react with the walls of the probe. Numerous materials such as glass, plastic, galvanized steel, and stainless steel were used for constructing the probe. Removable sample lines constructed of FEP or PTFE were placed to protrude into the manifold to provide each instrument with sample air. A laminar flow manifold could have a flow rate as high as 150 L/min, in order to minimize any losses, and large diameter tubing was used to minimize pressure drops. However, experience has shown that vertical laminar flow manifolds have demonstrated many disadvantages which are listed below:

- Since the flow rates are so high, it is difficult to supply enough audit gas to provide an adequate independent assessment for the entire sampling system;
- Long laminar flow manifolds may be difficult to clean due to size and length;
- Temperature differentials may exist that could change the characteristics of the gases, e.g., if a laminar manifold's inlet is on top of a building, the temperature at the bottom of the building may be much lower, thereby dropping the dew point and condensing water.
- Construction of the manifold is frequently of an unapproved material.

For these technical reasons, EPA strongly discourages the use of laminar flow manifolds in the national air monitoring network. It is recommended that agencies that utilize laminar manifolds migrate to conventional manifold designs that are described below.

Sampling Lines as Inlet and Manifold: Often air monitoring agencies will place individual sample lines outside of their shelter for each instrument. If the sample lines are manufactured out of polytetrafluoroethylene (PTFE), perfluoroalkoxy (PFA) or fluoroethylpropylene (FEP) Teflon®, this is acceptable to the EPA. The advantages to using single sample lines are: no breakage and ease of external auditing. In addition, rather than cleaning glass manifolds, some agencies just replace the sampling lines. However, please note the following caveats:

1. lines can deteriorate when exposed to atmospheric conditions, particularly ultraviolet radiation from the sun. Therefore, it is recommended that sample lines be inspected and replaced regularly.
2. Small insects and particles can accumulate inside of the tubing. It has been reported that small spiders build their webs inside of tubing. This can cause blockage and affect the response of the instruments. In addition, particles can collect inside the tubing, especially at the entrance, thus affecting precursor gas concentrations. Check the sampling lines and replace or clean the tubing on a regular basis.
3. Since there is no central manifold, these configurations sometimes have a "three-way" tee, i.e., one flow path for supplying calibration mixtures and the other for the sampling of ambient air. If the three-way tee is not placed near the outermost limit of the sample inlet

tubing, then the entire sampling system is not challenged by the provision of calibration gas. It is strongly recommended that at least on a periodic basis calibration gas be supplied so that it floods the entire sample line. This is best done by placing the three-way tee just below the sample inlet, so that calibration gas supplied there is drawn through the entire sampling line.

4. The calibration gas must be delivered to the analyzers at near ambient pressure. Some instruments are very sensitive to pressure changes. If the calibration gas flow is excessive, the analyzer may sample the gas under pressure. If a pressure effect on calibration gas response is suspected, it is recommended that the gas be introduced at more than one place in the sampling line (by placement of the tee, as described in item #3 above). If the response to the calibration gas is the same regardless of delivery point, then there is likely no pressure effect.

Conventional Manifold Design - A number of "conventional" manifold systems exist today. However, one manifold feature must be consistent: the probe and manifold must be constructed of borosilicate glass or Teflon® (PFA or PTFE). These are the only materials proven to be inert to gases. EPA will accept manifolds or inlets that are made from other materials, such as steel or aluminum, that are lined or coated with borosilicate glass or the Teflon® materials named above. However, all of the linings, joints and connectors that could possibly come into contact with the sample gases must be of glass or Teflon®. It is recommended that probes and manifolds be constructed in modular sections to enable frequent cleaning. It has been demonstrated that there are no significant losses of reactive gas concentrations in conventional 13 mm inside diameter (ID) 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. However, when the sample residence time exceeds 20 seconds, loss is detectable, and at 60 seconds the loss can be nearly complete. Therefore, EPA requires that residence times must be 20 seconds or less (except for NOy). Please note that for particulate matter (PM) monitoring instruments, such as nephelometers, Tapered Element Oscillating Microbalance (TEOM) instruments, or Beta Gauges, the ambient precursor gas manifold is not recommended. Particle monitoring instruments should 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.

T-Type Design: The most popular gas sampling system in use today consists of a vertical "candy cane" protruding through the roof of the shelter with a horizontal sampling manifold connected by a tee fitting to the vertical section (Figure 1). This type of manifold is commercially available. At the bottom of the tee is a bottle for collecting particles and moisture that cannot make the bend; this is known as the "drop out" or moisture trap bottle. Please note that a small blower at the exhaust end of the system (optional) is used to provide flow through the sampling system. There are several issues that must be mitigated with this design:

- The probe and manifold may have a volume such that the total draw of the precursor gas analyzers cannot keep the residence time less than 20 seconds (except NOy), thereby requiring a blower motor. However, a blower motor may prevent calibration and audit gases from being supplied in sufficient quantity, because of the high flow rate in the manifold. To remedy this, the blower motor must be turned off for calibration.

However, this may affect the response of the instruments since they are usually operated with the blower on.

- Horizontal manifolds have been known to collect water, especially in humid climates. Standing water in the manifold can be pulled into the instrument lines. Since most monitoring shelters are maintained at 20-30 ^{o}C, condensation can occur when warm humid outside air enters the manifold and is cooled. Station operators must be aware of this issue and mitigate this situation if it occurs. Tilting the horizontal manifold slightly and possibly heating the manifold have been used to mitigate the condensation problem. Water traps should be emptied whenever there is standing water.

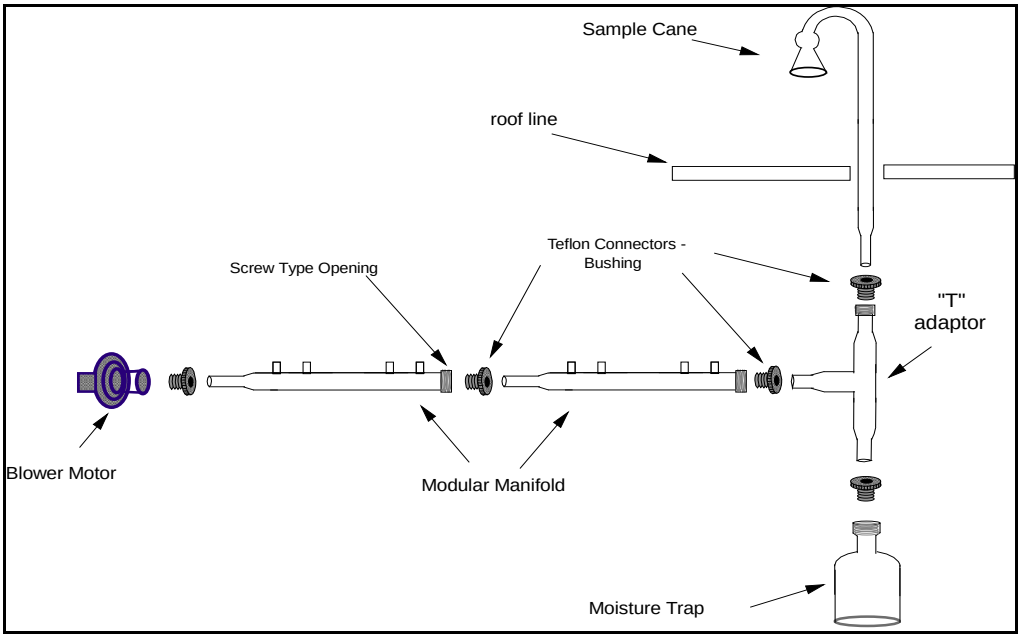

Figure 1. Conventional T-Type Glass Manifold System

California Air Resources Board "Octopus" Style: Another type of manifold that is being widely used is known as the California Air Resources Board (CARB) style or "Octopus" manifold, illustrated in Figure 2. This manifold has a reduced profile, i.e., there is less volume in the cane and manifold; therefore, there is less need for a blower motor. If the combined flow rates of the gas analyzers are high enough, then an additional blower is not required.

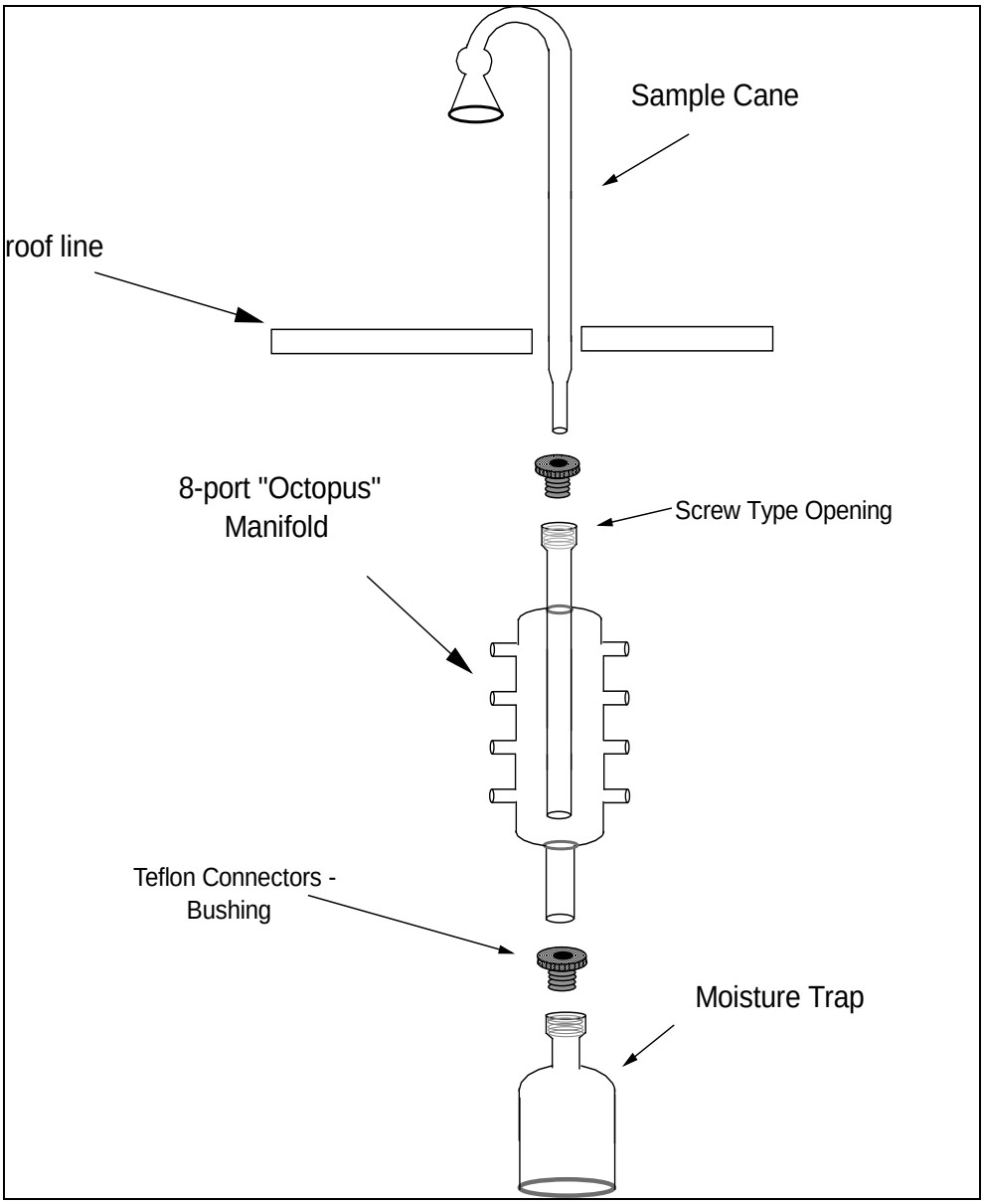

Figure 2. CARB or "Octopus" Style Manifold

Placement of Tubing on the Manifold: If the manifold employed at the station has multiple ports (as in Figure 2) then the position of the instrument lines relative to the calibration input line can be crucial. If a CARB "Octopus" or similar manifold is used, it is suggested that sample connections for analyzers requiring lower flows be placed towards the bottom of the manifold. Also, the general rule of thumb states that the calibration gas delivery line (if used) should be in a location so that the calibration gas flows past the analyzer inlet points before the gas is evacuated out of the manifold. Figure 3 illustrates two potential locations for introduction of the calibration gas. One is located at the ports on the "Octopus" manifold, and the other is upstream near the air inlet point, using an audit or probe inlet stub. This stub is a tee fitting placed so that "Through-the-Probe" audit line or sampling system tests and calibrations can be conducted.

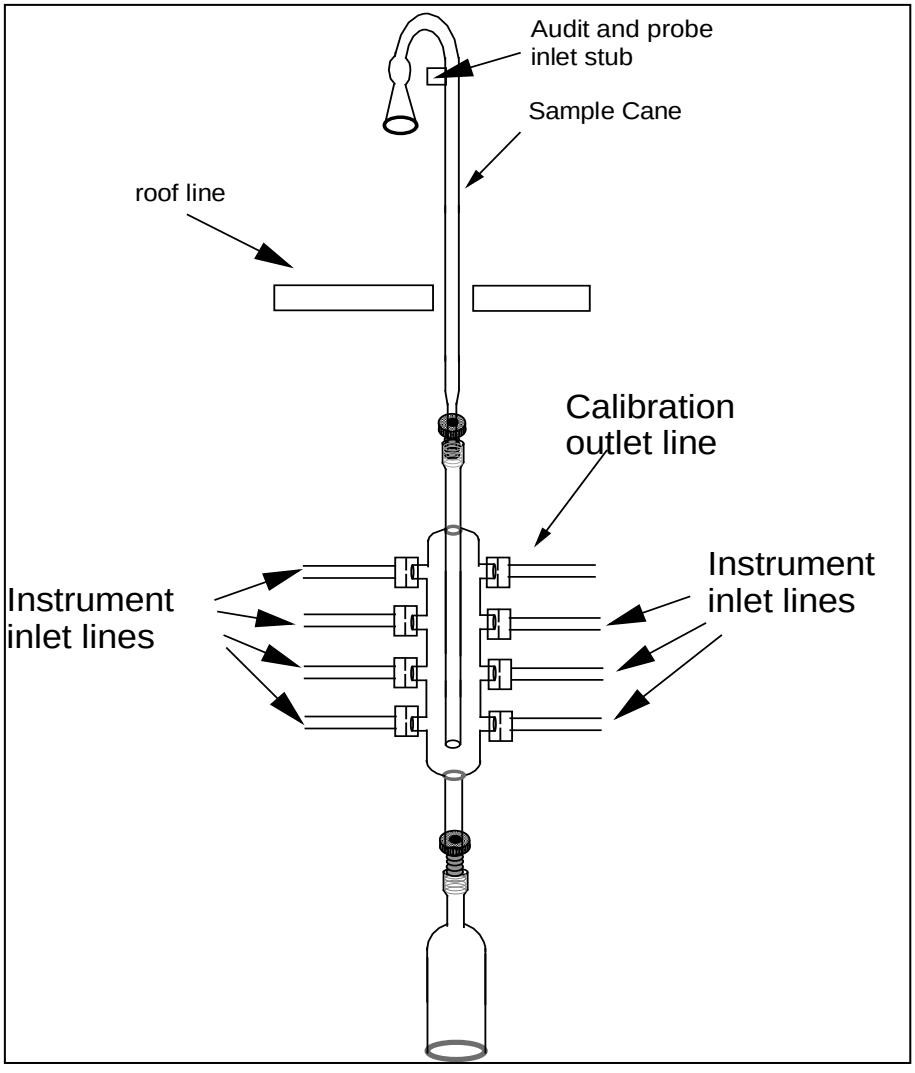

Figure 3. Placement of Lines on the Manifold

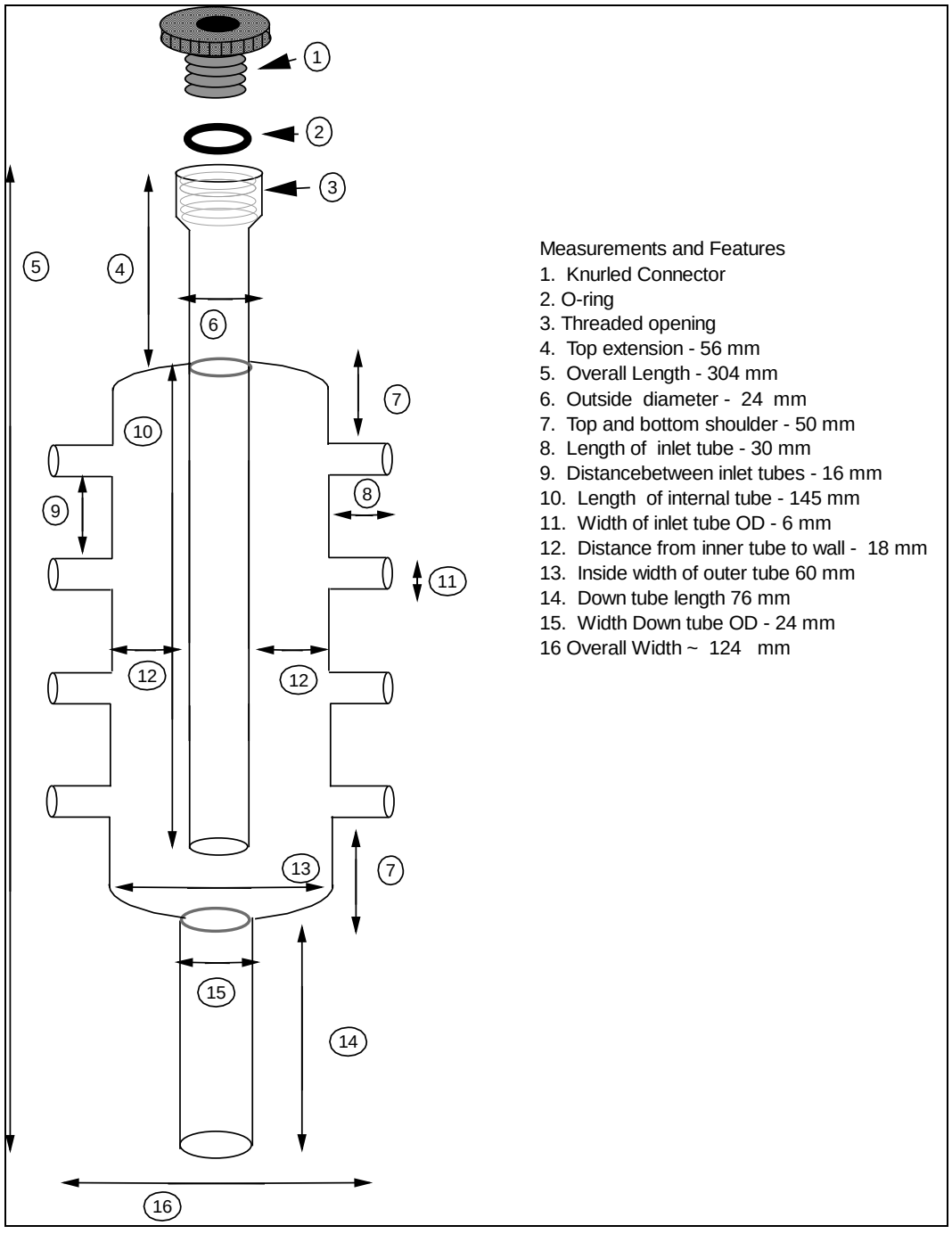

Figure 4. Specifications for an 'Octopus" Style Manifold

Figure 4 illustrates the specifications of an Octopus style manifold. Please note that EPA-OAQPS has used this style of manifold in its precursor gas analyzer testing program. This type of manifold is commercially available.

Vertical Manifold Design: Figure 5 shows a schematic of the vertical manifold design. Commercially available vertical manifolds have been on the market for some time. The issues with this type of manifold are the same with other conventional manifolds, i.e., when sample air moves from a warm humid atmosphere into an air-conditioned shelter, condensation of moisture can occur on the walls of the manifold. Commercially available vertical manifolds have the option for heated insulation to mitigate this problem. Whether the manifold tubing is made of glass or Teflon®, the heated insulation prevents viewing of the tubing, so the interior must be inspected often. The same issues apply to this manifold style as with horizontal or "Octopus" style manifolds: additional blower motors should not be used if the residence time is less than 20 seconds, and the calibration gas inlet should be placed upstream so that the calibration gas flows past the analyzer inlets before it exits the manifold.

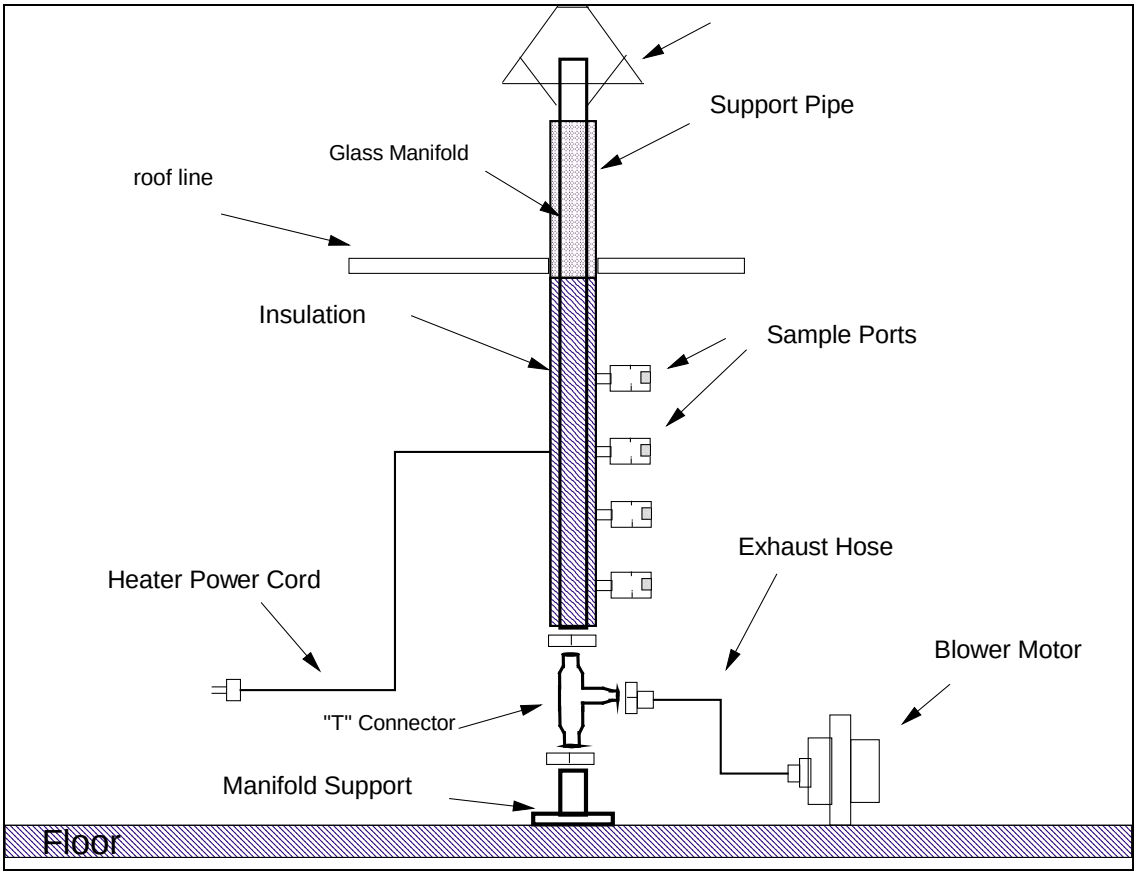

Figure 5. Example of Vertical Design Manifold

Manifold/Instrument Line Interface: A sampling system is an integral part of a monitoring station, however, it is only one part of the whole monitoring process. With the continuing integration of advanced electronics into monitoring stations, manifold design must be taken into consideration. Data Acquisition Systems (DASs) are able not only to collect serial and analog data from the analyzers, but also to control Mass Flow Calibration (MFC) equipment and solid state solenoid switches, communicate via modem or Ethernet, and monitor conditions such as shelter temperature and manifold pressure. As described in Chapter 6, commercially available DASs may implement these features in an electronic data logger, or via software installed on a personal computer. Utilization of these features allows the DAS and support equipment to perform automated calibrations (Autocals). In addition to performing these tasks, the DAS can flag data during calibration periods and allow the data to be stored in separate files that can be reviewed remotely.

Figure 6 shows a schematic of the integrated monitoring system at EPA's Burden Creek NCore monitoring station. Note that a series of solenoid switches are positioned between the ambient air inlet manifold and an additional "calibration" manifold. This configuration allows the DAS to control the route from which the analyzers draw their sample. At the beginning of an Autocal, the DAS signals the MFC unit to come out of standby mode and start producing zero or calibration gas. Once the MFC has stabilized, the DAS switches the analyzers' inlet flow (via solenoids) from the ambient air manifold to the calibration manifold. The calibration gas is routed to the instruments, and the DAS monitors and averages the response, flagging the data appropriately as calibration data. When the Autocal has terminated, the DAS switches the analyzers' inlet flow from the calibration manifold back to the ambient manifold, and the data system resets the data flag to the normal ambient mode.

The integration of DAS, solenoid switches, and MFC into an automated configuration can bring an additional level of complexity to the monitoring station. Operators must be aware that this additional complexity can create situations where leaks can occur. For instance, if a solenoid switch fails to open, then the inlet flow of an analyzer may not be switched back to the ambient manifold, but instead will be sampling interior room air. When the calibrations occur, the instrument will span correctly, but will not return to ambient air sampling. In this case, the data collected must be invalidated. These problems are usually not discovered until there is an external "Through-the Probe" audit, but by then extensive data could be lost. It is recommended that the operator remove the calibration line from the calibration manifold on a routine basis and challenge the sampling system from the inlet probe. This test will discover any leak or switching problems within the entire sampling system.

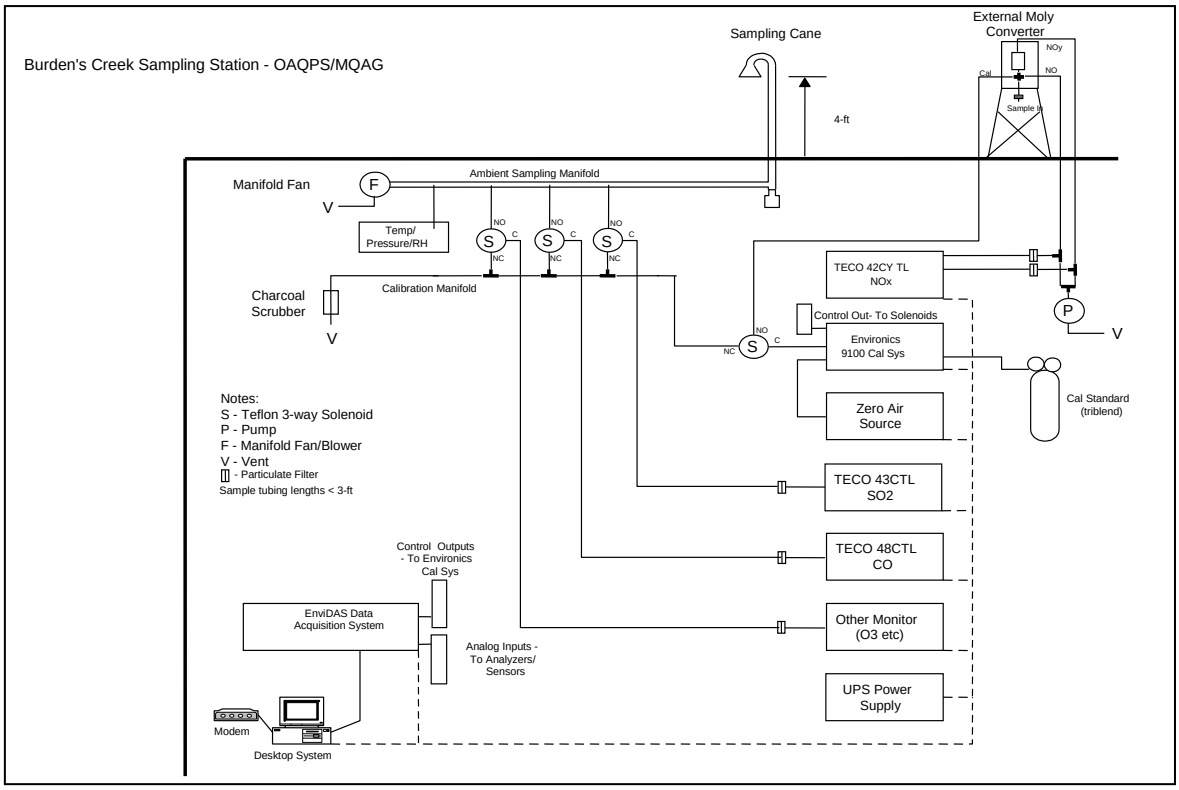

Figure 6. Example of a Manifold/Instrument Interface

Figure 7 shows a close up of an ambient/calibration manifold, illustrating the calibration manifold – ambient manifold interface. This is the same interface used at EPA's Burden's Creek monitoring station. The interface consists of three distinct portions: the ambient manifold, the solenoid switching system and the calibration manifold. In this instance, the ambient manifold is a T-type design that is being utilized with a blower fan at the terminal. Teflon® tubing connects the manifold to the solenoid switching system. Two-way solenoids have two configurations. Either the solenoid is in its passive state, at which time the ports that are connected are the normally open (NO) and the common (COM). In the other state, when it is energized, the ports that are connected are the normally closed (NC) and the COM ports. Depending on whether the solenoid is 'active' or not, the solenoid routes the air from the calibration or ambient manifold to the instrument inlets. There are two configurations that can be instituted with this system.

1. Ambient Mode: In this mode the solenoids are in "passive" state. The flow of air (under vacuum) is routed from the NO port through the solenoid to the COM port.
2. Calibration Mode: In this mode, the solenoids are in the "active" state. An external switching device, usually the DAS, must supply direct current to the solenoid. This causes the solenoid to be energized so that the NO port is shut and the NC port is now connected to the COM port. As in all cases, the COM port is always selected. The switching of the solenoid is done in conjunction with the MFC unit becoming active;

generally, the MFC is controlled by the DAS. When the calibration sequences have finished, the DAS stops the direct current from being sent to the solenoid and switches automatically back to the NO to COM (inactive) port configuration. This allows the air to flow through the NO to COM port and the instrument is now back on ambient mode.

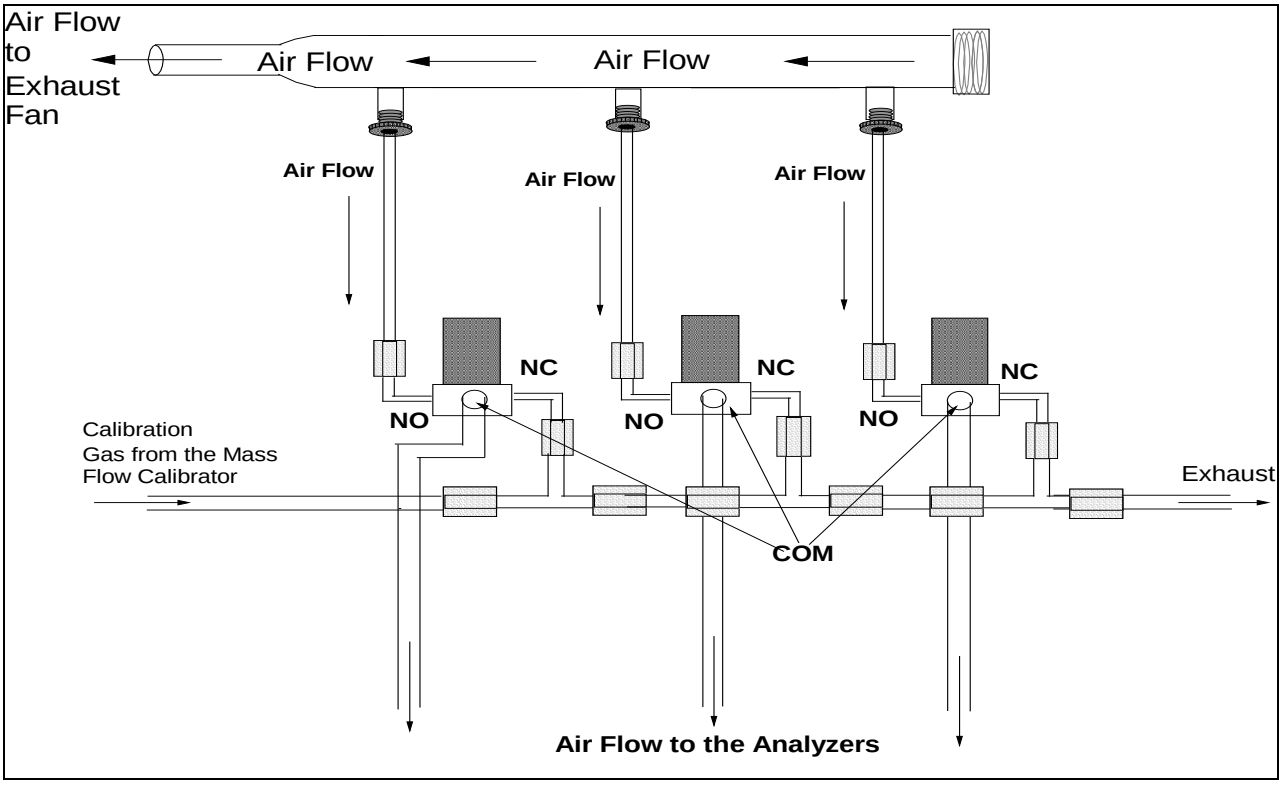

Figure 7. Ambient – Calibration Manifold Interface

Reference

1. Code of Federal Regulations, Title 40, Part 58, Appendix E.9

Appendix G

Example Procedure for Calibrating a Data Acquisition System

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DAS Calibration Technique

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. It is recommended that one use a NIST traceable voltmeter.

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 owner's manual.

4. After the background zero has been determined, it is time to adjust the full scale of the system. Most DAS systems 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 to 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 H

United States Environmental Protection Agency

National Ambient Air Monitoring Technical Systems Audit Checklist

This version attached is very similar to the checklist in the 2008 QA Handbook. It is an example that has been modified for use in EPA Region 5.

NOTE: At the time this Handbook was being finalized, EPA OAQPS and the EPA Regions were developing a guidance document for the implementation of technical systems audits. Once completed, the document will be posted on AMTIC at: https://www3.epa.gov/ttn/amtic/qalist.html. the checklist posted here may be revised in this forthcoming document.

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1) General / Quality Management

State/ Local / Tribal Agency Audited:

Address:

City, State, and Zip Code:

Date of Technical System Audit:

Auditor / Agency:

a) Program Organization

Key Individuals

Agency Director:

Ambient Air Monitoring (AAM) Network Manager:

Quality Assurance Manager:

QA Auditors:

Field Operations Supervisor / Lead:

Laboratory Supervisor:

QA Laboratory Manager:

Data Management Supervisor / Lead:

Attach an Organizational Chart:

Flow Chart:

Key position staffing. Number of personnel available to each of the following program areas:							
Program Area	Number of People Primary	Number of People Backup	Vacancies	Program Area	Number of People Primary	Number of People Backup	Vacancies
Network Design and Siting				Data and Data Management			
QC activities				Equipment repair and maintenance			
QA activities				Financial Management			

List available personnel by name and percentage of time spent on each task category.

Name	Network Design and Siting	QC Activities	QA Activities	Equipment repair and maintenance	Data and Data Management	Financial Management

Comment on the need for additional personnel if applicable.

List personnel who have authority or are responsible for:

Activity	Name	Title
QA Training Field/Lab		
Grant Management		
Purchases greater than $500		
Equipment and Service Contract Management		
Staff appointment		

b) Facilities

Identify the principal facilities where the agency conducts work that is related to air monitoring. Do not include monitoring stations but do include facilities where work is performed by contractors or other organizations.

Facility AAM Function	Offices responsible for ensuring adequacy	Location	Adequate Y/N To be completed by auditor
Instrument repair,			
Certification of Standards e.g. gases, flow transfers, MFC,			
PM filter weighing,			
Data verification and processing,			
General office space,			
Storage space, short and long term,			
Air Toxics (Carbonyls, VOCs, Metals):			

Indicate any facilities that should be upgraded. Identify by function:

Are facilities adequate concerning safety?	Yes☐	No☐

Please explain if answer is no:

Suggested improvements or recommendations for the items above:

Are there any significant changes which are likely to be implemented to agency facilities within the next one to two years? Comment on agency's needs for additional physical space (laboratory, office, storage, etc.).

Facility	Function	Proposed Change - Date

c) Independent Quality Assurance and Quality Control

Status of Quality Assurance Program			
Question	**Yes**	**No**	**Comment**
Does the agency perform QA activities with internal personnel? If no go to Section d.	☐	☐	
Does the agency maintain a separate laboratory to support quality assurance activities?	☐	☐	
Has the agency documented and implemented specific audit procedures separate from monitoring procedures?	☐	☐	
Are there two levels of management separation between QA and QC operations? Please describe below:	☐	☐	
Does the agency have identifiable auditing equipment and standards (specifically intended for sole use) for audits?	☐	☐	

Internal Performance Audits

Question	**Yes**	**No**	**Comment**
Does the agency have separate facilities to support audits and calibrations?	☐	☐	
If the agency has in place contracts or similar agreements either with another agency or contractor to perform audits or calibrations, please name the organization and briefly describe the type of agreement.			
If the agency does not have a performance audit SOP (included as an attachment), please describe performance audit procedure for each type of pollutant.			
Does the agency maintain independence of audit standards and personnel?	☐	☐	
Please provide information on certification of audit standards currently being used. Include information on vendor and internal or external certification of standards.			
Does the agency have a certified source of zero air for performance audits?	☐	☐	
Does the agency have procedures for auditing and/or validating performance of Meteorological monitoring?	☐	☐	

Please provide a list of the agency's audit equipment and age of audit equipment.			
Is audit equipment ever used to support routine calibration and QC checks required for monitoring network operations? If yes, please describe.			
Are standard operating procedures (SOPs) for air monitoring available to all field personnel?	☐	☐	
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	How is performance tracked (e.g., control charts)	Audit Result Acceptance Criteria
CO		
O3		
NO2		
SO2		
PM10		
PM2.5		
Pb		
VOCs		
Carbonyls		
PM2.5 speciation		
PM10-2.5 speciation		
PM10-2.5 FRM Mass		
Continuous PM2.5		
Trace Levels (CO)		
Trace Levels (SO2)		
Trace Levels (NO)		
Trace Levels (NOy)		
Surface Meteorology		
Others		

Question	**Yes**	**No**	**Comment**
Were these audit criteria based on, or derived from, the guidance found in Volume II of the QA Handbook for Air Pollution Measurement System, Section 10.3?	☐	☐	If no, please explain. If yes, please explain any changes or assumptions made in the derivation.

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) Planning Documents (including QMP, QAPP, & SOPs)

QMP questions	**Yes**	**No**	**Comment**
Does the agency have an EPA-approved quality management plan?	☐	☐	
If yes, have changes to the plan been approved by the EPA?	☐	☐	
Has the QMP been approved by EPA within the last five years?	☐	☐	
Please provide: Date of Original Approval: Date of Last Revision: Date of Latest Approval:			
QAPP questions	Yes	No	Comment
Does the agency have an EPA-approved quality assurance project plan?	☐	☐	
If yes, have changes to the plan been approved by the EPA?	☐	☐	
Has the QAPP been reviewed by EPA annually?	☐	☐	
Please provide: Date of Original Approval: Date of Last Revision: Date of Latest Approval:			
Does the agency have any revisions to your QA project plan still pending?	☐	☐	
How does the agency verify the QA project plan is fully implemented?			
How are the updates distributed?			
What personnel regularly receive updates?			
SOP questions			
Has the agency prepared and implemented standard operating procedures (SOPs) for all facets of agency operation?	☐	☐	
Do the SOPs adequately address ANSI/ASQC E-4 quality system required by 40 CFR 58, Appendix A?	☐	☐	
Are copies of the SOP or pertinent sections available to agency personnel?	☐	☐	
How does the agency verify that the SOPs are implemented as provided?			
How are the updates distributed?			

e) General Documentation Policies

Question	Yes	No	Comment
Does the agency have a documented records management plan?	☐	☐	
Does the agency have a list of files considered official records and their media type i.e., paper, electronic?	☐	☐	
Does the agency have a schedule for retention and disposition of records?	☐	☐	
Are records for at least three years?	☐	☐	
Who is responsible for the storage and retrieval of records?			
What security measures are utilized to protect records?			
Where/when does the agency rely on electronic files as primary records?			
What is the system for the storage, retrieval and backup of these files?			

f) Training

Question	Yes	No	Comment
Does the agency have a training program and training plan?	☐	☐	
Where is it documented?			
Does it make use of seminars, courses, EPA sponsored college level courses?	☐	☐	
Are personnel cross-trained for other ambient air monitoring duties?	☐	☐	
Are training funds specifically designated in the annual budget?	☐	☐	
Does the training plan include:			
Training requirements by position	☐	☐	
Frequency of training	☐	☐	
Training for contract personnel	☐	☐	
A list of core QA related courses	☐	☐	

Indicate below the three most recent training events and identify the personnel participating in them.		
Event	**Dates**	**Participant(s)**

g) Oversight of Contractors and Suppliers

Questions about Contractors	**Yes**	**No**	**Comment**
Who is responsible for oversight of contract personnel?			
What steps are taken to ensure contract personnel meet training and experience criteria?			
How often are contracts reviewed and/or renewed?			
Questions about Suppliers			
Have criteria and specification been established for consumable supplies and for equipment?	☐	☐	
What supplies and equipment have established specifications?			
Is equipment from suppliers open for bid?	☐	☐	

h) Corrective Action

Question	Yes	No	Comment
Does the agency have a comprehensive corrective action program in place and operational?	☐	☐	
Have the procedures been documented?	☐	☐	
As a part of the QA project plan?	☐	☐	
As a separate standard operating procedure?	☐	☐	
Does the agency have established and documented corrective limits for QA and QC activities?	☐	☐	
Are procedures implemented for corrective actions based on results of the following which fall outside the established limits:			
Performance evaluations?	☐	☐	
Precision goals?	☐	☐	
Bias goals?	☐	☐	
NPAP audits?	☐	☐	
PEP audits?	☐	☐	
Validations of one point QC check goals?	☐	☐	
Completeness goals?	☐	☐	
Data audits?	☐	☐	
Calibrations and zero span checks?	☐	☐	
Technical Systems Audit findings?	☐	☐	
Have the procedures been documented?	☐	☐	
How is responsibility for implementing corrective actions assigned? Briefly discuss.			

How does the agency follow up on implemented corrective actions?
Briefly describe recent examples of the ways in which the above corrective action system was employed to remove problems.

i) Quality Improvement

Question	Yes	No	Comment
What actions were taken to improve the quality system since the last TSA?			
Since the last TSA do your control charts indicate that the overall data quality for each pollutant steady or improving?	☐	☐	
For areas where data quality appears to be declining has a cause been determined?	☐	☐	
Have all deficiencies indicted on the previous TSA been corrected?	☐	☐	
If not explain.			
Are there pending plans for quality improvement such as purchase of new or improved equipment, standards, or instruments?	☐	☐	

j) External Performance Audits

Question	Yes	No	Comment
Does your agency participate in NPAP, $PM_{2.5}$ PEP, Pb PEP Pb Strip Audit, AA_PGVP and other performance audits performed by an external party and/or using external standards?	☐	☐	
If the agency does not participate, please explain why not.			
Are NPAP audits performed by QA staff, site operators, calibration staff, and/or another group?	☐	☐	

National Performance Audit Program (NPAP) and Additional Audits

Does the agency participate in the National Performance Audit Program (NPAP) as required under 40 CFR 58, Appendix A? If so, identify the individual with primary responsibility for the required participation in the National Performance Audit Program.
Name: Program Function:

Please complete the table below:	
Parameter Audited	**Date of Last NPAP Audit**
CO	
O_3	
SO_2	
NO_2	
PM_{10}	
$PM_{2.5}$	
Pb	
VOCs	
Carbonyls	
Trace CO	
Trace SO_2	
Trace NO	
Trace NO_Y	

2) Network Management/Field Operations

State/Local/Tribal Agency Audited:

Address:

City, State, and Zip Code:

Auditor / Agency:

Key Individuals

Ambient Air Monitoring Network Manager:

Quality Assurance Manager:

Field Operations Supervisor/Lead:

Field Operations Staff involved in the TSA:

a) Network Design

Complete the table below for each of the pollutants monitored as part of your air monitoring network. (Record applicable count by category.) Also indicate seasonal monitoring with an S for a Parameter/Category as appropriate. Provide the most recent annual monitoring network plan, including date of approval and AQS quick look or if not available, network description and other similar summary of site data, including SLAMS, Other and Toxics.

Category*	SO2	NO2	CO	O3	PM10	PM2.5	Pb	Other (type)	Other (type)
NCore									
SLAMS									
SPM									
PAMS									
Total									

*NCore - National Core monitoring stations; SLAMS - state and local air monitoring stations; SPM - special purpose monitors; PAMS - photochemical assessment monitoring stations

Question	**Yes**	**No**	**Comment**
What is the date of the most current Monitoring Network Plan?			
Is it available for public inspection?	☐	☐	
Does it include the information required for each site?			
AQS Site ID #?	☐	☐	
Street address and geographic coordinates?	☐	☐	
Sampling and Analysis Method(s)?	☐	☐	
Operating Schedule?	☐	☐	
Monitoring Objective and Scale of Representativeness?	☐	☐	
Site suitable/not suitable for comparison to annual PM2.5 NAAQS?	☐	☐	
MSA, CBSA or CSA indicated as required?	☐	☐	

Indicate by AQS Site ID # any non-conformance with the requirements of 40 CFR 58, Appendices D and E along with any waivers granted by the Regional Office (provide waiver documentation).

Monitor	**Site ID**	**Reason for Non-Conformance**
SO_2		
O_3		
CO		
NO_2		
PM_{10}		
$PM_{2.5}$		
Pb		

Question	Yes	No	Comment
Are hard copy site information files retained by the agency for all air monitoring stations within the network?	☐	☐	
Does each station have the required information including:			
AQS Site ID Number?	☐	☐	
Photographs/slides to the four cardinal compass points?	☐	☐	
Startup and shutdown dates?	☐	☐	
Documentation of instrumentation?	☐	☐	
Who has custody of the current network documents			Name: Title:
Does the current level of monitoring effort, station placement, instrumentation, etc., meet requirements imposed by current grant conditions?	☐	☐	
How often is the network siting reviewed?			Frequency: Date of last review:
Are there any issues?	☐	☐	
Do any sites vary from the required frequency in 40 CFR 58.12?	☐	☐	
Does the number of collocated monitoring stations meet the requirements of 40 CFR 58 Appendix A?	☐	☐	

b) Changes to the Network since the last audit

What is the date of the most recent network assessment? (Provide copy) Are all SLAMS parameters included? Any others?

Please provide information on any site changes since the last audit.

Pollutant	Site ID	Site Address	Site Added/Deleted/ Relocated	Reason (Assessment, lost lease, etc. Provide documentation of reason for each site change.)

c) Proposed changes to the Network

Are future network changes proposed?

Please provide information on proposed site changes, including documentation of the need for the change and any required approvals

Pollutant	Site ID	Site Address	Site to be Added/Deleted/ Relocated	Reason (Assessment, lost lease, etc. Provide documentation of reason for each site change.)

d) Field Support

Question	Yes	No	Comment
On average, how often are most of your stations visited by a field operator?			
Is this visit frequency consistent for all reporting organizations within your agency?	☐	☐	
On average, how many stations does a single operator have responsibility for?			
How many of the stations of your SLAMS/NCORE network are equipped with sampling manifolds?			
Do the sample inlets and manifolds meet the requirements for through the probe audits?			
I. Briefly describe most common manifold type.			
II. Are Manifolds cleaned periodically?	☐	☐	How often?
III. If the manifold is cleaned, what is used to perform cleaning?			
IV. Are manifold(s) equipped with a blower?	☐	☐	
V. Is there sufficient air flow through the manifold at all times?	☐	☐	Approximate air flow:
VI. How is the air flow through the manifold monitored?			
VII. Is there a conditioning period for the manifold after cleaning?	☐	☐	Length of time:
VIII. What is the residence time?			
Sampling lines: What material is used for instrument sampling lines?			
Are lines changed or cleaned once per year?	☐	☐	
Do you utilize uninterruptable power supplies or backup power sources at your sites?	☐	☐	
What instruments or devices are protected?	☐	☐	

i) SOPs

Question	Yes	No	Comment
Is the documentation of monitoring SOPs complete?	☐	☐	
Are any new monitoring SOPs needed?	☐	☐	
Are such procedures available to all field operations personnel?	☐	☐	
Are SOPs that detail operations during episode monitoring prepared and available to field personnel?	☐	☐	
Are SOPs based on the framework contained in Guidance for Preparing Standard Operating Procedures EPA QA/G-6?	☐	☐	

Please complete the following table:

Pollutant Monitored	Date of Last SOP Review	Date of Last SOP Revision
SO_2		
NO_2		
CO		
O_3		
PM_{10}		
$PM_{2.5}$ FRM mass		
Pb		
$PM_{2.5}$ speciation		
$PM_{10\text{-}2.5}$ FRM mass		
$PM_{10\text{-}2.5}$ speciation		
Continuous $PM_{2.5}$ mass		
Trace levels (CO)		
Trace levels (SO_2)		
Trace levels (NO)		
Trace levels (NO_y) Total reactive nitrogen		
Surface Meteorology Wind speed and direction, temperature, RH, precipitation and solar radiation		
Other parameters		

ii) Instrument Acceptance

Has your agency obtained necessary waiver provisions to operate equipment which does not meet the effective reference and equivalency requirements? List all waivers.

Please list instruments in your inventory

Pollutant	Number	Make and Models	Reference or Equivalent number
SO_2			
NO_2			
CO			
O_3			
PM_{10}			
$PM_{2.5}$			
Pb			
Multi gas calibrator			
$PM_{2.5}$ speciation			
$PM_{10\text{-}2.5}$ speciation			
$PM_{10\text{-}2.5}$ FRM mass			
Continuous $PM_{2.5}$ mass			
Trace levels (CO)			
Trace levels (SO_2)			
Trace levels (NO)			
Trace levels (NO_y)			
Surface Meteorology			
Others			

Please comment briefly and prioritize your currently identified instrument needs.

Question	Yes	No	Comment
Are criteria established for field QC equipment?	☐	☐	
Are criteria established for field QC gas standards?	☐	☐	

iii) Calibration

Please indicate the frequency of multi point calibrations.		
Pollutant	**Frequency**	**Name of Calibration Method**

Question	**Yes**	**No**	**Comment**
Are field calibration procedures included in the document? SOPs?	☐	☐	Location (site, lab etc.):
Are calibrations performed in keeping with the guidance in Vol. II of the QA Handbook for Air Pollution Measurement Systems?	☐	☐	If no, why not?
Are calibration procedures consistent with the operational requirements of Appendices to 40 CFR 50 or to analyzer operation/instruction manuals?	☐	☐	If no, why not?
Have changes been made to calibration methods based on manufacturer's suggestions for a particular instrument?	☐	☐	
Do standard materials used for calibrations meet the requirements of appendices to 40 CFR 50 (EPA reference methods) and Appendix A to 40 CFR 58 (traceability of materials to NIST-SRMs or CRMs)?	☐	☐	Comment on deviations
Are all flow-measurement devices checked and certified?	☐	☐	
Additional comments:			

Please list the authoritative standards used for each type of flow measurement, indicate the certification frequency of standards to maintain field material/device credibility.

Flow Device	**Primary Standard**	**Frequency of Certification**
Hi-Volume orifice		
Streamline		
TriCal		
BIOS		
Delta Cal		
Gilibrators		

Where do field operations personnel obtain gaseous standards?			
Standards are 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?	☐	☐	
Other (describe).	☐	☐	
How are the gas standards verified after receipt?			
How are flow measurement devices certified?			
Please provide copies of certifications of all standards currently in use from your master and/or satellite standard certification logbooks (i.e., chemical standards, ozone standards, flow standards, and zero air standards).			
What equipment is used to perform calibrations (e.g., dilution devices) and how is the performance of this equipment verified?			
Does the documentation include expiration date of certification?	☐	☐	
Reference to primary standard used?	☐	☐	
What traceability is used?			
Please attach an example of recent documentation of traceability			
Is calibration equipment maintained at each station?	☐	☐	
How is the functional integrity of this equipment documented?			
Who has responsibility for maintaining field calibration standards?			

Please list the authoritative standards and frequency of each type of dilution, permeation and ozone calibrator and indicate the certification frequency.

Calibrator	Primary Standard	Frequency of Certification
Permeation calibrator flow controller		
Permeation calibrator temperature		
Dilution calibrator air and gas flow controllers		
Field/working standard photometer		
Ozone generator		

Please identify station standards for gaseous pollutants at representative air monitoring stations (attach additional sheets as appropriate):			
Parameter	**Station(s)**	**Identification of Standard(s)**	**Recertification Date(s)**
CO			
NO_2			
SO_2			
O_3			

iv) Repair

Who is responsible for performing preventive maintenance?

Is special training provided them for performing preventive maintenance? Briefly comment on background or courses.

Is this training routinely reinforced? Yes☐ No☐

If no, why not?

What is your preventive maintenance schedule for each type of field instrumentation?

If preventive maintenance is MINOR, it is performed at (check one or more): field station☐, headquarters facilities☐, equipment is sent to manufacturer☐.

If preventive maintenance is MAJOR, it is performed at (check one or more): field station☐, headquarters facilities☐, equipment is sent to manufacturer☐.

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?

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?

Is the agency currently experiencing any recurring problem with equipment or manufacturer(s)? If so, please identify the equipment or manufacturer, and comment on steps taken to remedy the problem.

Have you lost any data due to repairs in the last 2 years?

More than 24 hours?

More than 48 hours?

More than a week?

Explain any situations where instrument down time was due to lack of preventive maintenance of unavailability of parts.

v) RECORD KEEPING

Question	Yes	No	Comment
What type of station logbooks are maintained at each monitoring station? (maintenance logs, calibration logs, personal logs, etc.)			
What information is included in the station logbooks?			
Who reviews and verifies the logbooks for adequacy of station performance?			
How is control of logbook maintained?			
Where is the completed logbook archived?			
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.			
Are calibration records or at least calibration constants available to field operators?	☐	☐	
Please attach an example field calibration record sheet to this questionnaire.			

vi) Site Information and monitor Information

PQAO:

AQS Site Name:

AQS Site Number:

Agency Site Name/No.:
(if different than AQS Site
Name/Number)

Site Address:

City & County:

Site Coordinates:
(specify lat/long or UTM)

Site Elevation (m):

Criteria Pollutants Monitored:

Other Parameters:

Nearest Meteorological Site:
('on site' is met tower present at this site)

Photographs to and from each cardinal direction attached?
(Yes or No)

Name(s) of Report Preparer(s):

Name(s) of Auditors:

Date:

Phone Number:

Site Map
Draw map of site and surrounding terrain and features, up to 100 meters.

Map notes

Monitor Information

	Pollutants		
Manufacturer			
Model			
Serial number			
Scale of representation Micro, Middle, Neighborhood, Urban			
Objective (Population, Max concentration, Background, Transport)			
Height of probe above ground(m)			
Distance from obstruction (m)			
Type of obstruction (Wall, Tree, etc)			
Distance from roadway (m)			
Unrestricted airflow (Yes, No)			
Designation (NCore, SLAMS, etc)			
Siting Criteria Met (Yes, No)			

	Pollutants		
Manufacturer			
Model			
Serial number			
Scale of representation Micro, Middle, Neighborhood, Urban			
Averaging time 1-, 8-, 24-hour			
Objective (Population, Max concentration, Background, Transport)			
Height of probe above ground(m)			
Distance from obstruction (m)			
Type of obstruction (Wall, Tree, etc)			
Distance from roadway (m)			
Unrestricted airflow (Yes, No)			
Designation (NCore, SLAMS, etc)			
Siting Criteria Met (Yes, No)			

Insert additional copies of table as needed:

Area Information

Street Name	Traffic Count (Vehicles/day)

Direction	Predominant Land Use (Industry, Residential, Commercial or Agriculture)
North	
East	
South	
West	

Direction	Obstructions	Height (m)	Distance (m)
North			
East			
South			
West			

Note: This table is for large obstructions that affect the entire site, such as large clusters of trees or entire buildings. Individual obstructions, such as walls, single trees, other monitors, etc, should be entered in the Monitor Information table.

Direction	Topographic Features (hills, valleys, rivers, etc.)	General Terrain (flat, rolling, rough)
North		
East		
South		
West		

Comments:

3) Laboratory Operations

State/Local/Tribal Agency Audited:

City, State, and Zip Code:

Date of Technical System Audit:

Auditor / Agency:

Key Individuals

Laboratory Manager:

Laboratory Supervisor:

Quality Assurance Manager:

Laboratory Staff involved in the TSA:

a) Routine Operations

What analytical methods are employed in support of your air monitoring network?

Analysis	Name or Description of Method
PM10	
PM2.5	
Pb	
Others (list by pollutant)	

1. Please describe areas where there have been difficulties meeting the regulatory requirements for any of the above analytical methods.

In the table below, please identify the current versions of written methods, supplements, and guidelines that are used in your agency.

Analysis	Documentation of Method
PM10	
PM2.5	
Pb	
Others (list by pollutant)	

Question	Yes	No	Comment
Were procedures for the methods listed above included in the agency's QAAP or SOPs and were they reviewed by EPA? Also, are SOPs easily/readily accessible for use and reference?	☐	☐	
Does you lab have sufficient instrumentation to conduct analyses?	☐	☐	

Please describe needs for laboratory instrumentation

b) Laboratory Quality Control

Please identify laboratory standards used in support of the air monitoring program, including standards which may be kept in an analytical laboratory and standards which may be kept in a field support area or quality assurance laboratory that is dedicated to the air monitoring program (attach additional sheets if appropriate):

Parameter	Location of Standards	Laboratory Standard	Recertification Date	Primary Standard*
CO				
NO2				
SO2				
O3				
Weights				
Temperature				
Moisture				
Barometric Pressure				
Flow				
Other Flow Standard				
Lead				
Other				

***Standards to which the laboratory standards can be traced.**

Question	Yes	No	Comment
Are all chemicals and solutions clearly marked with an indication of shelf life?	☐	☐	
Are chemicals removed and properly disposed of when shelf life expires?	☐	☐	
Are only ACS grade chemicals used by the laboratory?	☐	☐	
Comment on the traceability of chemicals used in the preparation of calibration standards.			

Question	Yes	No	Comment
Does the laboratory purchase standard solutions such as those for use with lead or other metals analysis?	☐	☐	
Are all calibration procedures documented?	☐	☐	
If answer "yes" to (f), please describe the following:			
Title of the document:			
Revision number:			
Where the document is:			
Are at least one duplicate, one blank, and one standard or spike included with a given analytical batch?	☐	☐	
Briefly describe the laboratory's use of data derived from blank analyses.			

Question	Yes	No	Comment
Are criteria established to determine whether a blank data are acceptable?	☐	☐	

How frequently and at what concentration ranges does the lab perform duplicate analysis? What constitutes an acceptable agreement? Please comment in the space below.
Please describe how the lab use data obtained from spiked samples, including the acceptance criteria (e.g., acceptable percent recovery).

Question	Yes	No	Comment
Does the laboratory routinely include samples of reference material within an analytical batch?	☐	☐	
If yes, indicate frequency, level, and material used.			
Are mid-range standards included in analytical batches?	☐	☐	
Please describe the frequency, level and compound used in the space provided below.			
Are criteria for real time quality control established that are based on the results obtained for the mid-range standards discussed above?	☐	☐	
If yes, briefly discuss them below or indicate the document in which they can be found.			
Are appropriate acceptance criteria for each type of analysis documented?	☐	☐	

c) Laboratory Preventive Maintenance

Question	Yes	No	Comment
For laboratory equipment, who has the responsibility for performing preventive maintenance?			
Is most maintenance performed in the lab?	☐	☐	
Is a maintenance log maintained for each major laboratory instrument?	☐	☐	
Are service contracts in place for major analytical instruments?	☐	☐	

d) Laboratory Record Keeping

Question	Yes	No	Comment
Are all samples that are received by the laboratory logged in?	☐	☐	
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.			
Are log books kept for all analytical laboratory instruments?	☐	☐	
Are there log books or other records that indicate the checks made on materials and instruments such as weights, humidity indicators, balances, and thermometers?	☐	☐	
Identify type of record, acceptable/non-acceptable.			
Are log books maintained to track the preparation of filters for the field?	☐	☐	
Are they current?	☐	☐	
Do they indicate proper use of conditioning?	☐	☐	
Weightings?	☐	☐	
Stamping and numbering?	☐	☐	
Are log books kept which track filters returning from the field for analysis?	☐	☐	
How are data records from the laboratory archived? Where? Who has the responsibility? Title: How long are records kept? Years			
Does a chain-of-custody procedure exist for laboratory samples?	☐	☐	
If yes, indicate date, title and revision number where it can be found.			

e) Laboratory Data Acquisition and Handling

Question	Yes	No	Comment
Identify those laboratory instruments which make use of computer interfaces directly to record data. Which ones use strip charts? Integrators?			
Are QC data readily available to the analyst during a given analytical run?	☐	☐	
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.			
Has a user's manual been prepared for the automated data acquisition instrumentation?	☐	☐	
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 by the laboratory.			

f) Specific Pollutants: PM_{10}, $PM_{2.5}$ and Lead

Question	Yes	No	Comment
PM10 and PM2.5			
Does the agency use filters supplied by EPA?	☐	☐	
Do filters meet the specifications in 40 CFR 50?	☐	☐	
Are filters visually inspected via strong light from a view box for pinholes and other imperfections?	☐	☐	
Where does the laboratory keep records of the serial numbers of filters?			
Are unexposed filters equilibrated in controlled conditioning environment which meets or exceeds the requirements of 40 CFR 50?			
Are the temperature and relative humidity of the conditioning environment monitored?	☐	☐	
Are the temperature and humidity monitors calibrated?	☐	☐	
Are balances checked with Class S or Class M weights each day when they are used?	☐	☐	
Is the balance check information placed in QC log book?	☐	☐	
To what sensitivity are filter weights recorded?			
Are filter serial numbers and tare weights recorded in a bound notebook?	☐	☐	
Are filters packaged for protection while transporting to and from the monitoring stations?	☐	☐	
How often are filter samples collected? (Indicate the average elapsed time in hours between end of sampling and laboratory receipt.)			
In what medium are field measurements recorded (e.g., in a log book, on a filter folder, or on standard forms)?			
Are exposed filters reconditioned for at least 24 hrs in the same conditioning environment as for unexposed filters?			
Briefly describe how exposed filters are prepared for conditioning.			

Briefly describe how exposed filters are stored after being weighed.			
Are blank filters reweighed? How often?			
Are chemical analyses performed on filters?	☐	☐	
LEAD			
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?
Is either the hot acid or ultrasonic extraction procedure being followed precisely?	☐	☐	Which?
Is Class A borosilicate glassware used throughout the analysis?	☐	☐	
Is all glassware cleaned with detergent, soaked and rinsed three times with distilled or de-ionized water?	☐	☐	
If extracted samples are stored, are linear polyethylene bottles used?	☐	☐	
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.
Are ACS reagent grade HNO3 and HCl used in the analysis?	☐	☐	
Is a calibration curve available having concentrations that cover the linear absorption range of the atomic absorption instrumentation?	☐	☐	
Is the stability of the calibration curve checked by alternately re-measuring every 10th sample a concentration of < = 1ug Pb/ml; < = 10 ug Pb/ml?	☐	☐	

4) DATA AND DATA MANAGEMENT

State/Local/Tribal Agency Audited:

City, State, and Zip Code:

Date of Technical System Audit:

Auditor / Agency:

Key Individuals

Data Manager:

Data Supervisor:

Quality Assurance Manager:

a) Data Handling

Question	Yes	No	Comment
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.			
Are procedures for data handling (e.g., data reduction, review, etc.) documented?	☐	☐	
In what media (e.g., diskette, data cartridge, or telemetry) and formats do data arrive at the data processing location? Please list below.			

Category of Data (by Pollutant)	Data Media and Formats

How often are data received at the processing location from the field sites and laboratory?			
Is there documentation accompanying the data regarding any media changes, transcriptions, or flags which have been placed into the data before data are released to agency internal data processing?	☐	☐	
Describe the type of documentation.			
How data are actually entered to the computer system (e.g., computerized transcription (copy from disk or data transfer device), manual entry, digitization of strip charts, or other)?			

b) Software Documentation

Question	Yes	No	Comment
Does your agency use any AQS Manual?	☐	☐	
Does your agency use any Air Now Manual?	☐	☐	
If yes, list the title of manual used including the, version number and date published.			
Does the agency have information on the reporting of precision and accuracy data available (i.e. AMP 255)?	☐	☐	
What are the origins of the software used to prepare air monitoring data for release into the AQS and Air Now database? Please list the documentation for the software currently in use for data processing, including the names of the software packages, vendor or author, revision numbers, and the revision dates of the software.			
What is the recovery capability in the event of a significant computer problem (i.e., how much time and data would be lost)?			
Has your agency tested the data processing software to ensure its performance of the intended function is consistent with the QA Handbook, Volume II, and Section 14.0?	☐	☐	
Does your agency document software tests?	☐	☐	
If yes, provide the documentation.			

c) Data Validation and Correction

Question	Yes	No	Comment
Have your agency established and document the validation criteria?	☐	☐	If yes, indicate document where such criteria can be found (title, revision date).
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?	☐	☐	
Does your agency document the data validation criteria including limits for values such as flow rates, calibration results, or range tests for ambient measurements?	☐	☐	
If yes, please describe what action the data validation will take if he/she fined data with limits exceeded (e.g., flags, modifies, or delete, etc.)			
If yes, give examples to illustrate actions taken when limits were exceeded.			
Please describe how changes made to data that were submitted to AQS and Air Now are documented.			
Who has signature authority for approving corrections?			
Name:			Program Function:
What criteria are used to determine a data point is deleted? Discuss briefly.			
What criteria are used to determine if data need to be reprocessed? Discuss.			
Are corrected data resubmitted to the issuing group for cross-checking prior to release?	☐	☐	

d) Data Processing

Question	Yes	No	Comment
Does the agency generate data summary reports?	☐	☐	

Please list at least three reports routinely generated, including the information requested below.

Report Title	Distribution	Period Covered

Question	Yes	No	Comment
How often are data submitted to AQS and Air Now?			
Briefly comment on difficulties the agency may have encountered in coding and submitting data following the guidance of the AQS guidelines?			
Does the agency routinely request a hard copy printout on submitted data from AQS?	☐	☐	
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.			
Has your agency submitted data along with the appropriate calibration equations used to the processing center?	☐	☐	
Are concentrations of pollutants (other than PM2.5) corrected to EPA standard temperature and pressure conditions (i.e., 298 K, 760 mm Hg) before input to AQS, and concentrations of PM2.5 reported to AQS under actual (volumetric) conditions?	☐	☐	
I) Are audits on data reduction procedure performed on a routine basis?	☐	☐	
If yes, at what frequency?			
Are data precision and accuracy checked each time they are calculated, recorded, or transcribed to ensure that incorrect values are not submitted to EPA?	☐	☐	

e) Internal Reporting

What internal reports are prepared and submitted as a result of the audits required under 40 CFR 58, Appendix A?

Report Title	Frequency

What internal reports are prepared and submitted as a result of precision checks also required under 40 CFR 58, Appendix A?

Report Title	Frequency

Question	Yes	No	Comment
Do either the audit or precision check reports indicated include a discussion of corrective actions initiated based on audit or precision check results?	☐	☐	

Who has the responsibility for the calculation and preparation of data summaries? To whom are such summaries delivered?

Name	Title	Type of Report	Recipient

f) External Reporting

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 on time.

Percent Submitted on Time*			**Period Covered:**				
Monitoring Qtr.	**SO2**	**CO**	**O3**	**NO2**	**PM10**	**PM2.5**	**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.**

For the same period, what fraction of the stations (by pollutant) reported less than 75% of the data (adjusted for seasonal monitoring and site start-ups and terminations)?

Percent of Stations <75% Data Recovery			**Period Covered:**				
Monitoring Qtr.	**SO2**	**CO**	**O3**	**NO2**	**PM10**	**PM2.5**	**Pb**
1 (Jan 1 - March 31)							
2 (Apr 1 - June 30)							
3 (July 1 - Sept. 30)							
4 (Oct.1 - Dec. 31)							

Identify the individual within the agency with the responsibility for reviewing and releasing the data.
Name: **Program Function:**

Question	**Yes**	**No**	**Comment**
Does your agency report the Air Quality Index?	☐	☐	
Has your agency submitted its annual data summary report as required in 40 CFR 58.15(b)?	☐	☐	
If yes, did your agency's annual report include the following:			
Annual precision and accuracy information (i.e. AMP 255) described in 40 CFR 58.15 (c)?	☐	☐	
Location, date, pollution source and duration of all episodes reaching the significant harm levels?	☐	☐	
Is Data Certification signed by a senior officer of your agency?	☐	☐	

Appendix I

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 Primary Quality Assurance Organization, Annual Quality Assurance Report for 2015".

NOTE: The data in the report are not meant to coincide with the acceptance criteria in the validation templates found in Appendix D which are reviewed and updated more frequently than this appendix. The report is an example of the type of information that could be presented for an internal QA Report and should not be used to represent current acceptance criteria.

ACME PRIMARY QUALITY ASSURANCE ORGANIZATION
ANNUAL QUALITY ASSURANCE REPORT FOR 2015

Prepared by

Quality Assurance Department
Acme Primary Quality Assurance Organization
110 Generic Office Building
Townone XX, 00001

April 2016

ACME PRIMARY QUALITY ASSURANCE ORGANIZATION
ANNUAL QUALITY ASSURANCE REPORT FOR 2015
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ACME PRIMARY QUALITY ASSURANCE ORGANIZATION
ANNUAL QUALITY ASSURANCE REPORT FOR 2015

EXECUTIVE SUMMARY

This summary describes the Acme Primary Quality Assurance Organization's (APQAO's) success in meeting its quality objectives for ambient air pollution monitoring data. APQAO's attainment of quantitative objectives, such as promptness, completeness, precision, and bias, are shown in Table 1, below. APQAO 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 APQAO'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 APQAO'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 2015.
- 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 Primary Quality Assurance Organization (APQAO) 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)
- 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 APQAO 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 from the field to the laboratory for analysis. For this reason, we will divide quality assurance procedures into two parts – field 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 Primary Quality Assurance 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 2015, the Acme Primary Quality Assurance Organization operated 38 ambient air monitoring stations that measured gaseous criteria pollutants. On March 1, 2015, 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 2015.

QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the Acme Primary Quality Assurance 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	$O_3 \pm 7\%$; CO, $SO_2 \pm 10\%$; $NO_2 \pm 15\%$
Bias	$O_3 \pm 7\%$; CO, $SO_2 \pm 10\%$; $NO_2 \pm 15\%$
Completeness	75%
Promptness	100%

DATA QUALITY ASSESSMENT

Summary

Assessment of the data quality for APQAO 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 APQAO 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.

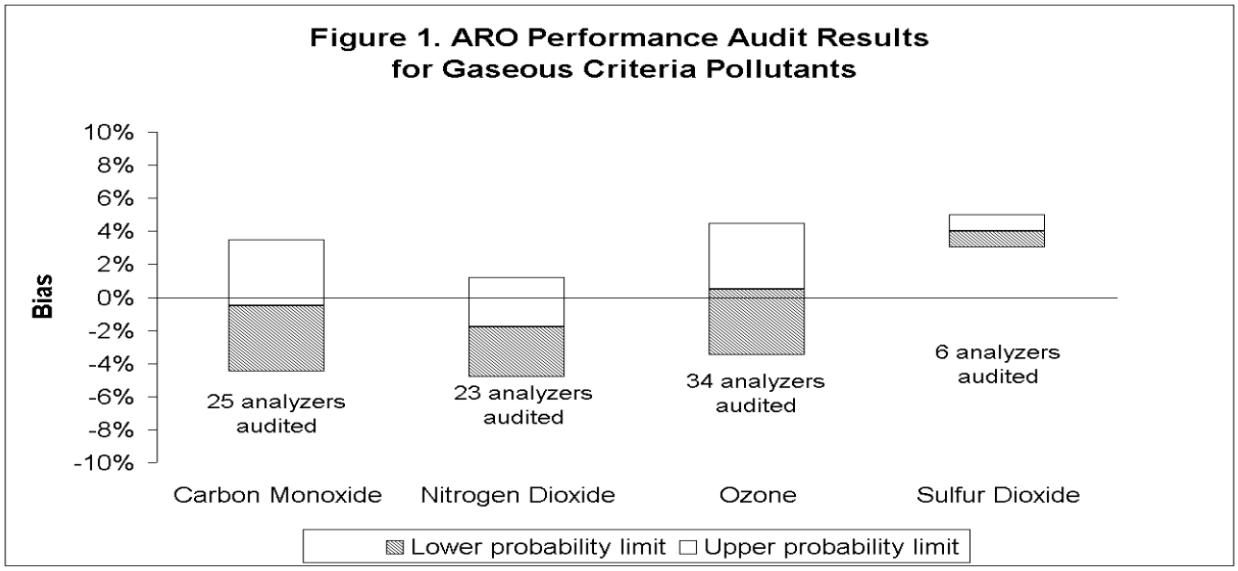
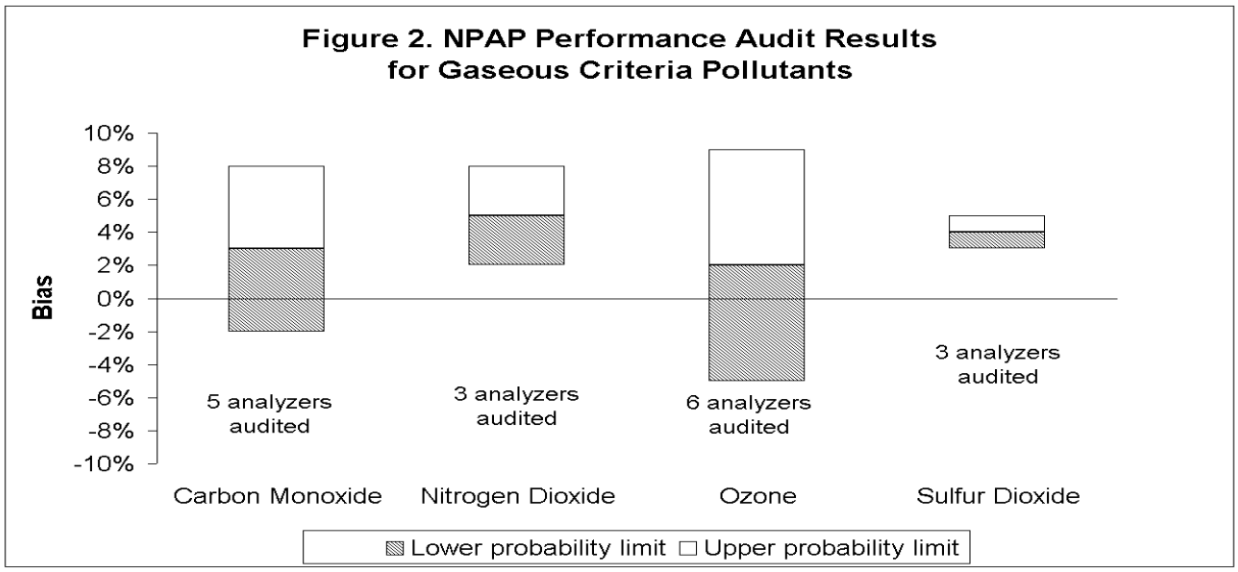


Figure 2 shows the results of external performance audits performed with the National Performance Audit Program (NPAP), administered by the U.S. EPA.



System Audits

Systems audits were performed at approximately 25 percent of the sites during the calendar year 2015. 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 2015.
- 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 vegetation.

PARTICULATE CRITERIA POLLUTANTS

The Acme Primary Quality Assurance 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 2015, the Acme Primary Quality Assurance Organization operated 22 ambient air monitoring stations that measured particulate criteria pollutants. On March 1, 2015, 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 2015.

QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the Acme Primary Quality Assurance 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	$\pm$ 10%
Bias	$\pm$10%
Completeness	75%
Promptness	100%

DATA QUALITY ASSESSMENT

Summary

Assessment of the data quality for APQAO 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 (0.002 $\mu g/m^3$ for lead, 15 $\mu g/m^3$ for PM_{10} (hi-vol), 3 $\mu g/m^3$ for PM_{10} (lo-vol), and 3$\mu g/m^3$ for $PM_{2.5}$) are used to evaluate precision. Table 7 summarizes the results of collocated measurements made during the calendar year 2015.

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 $\pm$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 APQAO 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.

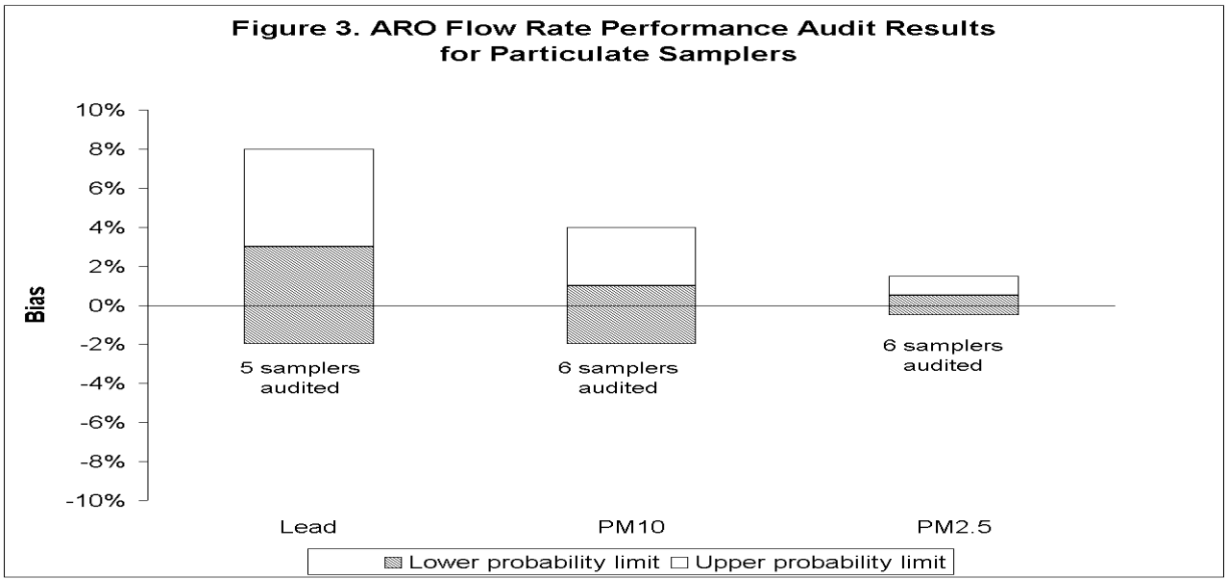
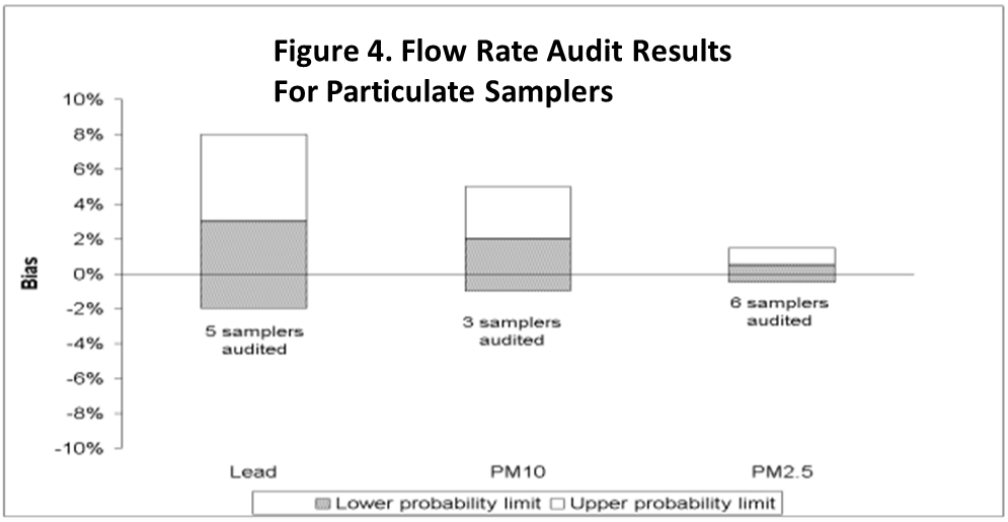


Figure 4 shows the results of flow rate audits for PM_{10} and lead samplers performed with the. The NPAP audits of $PM_{2.5}$ samplers involve sampler collocation rather than flow rate checks



Measurement Bias

Measurement bias is evaluated for $PM_{2.5}$ analyzers by collocated sampling using an audit sampler. For internal audits, the collocated measurements provide an estimate of bias resulting from sampler operations. For external audits, the collocated measurements provide an estimate of bias resulting from both sampler and laboratory operations. Measurement bias for lead is also evaluated by use of lead analysis audit test samples. This provides an estimate of the bias resulting from laboratory operations. The results of the internal audits of $PM_{2.5}$ and lead conducted by APQAO personnel are shown in Figure 5, below.

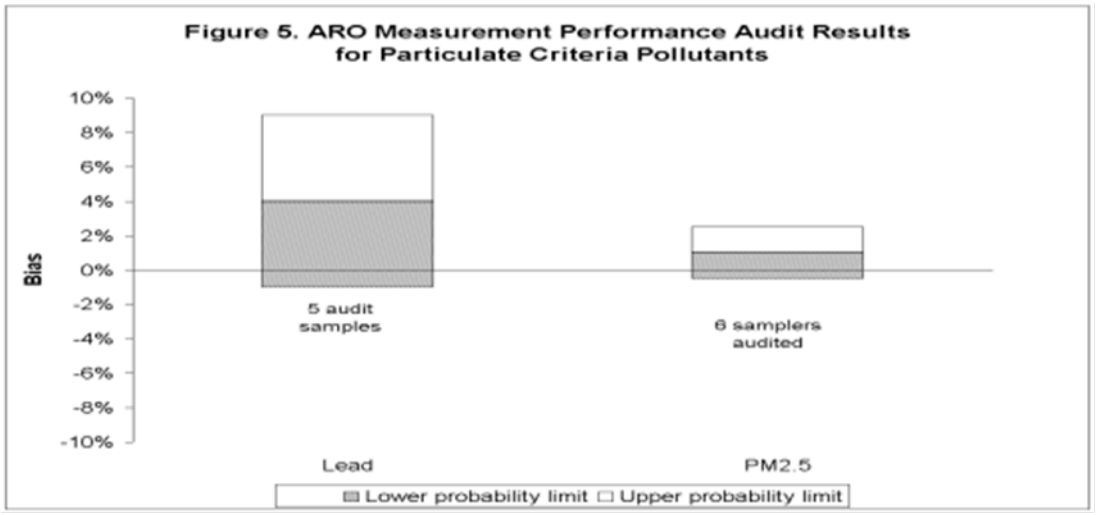
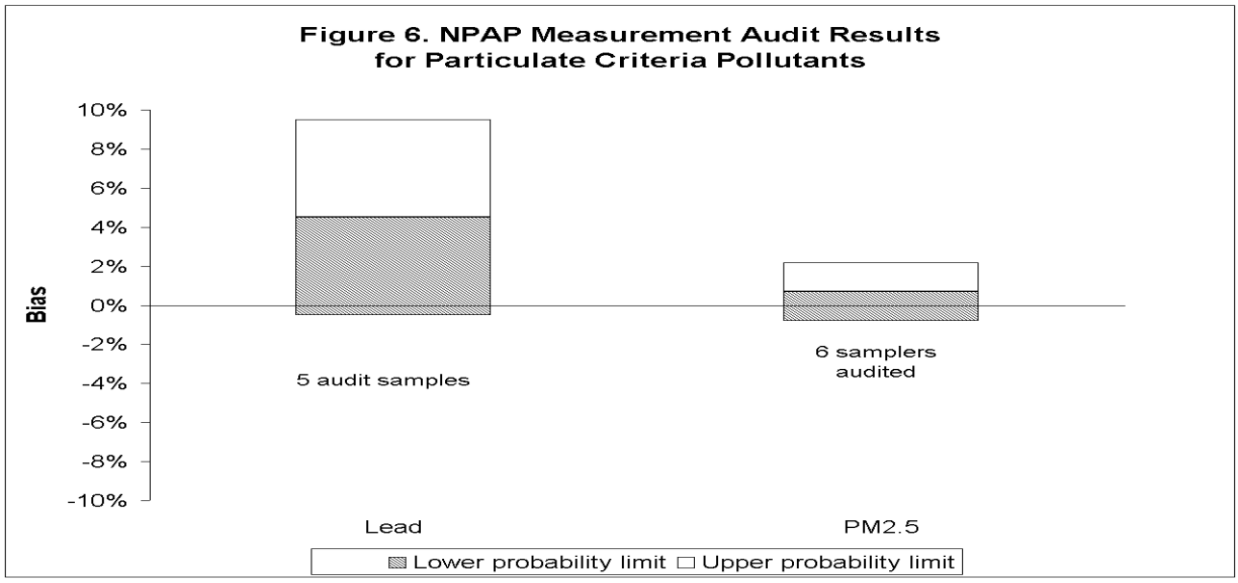


Figure 6 shows the results of external performance audits for PM_{10} and lead performed with the National Performance Evaluation Program (PEP) which is administered by the U.S. EPA.



System Audits

Systems audits were performed at approximately one fourth of the sites and at the central analytical laboratory during calendar year 2015. 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 2015.
- 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 Primary Quality Assurance 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 2015, the Acme Primary Quality Assurance Organization operated 5 ambient air monitoring stations that measured ozone precursors. On March 1, 2015, a station was opened at Townone to monitor VOCs, carbonyls, and NO_x.

QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the Acme Primary Quality Assurance 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)	$\pm$10%
Precision (VOC, Carbonyls)	$\pm$25%
Bias (NO_x)	$\pm$15%
Bias (VOC, Carbonyls)	$\pm$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 2015.

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 APQAO 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.

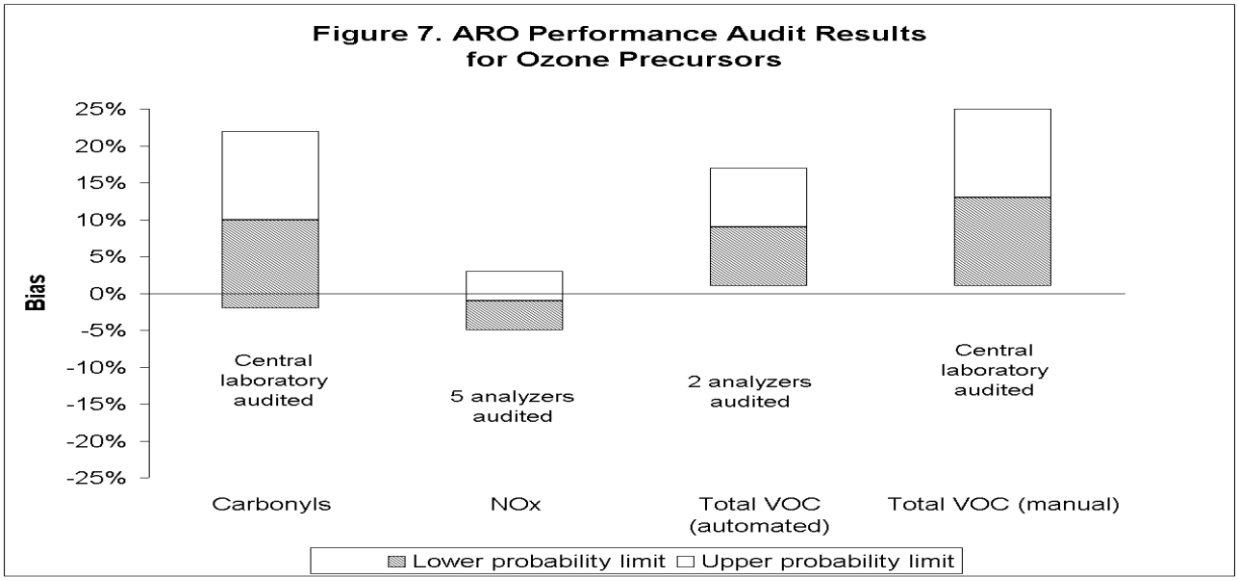
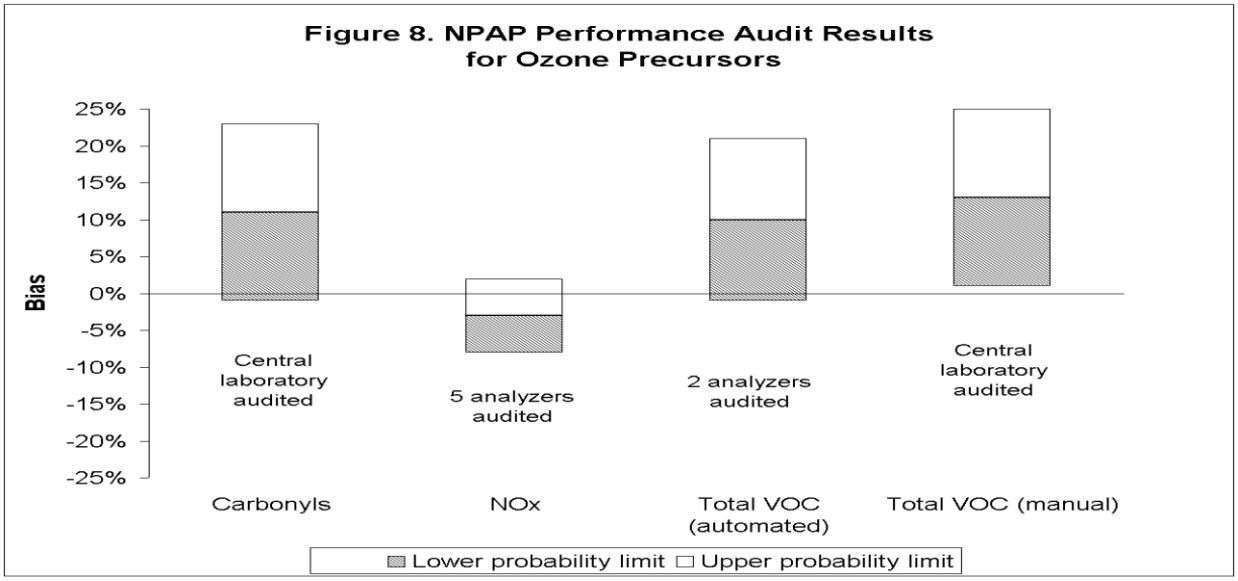


Figure 8 shows the results of the external performance audits performed with the National Performance Evaluation Program (NPEP) which is administered by the U.S. EPA.



System Audits

Systems audits were performed at two sites during calendar year 2015. 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 Primary Quality Assurance 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 2015, the Acme Primary Quality Assurance Organization operated five ambient air monitoring stations that measured ambient air toxics. On March 1, 2015, a station was opened at Townone to monitor air toxics.

QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the Acme Primary Quality Assurance 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 2015.

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 APQAO 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.

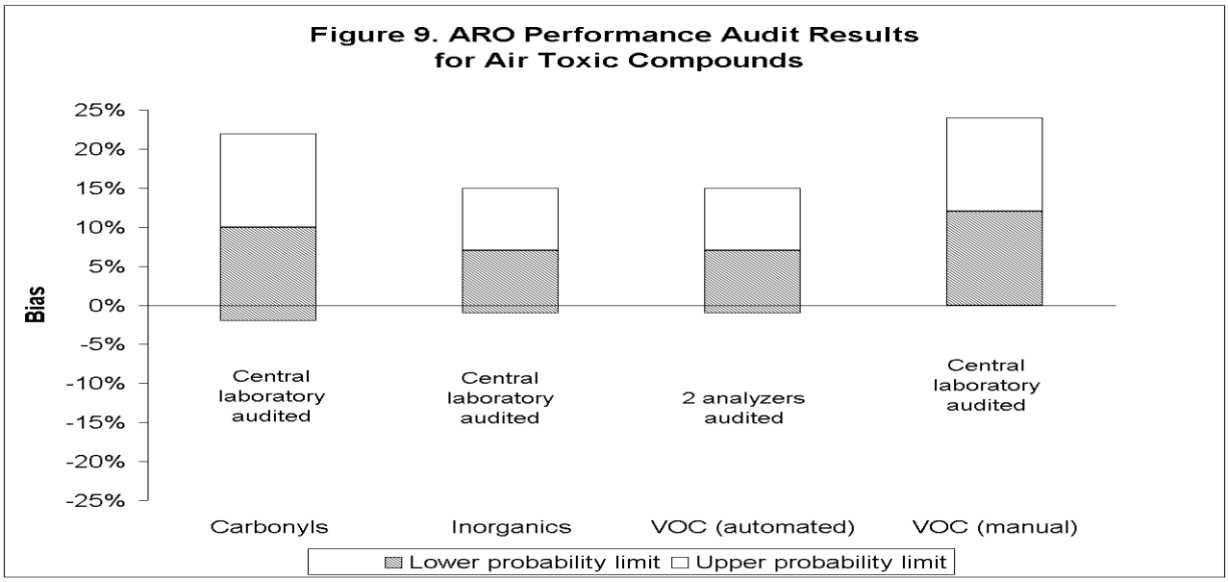
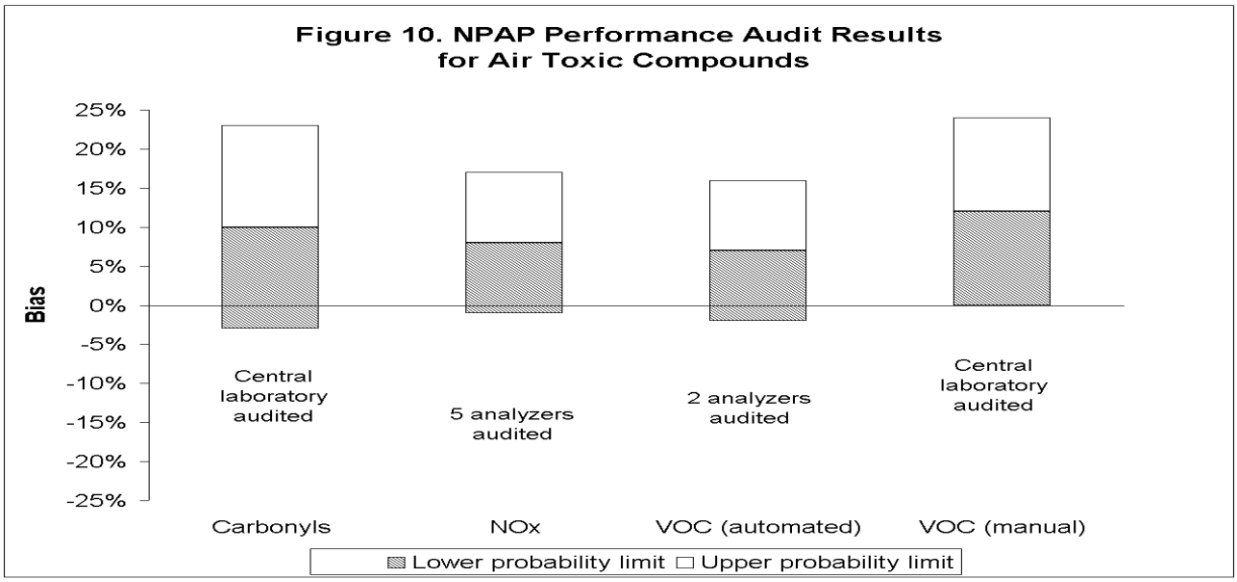


Figure 10 shows the results of the external performance audits performed with the National Performance Evaluation Program (NPAP) which is administered by the U.S. EPA.



System Audits

Systems audits were performed at two sites during the calendar year 2015. 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 Primary Quality Assurance Organization notes a problem that demands either immediate or long-term action to correct a safety defect, an 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.

APQAO - Corrective Action Request

Part A - To be completed by requestor

To: *John S. Visor*

Organization Responsible for Action *APQAO Ambient Air Monitoring Section*

Urgency:

9 Emergency (failure to take action immediately may result in injury or property damage)

9 Immediate (4 hours) : Urgent (24 hours) 9 Routine (7 days)

9 As resources allow 9 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 APQAO Site Coordinator at 115 Generic Office Building, Townone XX, 00001)

Problem Identification

Site(Location): *Townsix site*

System: *sample inlet*

Date problem identified: *Aug. 1, 2015*

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, 2015*

Part B - to be completed by responsible organization

Problem Resolution

Date corrective action taken: *August 4, 2015*

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, 2015*

Phone: *(000) 555 - 2015* Fax: *(000) 555 - 2001*

e-mail: *jsv@localhost*

Send copies of the completed form to the requestor and the APQAO Site Coordinator at 115 Generic Office Building, Townone XX, 00001)

APQAO form CAR-1 , May 1, 2005

Appendix J

Guidance on the use of Electronic Logbooks

The purpose of this guidance is to establish minimum requirements for documenting and maintaining electronic logbook (e-logbook) information for the Ambient Air Monitoring Program. This document is not intended to be inclusive of all electronic records initiatives presently being conducted in the EPA, but rather is seen as a starting point for an e-logbook practice to ensure some consistency across all the monitoring organizations utilizing e-logbooks for ambient air monitoring in accordance with 40 CFR Part 58.

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The use and storage of electronic information is increasing at ever faster paces in our environment. Real time ambient air data is now being posted on PC and smart phones that allows the public instant access to this information. Funding transactions are occurring on smart phones and electronic signatures are legally binding[a]. Virtually all air monitoring programs collect, validate and certify data electronically using new generation data logging and transmittal systems. This demonstrates progress from our analog information management systems where monitoring organizations reviewed strip charts to determine concentrations and evaluate data quality. An area where more progress can be made in the ambient air monitoring program is the entry and storage of logbook information in electronic formats.

Goal

The purpose of this guidance is to establish minimum requirements for documenting and maintaining electronic logbook (e-logbook) information for the Ambient Air Monitoring Program. This document is not intended to be inclusive of all electronic records initiatives presently being conducted in the EPA, but rather is seen as a starting point for an e-logbook practice to ensure some consistency across all the monitoring organizations utilizing e-logbooks for ambient air monitoring in accordance with 40 CFR Part 58.

Adherence and implementation of this e-logbook guidance is the ultimate responsibility of the monitoring organization lead (MOL) with assistance from the quality assurance (QA) manager and records manager[b]. A monitoring program can maintain both paper and electronic information. Storage and archiving of all records are the responsibility of the MOL and must be documented or referenced in the monitoring organizations quality management plan (QMP) and quality assurance project plan (QAPP) and be available for external review.
OAQPS supports the use of electronic data collection systems for the collection of ambient air logbook information in a manner that ensures that:

- The system has adequate levels of security and administration to ensure e-logbook data cannot be tampered with and have adequate levels of backup (i.e., frequency and multiple storage locations)
- Personnel entering or editing information are uniquely identified and have been given authority to enter/edit. A list of the personnel, their authority and access privileges should be included or referenced in the organizations QA documentation (QAPP/QMP) and be available to EPA. E-signatures are strongly suggested for use.
- Every logbook entry/edit (entry session[c]) is date/time stamped and the entry person identified.

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[a] http://www.gpo.gov/fdsys/pkg/BILLS-106s761enr/pdf/BILLS-106s761enr.pdf
https://www.whitehouse.gov/sites/default/files/omb/assets/omb/memoranda/esign-guidance.pdf

[b] QMP or QAPP would identify individuals responsible for managing the e-logbook system.

[c] An entry session is defined as a unique data collection period when e-logbook information is entered into the system either through automated means (i.e., from automated instruments or a data logger) or by a site operator where a date/time stamp and a unique identifier of the entry person is recorded.

- Original entries are recorded and archived. Initial entries are not erased when revisions (edits to previous entries in a different entry session) are made. This ensures an audit trail is available for all entries.

Scope of Document

This guidance document addresses the use of e-logbooks for the Ambient Air Monitoring Program described in 40 CFR Part 58. This document will provide a background of the monitoring program, the traditional use of logbooks, and the minimum features necessary for monitoring organizations to migrate towards an e-logbook system if they so desire. Traditional use of hardcopy logbooks remains an acceptable practice and this guidance simply provides an alternative approach.

Authority

EPA Regional Offices, as part of QMP/QAPP review and implementation of technical systems audits, will be responsible for ensuring that implementation of e-logbooks meet the minimum requirements described in this document.

Background -Ambient Air Monitoring Networks and Monitoring Objectives

Between the years 1900 and 1970, the emission of six principal pollutants increased significantly. The principal pollutants, also called criteria pollutants are: particulate matter (PM10 and PM2.5), sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead. In 1970, the Clean Air Act (CAA) was signed into law. The CAA and its amendments provide the framework for the protection of air quality. As part of this framework, EPA establishes and periodically revises National Ambient Air Quality Standards (NAAQS) for the criteria pollutants, and the Agency has established requirements for monitoring networks for these pollutants. 40 CFR Part 58, Appendix D requires that monitoring networks be designed for three basic monitoring objectives:

- to provide air pollution data to the general public in a timely manner
- to support compliance with ambient air quality standards (primary and secondary) and emission strategy development
- to support air pollution research studies

Most of the ambient air monitoring sites have been implemented to support NAAQS decisions. The monitoring data and its associated data quality attributes, including logbooks, are used in decisions regarding the status of areas' attainment or nonattainment of the NAAQS and as such our quality systems and record keeping processes must ensure that our ambient air measurements and its associated data quality information are credible, reliable and legally defensible. Much of the documentation that is used to verify that monitoring sites are properly located and maintained and that field monitors/samplers and analytical instruments are meeting regulations for method

implementation and data quality is located in logbooks. These logbooks come in many forms and include:

Site Logbooks -observations upon visiting a site, site evaluations against regulatory siting criteria, scheduled maintenance activities, instrumentation and consumable inventories (i.e., gas standard expiration dates and quantities left etc.).

Instrument logbooks- logbooks associated with each sampler or monitor that contain specific routine maintenance information, repairs, quality control checks, verifications, calibration etc. In many cases this instrument logbook "travels" with the instrument as it is transported to and from monitoring sites for repair or calibration.

Laboratory Logbooks- Similar to logbooks utilized in the field, laboratory logbooks are maintained in analytical laboratories for overall maintenance of the lab, as well as maintenance of analytical equipment, quality control checks, calibrations, and standards.
This guidance does not require separate e-logbooks for each type of logbook used in a monitoring organization. Monitoring organizations may develop e-logbook systems that combine a number of logbook types into one program. In addition, some monitoring organizations may have systems that include both hardcopy and e-logbooks.
A discussion of logbooks can be found in the *QA Handbook for Ambient Air Measurements Systems*[d] including references to a number of good sources of information on how to develop and implement logbooks. Some monitoring organizations use logbooks in a free-form note style to provide a record of the activities that were performed at a site and a lab on a particular day. Some use standardized forms that provide for consistent implementation of specific activities at specific frequencies across all sites in a monitoring network. In either case, the advantage of the logbook is to be able to directly document what has occurred during a work session and be able to review earlier events/activities at a site or with a particular instrument. This can be important for sites that are remote and cannot be accessed through internet or other means. However, with the advent of PCs and tablets and better communication to central office information management (IM) systems, the advantages of having a hardcopy logbook at the site has diminished and they have some of the following drawbacks:

- With only one version (unless scanned frequently), logbooks can be destroyed and damaged to a point of being illegible, and can be lost.
- Data is not available to anyone without traveling to the site.
- Quantitative assessment of logbook data is not easily accomplished without additional data entry which could lead to entry errors.
- Events and dates can be falsified since there is no electronic timestamp on when someone was actually at the site to perform required activities.

Hardcopy logbooks traditionally had some advantages that will need to be satisfactorily addressed with e-logbooks:

[d] http://www.epa.gov/ttnamti1/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf

- Once written down (non-erasable pen is required) a hardcopy logbook can't be erased and entry errors must be crossed out and initialed. In an e-logbook open entry session[e], entries need to be developed in a way that they are saved upon entry not just at the end of a full session. This also minimizes any data loss if the log system crashes during an entry session.
- Many types of logbooks are kept at the monitoring site so one can expect that a logbook entry will occur at the site where the work is performed. E-logbooks can achieve this by recording location information of an entry session.
- Logbook pagination allows for one to evaluate the chronology of information collection and can identify when information has been deleted (e.g., a page is missing from the logbook). Using an entry system with date and time stamp will satisfy this issue. Backing up e-logs system (an advantage over hardcopy logbooks) will minimize data loss or deletion as long as there is good security against tampering.
- Handwritten logs (signed/initialed) are difficult (but not impossible) to falsify. Good password secure e-logbooks systems, including use of secondary authenticating factors, can protect electronic data from fraudulent activity.

The goal of this document is to ensure that the salient features of good logbook practices are presented so that e-logbook data is captured and maintained in a manner that is secure, tamper proof, and legally defensible.

Minimum Requirements

An e-logbook system should meet National Archives and Records Administration (NARA)[f] requirements that pertain to e-logbooks. The e-logbook system should and be able to: 1) collect, organize, and categorize, and 2) facilitate the preservation, retrieval, use, and disposition of records. Attachment A provides the current version (2015) of this federal regulation for informational purposes. Although not all of the regulation pertains to e-logbooks, many of the requirements described are applicable to e-logbooks and are included in the information provided below. EPA acknowledges that monitoring organizations may also have local records policies, and they will need to ensure their system meets the need of both EPA & their own policies. Much of the information that follows comes from the website: *Basic Requirements of an Electronic Recordkeeping System at EPA*[g] and are the features that must be addressed when developing or evaluating an e-logbook system for data defensibility. This information needs to either be included or referenced in the monitoring organizations QMP or QAPP in order for the EPA approving authority to be able to review and approve the e-logbook process as adequate.

- **Integrity** - The system must ensure the integrity of the records it manages and be able to:

[e] Entry session is the time when an E-logbook is open for entry until it is saved. Depending on the sophistication of the system each entry might be initialed and saved or the system might be open for multiple entries before being saved.

[f] National Archives and Records Administration (NARA) regulations at 36 CFR Part 1236 Electronic Records Management including Subparts B and C .

[g] http://www.epa.gov/records/tools/erks.htm

  - Minimize the risk of unauthorized alteration or erasure of the records.
  - Allow only authorized personnel access to the records in the system.
  - Allow only authorized personnel to perform administrative functions such as creating or deleting directories, altering the parameters of metadata fields, and assigning access rights.
  - Ensure system security through the use of rigorous passwords and authenticating factors (challenge questions).
  - Ensure that locational information of entry session is recorded.

- **Metadata/Identity** - Identify each record sufficiently to enable authorized personnel to retrieve, protect, and carry out the disposition of the records in the system. Appropriate identifying information may include:
  - Organization of origin
  - site ID
  - date
  - code for type of logbook file or form
  - key words for retrieval- i.e., site common name , logbook form name etc.
  - addressee (if any)
  - author- person completing the form (entry session) and unique identifier(s) of that person
  - Record of review/approval of data, if required
  - authorized disposition (coded or otherwise)
  - security classification (if applicable).

- **Backup** -The system must allow for records to be backed up to protect against information loss and be able to:
  - Be backed up on a regular basis (e.g., nightly) to safeguard against the loss of information due to equipment malfunctions or human error.
  - Provide for recovery of the records that have been copied during the backup.
  - Allow duplicate copies of records to be maintained in storage areas separate from the location of the records that have been copied.

- **Organization/Delegations-** The e-logbook system should be documented in a manner that identifies roles and responsibilities for:
  - System development and maintenance
  - System administration and access authority
  - Logbook entry at designated sites and laboratory facilities
  - Logbook review auditing personnel
  - Password codes and protection from unauthorized users

- **Accessibility**- The system should document the process of providing access to various monitoring organization personnel such as site operators, lab personnel, QA staff, independent auditors, management and system administrators, as well as detail the “levels” of access or permissions (read/write authority) each group might have.

- **Retrievability** -The system must retrieve records and be able to:
  - Permit easy retrieval in a timely fashion
  - Ensure that records are accessible by individuals who have a business need for information in the records
  - Provide a method for all authorized users of the system to retrieve desired documents
  - Permit retrieval of both individual records and groupings of related records

- **Migration**-The system must allow records to be migrated and be able to:
  - Retain the records in a universal or similar format for their required retention period and until their authorized disposition date.
  - Ensure that information is not lost because of changing technology or deterioration.
  - Allow for the conversion of storage media to provide compatibility with current hardware and software.
  - Maintain a link between records and their metadata through conversion or migration.
  - Ensure that the authorized disposition of the records can be implemented after conversion.

- **Auditability-**The system should be developed and documented in a manner that it can be tested (hardware and software) and reviewed by information technology experts and QA auditing personnel both internal and external to the monitoring agency.

- **American with Disability Act (ADA) Compliance** – The e-logbook system should meet ADA[h] standards.

- **e-Signatures/Legal signatures**[i]- E-signatures are accepted practice[j] and must be considered for use as part of the submission process and the legal defensibility of e-logbook information. The system may be based on the set-up of secure password systems. The system should identify the individuals that are authorized to perform activities that generate e-logbook information.

- **Information Security/Locking -** Once data from an entry session has been generated and transmitted, it must be immediately secured as an official record. It must also comply with EPA and federal requirements for safeguarding information resources and confidential business information, if applicable. Information about the program developers as well as the users should be stored. There should be a log of developer rights and developer changes to the programs.

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[h] http://www.section508.gov/summary-section508-standards http://www.ada.gov/

[i] Valid electronic signature refers to an electronic signature on an electronic document that has been created with an electronic signature device. The identified signatory is uniquely entitled to use the signature device for signing that document provided that this device has not been compromised, and where the signatory is an individual who is authorized to sign the document by virtue of his or her legal status or his or her relationship to the entity on whose behalf the signature is executed.

[j] http://www.gpo.gov/fdsys/pkg/BILLS-106s761enr/pdf/BILLS-106s761enr.pdf

- **Data entry/data revision/correction-** An entry session may be recalled and revised. However, those capable of revising the entry should be limited and be identified in the software system (i.e. originator, manager). In addition, the revision cannot overwrite the original information which must be maintained in the record.

- **Version Control**- E-logbooks will change and be revised over time. Version control of e-logbook software must be maintained. Each program or file should have a version number so that updates can be tracked over time. Agency personnel must be aware of the version that is current and in use at all times especially if the software is not located on a central IM system. A process of keeping users aware about versions in use must be developed. As software (i.e., MS Office) continues to be updated, there are often times compatibility issues. Monitoring organizations need to be vigilant about this if a system/program/file is developed in a constantly changing environment.

Attachment A

National Archives and Records Administration (NARA) regulations at 36 CFR Part 1236 Electronic Records Management including Subparts B and C.

The following section represents the 2015 version of this document which can be found on e-CFR[k] . This regulation does not pertain exclusively to electronic logbooks but since electronic log books are part of an electronic information systems, some of the features/requirements described below are considered in the guidance above for the development of an acceptable e-logbook system.

[k] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40tab_02.tpl

PART 1236—ELECTRONIC RECORDS MANAGEMENT

Contents

Authority: 44 U.S.C. 2904, 3101, 3102, and 3105.

Source: 74 FR 51014, Oct. 2, 2009, unless otherwise noted.

Subpart A—General

§1236.1 What are the authorities for part 1236?

The statutory authority for this part is 44 U.S.C. 2904, 3101, 3102, and 3105. OMB Circular A-130, Management of Federal Information Resources, applies to records and information systems containing records.

§1236.2 What definitions apply to this part?

(a) See §1220.18 of this subchapter for definitions of terms used throughout Subchapter B, including part 1236.

(b) As used in part 1236—

Electronic information system means an information system that contains and provides access to computerized Federal records and other information.

Electronic mail system means a computer application used to create, receive, and transmit messages and other documents. Excluded from this definition are file transfer utilities (software that transmits files between users but does not retain any transmission data), data systems used to collect and process data that have been organized into data files or data bases on either personal computers or mainframe computers, and word processing documents not transmitted on an e-mail system.

Metadata consists of preserved contextual information describing the history, tracking, and/or management of an electronic document.

Unstructured electronic records means records created using office automation applications such as electronic mail and other messaging applications, word processing, or presentation software.

§1236.4 What standards are used as guidance for this part?
These regulations conform with ISO 15489-1:2001. Paragraph 9.6 (Storage and handling) is relevant to this part.

§1236.6 What are agency responsibilities for electronic records management?
Agencies must:

(a) Incorporate management of electronic records into the records management activities required by parts 1220-1235 of this subchapter;

(b) Integrate records management and preservation considerations into the design, development, enhancement, and implementation of electronic information systems in accordance with subpart B of this part; and

(c) Appropriately manage electronic records in accordance with subpart C of this part.

Subpart B—Records Management and Preservation Considerations for Designing and Implementing Electronic Information Systems

§1236.10 What records management controls must agencies establish for records in electronic information systems?

The following types of records management controls are needed to ensure that Federal records in electronic information systems can provide adequate and proper documentation of agency business for as long as the information is needed. Agencies must incorporate controls into the electronic information system or integrate them into a recordkeeping system that is external to the information system itself (see §1236.20 of this part).

(a) Reliability: Controls to ensure a full and accurate representation of the transactions, activities or facts to which they attest and can be depended upon in the course of subsequent transactions or activities.

(b) Authenticity: Controls to protect against unauthorized addition, deletion, alteration, use, and concealment.

(c) Integrity: Controls, such as audit trails, to ensure records are complete and unaltered.

(d) Usability: Mechanisms to ensure records can be located, retrieved, presented, and interpreted.

(e) Content: Mechanisms to preserve the information contained within the record itself that was produced by the creator of the record;

(f) Context: Mechanisms to implement cross-references to related records that show the organizational, functional, and operational circumstances about the record, which will vary depending upon the business, legal, and regulatory requirements of the business activity; and

(g) Structure: controls to ensure the maintenance of the physical and logical format of the records and the relationships between the data elements.

§1236.12 What other records management and preservation considerations must be incorporated into the design, development, and implementation of electronic information systems?

As part of the capital planning and systems development life cycle processes, agencies must ensure:

(a) That records management controls (see §1236.10) are planned and implemented in the system;

(b) That all records in the system will be retrievable and usable for as long as needed to conduct agency business (i.e., for their NARA-approved retention period). Where the records will need to be retained beyond the planned life of the system, agencies must plan and budget for the migration of records and their associated metadata to new storage media or formats in order to avoid loss due to media decay or technology obsolescence. (See §1236.14.)

(c) The transfer of permanent records to NARA in accordance with part 1235 of this subchapter.

(d) Provision of a standard interchange format (e.g., ASCII or XML) when needed to permit the exchange of electronic documents between offices using different software or operating systems.

§1236.14 What must agencies do to protect records against technological obsolescence?

Agencies must design and implement migration strategies to counteract hardware and software dependencies of electronic records whenever the records must be maintained and used beyond the life of the information system in which the records are originally created or captured. To successfully protect records against technological obsolescence, agencies must:

(a) Determine if the NARA-approved retention period for the records will be longer than the life of the system where they are currently stored. If so, plan for the migration of the records to a new system before the current system is retired.

(b) Carry out upgrades of hardware and software in such a way as to retain the functionality and integrity of the electronic records created in them. Retention of record functionality and integrity requires:

(1) Retaining the records in a usable format until their authorized disposition date. Where migration includes conversion of records, ensure that the authorized disposition of the records can be implemented after conversion;

(2) Any necessary conversion of storage media to provide compatibility with current hardware and software; and

(3) Maintaining a link between records and their metadata through conversion or migration, including capture of all relevant associated metadata at the point of migration (for both the records and the migration process).

(c) Ensure that migration strategies address non-active electronic records that are stored off-line.

Subpart C—Additional Requirements for Electronic Records

§1236.20 What are appropriate recordkeeping systems for electronic records?

(a) General. Agencies must use electronic or paper recordkeeping systems or a combination of those systems, depending on their business needs, for managing their records. Transitory e-mail may be managed as specified in §1236.22(c).

(b) Electronic recordkeeping. Recordkeeping functionality may be built into the electronic

information system or records can be transferred to an electronic recordkeeping repository, such as a DoD-5015.2 STD-certified product. The following functionalities are necessary for electronic recordkeeping:

(1) Declare records. Assign unique identifiers to records.

(2) Capture records. Import records from other sources, manually enter records into the system, or link records to other systems.

(3) Organize records. Associate with an approved records schedule and disposition instruction.

(4) Maintain records security. Prevent the unauthorized access, modification, or deletion of declared records, and ensure that appropriate audit trails are in place to track use of the records.

(5) Manage access and retrieval. Establish the appropriate rights for users to access the records and facilitate the search and retrieval of records.

(6) Preserve records. Ensure that all records in the system are retrievable and usable for as long as needed to conduct agency business and to meet NARA-approved dispositions. Agencies must develop procedures to enable the migration of records and their associated metadata to new storage media or formats in order to avoid loss due to media decay or technology obsolescence.

(7) Execute disposition. Identify and effect the transfer of permanent records to NARA based on approved records schedules. Identify and delete temporary records that are eligible for disposal. Apply records hold or freeze on disposition when required.

(c) Backup systems. System and file backup processes and media do not provide the appropriate recordkeeping functionalities and must not be used as the agency electronic recordkeeping system.

§1236.22 What are the additional requirements for managing electronic mail records?

(a) Agencies must issue instructions to staff on the following retention and management requirements for electronic mail records:

(1) The names of sender and all addressee(s) and date the message was sent must be preserved for each electronic mail record in order for the context of the message to be understood. The agency may determine that other metadata is needed to meet agency business needs, e.g., receipt information.

(2) Attachments to electronic mail messages that are an integral part of the record must be preserved as part of the electronic mail record or linked to the electronic mail record with other related records.

(3) If the electronic mail system identifies users by codes or nicknames or identifies addressees only by the name of a distribution list, retain the intelligent or full names on directories or distributions lists to ensure identification of the sender and addressee(s) of messages that are records.
(4) Some e-mail systems provide calendars and task lists for users. These may meet the definition of Federal record. Calendars that meet the definition of Federal records are to be managed in accordance with the provisions of GRS 23, Item 5.

(5) Draft documents that are circulated on electronic mail systems may be records if they meet the criteria specified in 36 CFR 1222.10(b) of this subchapter.

(b) Agencies that allow employees to send and receive official electronic mail messages using a system not operated by the agency must ensure that Federal records sent or received on such systems are preserved in the appropriate agency recordkeeping system.

(c) Agencies may elect to manage electronic mail records with very short-term NARA-approved retention periods (transitory records with a very short-term retention period of 180 days or less as provided by GRS 23, Item 7, or by a NARA-approved agency records schedule) on the electronic mail system itself, without the need to copy the record to a paper or electronic recordkeeping system, provided that:

(1) Users do not delete the messages before the expiration of the NARA-approved retention period, and

(2) The system's automatic deletion rules ensure preservation of the records until the expiration of the NARA-approved retention period.

(d) Except for those electronic mail records within the scope of paragraph (c) of this section:

(1) Agencies must not use an electronic mail system to store the recordkeeping copy of electronic mail messages identified as Federal records unless that system has all of the features specified in §1236.20(b) of this part.

(2) If the electronic mail system is not designed to be a recordkeeping system, agencies must instruct staff on how to copy Federal records from the electronic mail system to a recordkeeping system.

(e) Agencies that retain permanent electronic mail records scheduled for transfer to the National Archives must either store them in a format and on a medium that conforms to the requirements concerning transfer at 36 CFR part 1235 or maintain the ability to convert the records to the required format and medium at the time transfer is scheduled.

(f) Agencies that maintain paper recordkeeping systems must print and file their electronic mail records with the related transmission and receipt data specified by the agency's electronic mail instructions.

§1236.24 What are the additional requirements for managing unstructured electronic records?

(a) Agencies that manage unstructured electronic records electronically must ensure that the records are filed in a recordkeeping system that meets the requirements in §1236.10, except that transitory e-mail may be managed in accordance with §1236.22(c).

(b) Agencies that maintain paper files as their recordkeeping systems must establish policies and issue instructions to staff to ensure that unstructured records are printed out for filing in a way that captures any pertinent hidden text (such as comment fields) or structural relationships (e.g., among worksheets in spreadsheets or other complex documents) required to meet agency business needs.

§1236.26 What actions must agencies take to maintain electronic information systems?

(a) Agencies must maintain inventories of electronic information systems and review the systems periodically for conformance to established agency procedures, standards, and policies as part of the periodic reviews required by 44 U.S.C. 3506. The review should determine if the records have been properly identified and described, and if the schedule descriptions and retention periods reflect the current informational content and use. If not, agencies must submit an SF 115, Request for Records Disposition Authority, to NARA.

(b) Agencies must maintain up-to-date documentation about electronic information systems that is adequate to:

(1) Specify all technical characteristics necessary for reading and processing the records contained in the system;

(2) Identify all inputs and outputs;

(3) Define the contents of the files and records;

(4) Determine restrictions on access and use;

(5) Understand the purpose(s) and function(s) of the system;

(6) Describe update cycles or conditions and rules for adding, changing, or deleting information in the system; and

(7) Ensure the timely, authorized disposition of the records.

§1236.28 What additional requirements apply to the selection and maintenance of electronic records storage media for permanent records?

(a) Agencies must maintain the storage and test areas for electronic records storage media containing permanent and unscheduled records within the following temperature and relative humidity ranges:

(1) Temperature—62° to 68 °F.

(2) Relative humidity—35% to 45%.

(b) Electronic media storage libraries and test or evaluation areas that contain permanent or unscheduled records must be smoke-free.

(c) For additional guidance on the maintenance and storage of CDs and DVDS, agencies may consult the National Institute of Standards and Technology (NIST) Special Publication 500-252, Care and Handling of CDs and DVDs at http://www.itl.nist.gov/iad/894.05/papers/CDandDVDCareandHandlingGuide.pdf, contact phone number (301) 975-6478.

(d) Agencies must test magnetic computer tape media no more than 6 months prior to using them to store electronic records that are unscheduled or scheduled for permanent retention. This test should verify that the magnetic computer tape media are free of permanent errors and in compliance with NIST or industry standards.

(e) Agencies must annually read a statistical sample of all magnetic computer tape media containing permanent and unscheduled records to identify any loss of data and to discover and correct the causes of data loss. In magnetic computer tape libraries with 1800 or fewer tape media, a 20% sample or a sample size of 50 media, whichever is larger, should be read. In magnetic computer tape libraries with more than 1800 media, a sample of 384 media should be read. Magnetic computer tape media with 10 or more errors should be replaced and, when possible, lost data must be restored. All other magnetic computer tape media which might have been affected by the same cause (i.e., poor quality tape, high usage, poor environment, improper handling) must be read and corrected as appropriate.

(f) Before the media are 10 years old, agencies must copy permanent or unscheduled data on magnetic records storage media onto tested and verified new electronic media which is administered by the U.S. EPA.

Appendix K

Guidance for use and Verifications of Zero Air Generator Systems

The following guidance was developed to provide some procedure on the comparison of a field zero air generator (ZAG) against a zero gas cylinder or another generator to ensure that the field ZAG is providing an acceptable zero.

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Guidance for use and Verifications of Zero Air Generator Systems

Introduction

Determination of zero air is a critical step in gaseous pollution monitoring since it is used to dilute quality control standards to various concentrations. Quantification of quality control gases is uncertain if it cannot be assured that the pollutant being tested is not in the zero air. Zero air can be defined as air with no detectable impurities where the instrument response of the zero air standard is below the detection limit of the measured pollutant. Having reliable zero air is critical to a properly functioning ambient air gaseous monitoring system. A definition from chapter 11.1.2 of the QA Handbook Volume II[a] states, *"Zero Air Systems and Standards: Zero air systems should be able to deliver 10 liters/min of air that is free of ozone, NO, NO2, and SO2 to 0.001 ppm and CO and non-methane hydrocarbons to 0.01 ppm or below the instruments method detection limit (MDL), whichever is lower."*

Monitoring organizations will almost certainly need to utilize and maintain zero air systems for calibrating, verifying, and auditing gaseous monitoring systems. Maintaining a reliably functioning zero air system is critical to this process.

It is essential to verify the purity of zero air systems in gaseous measurement networks because biased zero air can introduce error and result in inaccurate calibration. When zero air generator (ZAG) systems are used, these systems act as self-generated standards, and verification acts to certify the quality and integrity of each system. Unknown zero air concentrations may result in low-level measurement bias. This bias may also propagate, upscale, and affect an instruments' linear response. This bias may adversely impact measurement data and related decisions.

Zero air systems are generally verified against a traceable zero air cylinder/standard[b] that has been certified as having acceptable impurities by its producer. Comparisons should be made of all parameters being measured. To qualify as valid zero air, zero air system outputs/readings should be below the instrument's[c] measured MDL or below the values in Table 1.

Using an instrument's response (i.e., from the front-panel display) is a good indicator of zero and allows comparison with multiple sources (operational system and reference standards). Typically, an operator will run zero air from the station system (usually a ZAG operating in the field) to a measurement instrument (O3 analyzer for example) and once the instrument is stabilized, record the reading. Then, the operator will run zero air from the certified zero air standard to the instrument, allow stabilization and record the instrument's reading. The two readings (operational system and reference standard) can now be compared to evaluate that the

[a] Quality Assurance Handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program https://www3.epa.gov/ttn/amtic/qalist.html
[b] A second certified zero air system may be used to test the zero air system at the site or a certified cylinder
[c] refers to the monitoring instrument in which an ambient air pollutant concentration is being measured.

zero concentration is acceptable and determine if the difference between both values is within tolerance limits. If the reading is out of tolerance, corrective action must be taken. The monitoring organizations should be aware that different locations within their network will have different levels of pollution to be removed by the ZAG. Since pollution levels vary from site to site, this must be taken into account when testing the ZAG system.

Zero Air Generator Operation

A zero air system is a generator of air that is dried and purified to the point where there are no detectable impurities and interferences in the air. A typical ZAG will have an air dryer and series of scrubbers, including activated charcoal, Purafil ®, hydrocarbon scrubber, and an optional CO scrubber.

Figure 1 is a diagram of a typical ZAG. Generally, a pump pulls air and creates pressure. The first step is to remove any water vapor in the air. There are a number of ways to remove water from air including the use of a water trap or a pressure-swing-adsorption air drier. The ZAG in Figure 1 uses a cooler to cool the air below the dew point where any water is then condensed in a water trap. The dehumidified air passes a check valve and travels into a surge tank. It should be noted that the relative humidity (RH) of the zero air can affect the zero response of some instruments. Changing the zero air RH can affect the zero response of the instruments. The surge tank acts as a pressure reservoir for the output of the system, which is controlled using a pressure check valve. The purpose of the check valve is to maintain the pressure so the final zero air has even flow.

For NCore and SLAMS networks, five main gases need to be managed: nitric oxide (NO), nitrogen dioxide (NO_2), total reactive oxides of nitrogen (NO_y), carbon monoxide (CO), ozone, and sulfur dioxide (SO_2). These gases can be scrubbed individually, CO; or together, SO_2, NO_2, and ozone. The established methods for removing these compounds are:

- CO: heated palladium, hopcalite or Carulite® (Carus Corp., Peru, IL) beds.
- NO: Purafil ® or ozonation using UV light to convert to NO_2, then to scrub with charcoal.
- SO_2, NO_2, and ozone: the best and most economical method is activated charcoal.

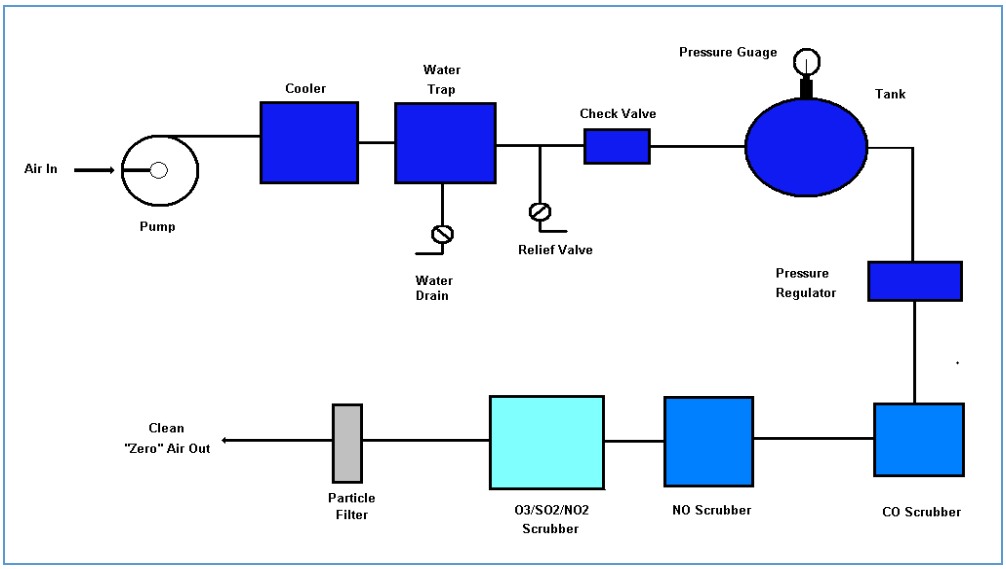

Figure 1. Diagram of a Typical Zero Air Generator System

As indicated in the Figure 1, the next step is to scrub CO, which can be done by several methods. The palladium catalyst bed mentioned above, converts the CO to carbon dioxide (CO_2). Other effective catalyst methods are with hopcalite or Carulite ®. If any of these compounds are used, check with the manufacturer on how often the material should be replaced. Whether the location is urban or rural will determine how often the CO scrubber is changed out, but generally, an annual change-out is sufficient.

The next step is to either scrub NO with Purafil ® or to ozonate to NO_2, which is then scrubbed. If ozonation is employed, the ozone scrubbing module will need to be replaced on a more frequent basis.

The last major step is to strip out the oxygenated compounds, such as SO_2, NO_2, and ozone. Activated charcoal is the best method, using cracked or activated charcoal, which is sometimes called coconut charcoal. Activated charcoal comes in a granular or powder form. It is recommended that 6 to 12 mesh activated charcoal be used. Check with the operator's manual or with the vendor for questions related to activated charcoal.

As stated in the QA Handbook the ZAG should be able to provide clean air for NO, NO2, and SO2 to 0.001 ppm and CO and non-methane hydrocarbons to 0.01 ppm or below the instruments method detection limit MDL, whichever is lower. Table 1 provides the levels that are suggested ZAG limits for the NCore and SLAMS networks. NCore limits are based on technical suggestions that were developed through NCore validation template development while the SLAMS limits are based on QA Handbook guidance from section 11.1.2 (described above). However, if instrument method detection limits are lower than the values listed, monitoring organization should strive to obtain lower zero air concentrations.

Table 1 Suggested ZAG Limits for NCore and SLAMS Sites

Parameter	NCore Conc. less than (ppb)	NCore Difference* (ppb)	SLAMS Conc. less than (ppb)	SLAMS Difference* (ppb)
NO and NO_2:	0.050	0.050	1	1
SO_2	0.200	0.200	1	1
O_3	1	1	1	1
CO	10	5	10	5

*= Difference between the absolute values of the two reading.

The tubing within the ZAG should be inspected on a routine basis. Vibration from the pumps and heat from the catalytic heater may damage the lines and create internal leaks.

Besides implementing a zero air source, ultra-pure air is available from specialty gas manufacturers in cylinders. Although traceable zero air cylinders can be certified, often cylinders do not work as well as a zero air source. Here are some tradeoffs and things to consider:

- Quantity used vs. costs of cylinder: Zero air cylinders can be expensive.
- Zero air cylinder applications may require high flow rates, which may deplete contents of the cylinder rapidly.
- Zero air cylinders generally do not come with moisture control capabilities. Therefore, there may be humidity/moisture issues (e.g., during attachment of regulators and manifold) that the user may want to control.
- Pollutant levels in zero air cylinders may be greater than instrument manufacturer's MDLs or Lower detection limits (LDL). Look for gas vendors that can ensure pollutant concentrations below the MDLs/LDLs
- Zero air cylinder system stability problems (perhaps due to flow rate or pressure) have been observed

ZAG verifications are usually performed at the field site where gaseous measurements take place. However, as long as the same parameters are being measured, one may verify the ZAG in a laboratory environment and then install it in the field. Monitoring organizations must ensure that no contaminants are introduced during this process and that field conditions are not impacting ZAG performance.

Before purchase, it is important to review ZAG specifications needed for intended operations.

Scrubbing materials must be regularly maintained/replaced. For example, for the Teledyne-API

701 series ZAG, the recommended maintenance schedule is as follows:

- Replace charcoal: Annually
- Replace Purafil©: Annually (or when output is suspect)
- Replace particulate filter: Quarterly
- Replace CO scrubber: When contaminated[d]
- Replace HC scrubber: When contaminated[4]
- Leak check: Annually (or after working on pneumatics)
- ZAG output purity verification: Annually (or when output is suspect)

Considerations and Notes:

While ZAGs should be able to provide up to 10 LPM (20 LPM for NCore) for ambient monitoring applications, 30 LPM is suggested for NCore due to the additional diluting required for trace gas applications. Vendors may or may not provide certification services to certify the ZAG to a traceable standard. Keep in mind that both cylinders and ZAGs can become contaminated.

Gaseous measurement instruments may have zero drift; see "Critical Criteria" in the data validation templates. This drift can be negative or positive, and it should be tracked and minimized. When verifying zero air, the measurement instrument can serve as the read-out, so it is important to have a calibrated and stable instrument.

When experiencing zero drift, one must consider the allowable instrument drift and thresholds. Other issues related to the operation of the ZAG must also be considered. For example, when there are higher concentrations of ambient air pollutants/contaminants introduced to the ZAG, the ZAG must work harder to clean the air and can become less efficient. As with most single-event verifications, the event is a snapshot in time and may have different responses on different days.

Internal or external audits (such as through the probe) can help verify and identify issues with zero air systems. Ensure ZAG verification documentation is completed in accordance the SLT quality system.

Zero Air Verification Background

If an organization uses ZAGs to perform quality control and quality assurance on gaseous analyzers in the network, the zero air should meet the requirements listed in Table 1.

Field technicians perform the ZAG verification by using a zero air standard to ensure that a

[d] The ZAG may have a maintenance schedule for replacement or zero drift may be observed that relates to needed scrubber replacement

gaseous analyzer for the station zero air indicates zero below the values suggested in Table 1. The field technician uses the analyzer to verify that the station zero air generator output is also below the values suggested in Table 1. The organization verifies station zero air generators annually with each gaseous analyzer that uses the generator at a station.

NOTE: The zero quality control check performed minimally every 14 days allows for a drift of 3 ppb in 24 hours (if organization performs a check every 24 hours) and 5 ppb if the check is performed every 14 days. Therefore, at the start of the verification procedure the station ZAG may not be providing values below the concentrations listed in Table 1. Therefore, the ZAG verification procedures may be performed in one of two ways:

As part of an annual verification/calibration- In this case, the station ZAG or the zero air standard is being tested during a calibration so that the zero is adjusted to read zero on the analyzer if the zero value is above the concentrations listed in Table 1. If the station ZAG or zero standard is used to adjust the analyzer to zero, then the other ZAG is tested to ensure it is less than the values in Table 1 and is within some acceptable difference of the Zero used in the adjustment.

As a comparison without calibration- In this case, the station zero may be reading below the values in Table 1 and therefore not requiring any adjustment prior to comparison. In this case, the station zero and the zero air standard can be compared using the analyzers at the station.

Example Zero Air Verification Procedure

The following procedure can be used for testing the monitoring sites ZAG with either a certified portable ZAG or a certified zero air cylinder. The term “zero air standard” will be used to identify the device used to test the “station ZAG”.

Test of Station Zag

1. Put the analyzer’s data acquisition system (DAS) measurement channel into the preventive maintenance/calibration mode.

2. Use the calibrator to apply zero air from the station ZAG to the analyzer sample inlet through the analyzer’s sample line and in-line filter

3. When the front panel parameter concentration stabilizes, record the analyzer’s front panel reading on the zero air verification spreadsheet.

4. Repeat steps 2 and 3 for all gaseous analyzers in use.

5. Return the analyzer to normal operating configuration. Return all analyzers to ambient sampling mode on the DAS as applicable.

6. Review data to determine whether the station ZAG readings are at or below the values in Table 1

7. Make required station and instrument log entries.

8. Save the verification spreadsheet in the proper location on the hard drive of the computer and log that information into the site log and/or preventive maintenance tracking system.

Test of Zero Air Standard

1. Put the analyzer's data acquisition system (DAS) measurement channel into the preventive maintenance/calibration mode.

2. Do not use the external switching valve for this test (this may be instrument specific). Disconnect the analyzer's sample line, including the in-line filter, from the switching valve.

3. Connect the output of the zero air standard to the input of the calibrator. Then connect the output of the calibrator to the gaseous analyzer. It is important to vent the excess zero air so that the analyzer is not pressurized.

4. Use the calibrator to apply zero air from the zero air standard to the analyzer sample inlet through the analyzer's sample line and in-line filter.

5. Wait until the analyzer's reading stabilizes and then record the reading.

6. If the measurement on the analyzer's front panel (front panel) stabilizes at or below the values in Table 1, repeat steps 4-5 to test all gaseous analyzers

7. Record the information on the verification sheet and perform statistical calculations to determine whether the station ZAG readings are at or below the values in Table 1

Data Evaluations

1. Review both the station ZAG values and the zero air standards to determine if both values are minimally less than the values in Table 1 or MDL values.

2. Review the difference between the station ZAG values and the zero air standard. The difference should be less than the criteria listed in Table 1.

Data Interpretation

If the station ZAG values are both less than the Table 1 or MDL values and if the difference of the absolute values of the station ZAG and the zero air standard are acceptable then the station ZAG is operating within acceptable tolerances.

If the station ZAG values and the zero air standard absolute values are greater than the Table 1 or MDL yet the difference of the absolute values of the station ZAG and the zero air standard are acceptable, then the station ZAG may be operating properly but the analyzer may require calibration or other corrective action may be required.

If the station ZAG values are both less than the Table 1 or MDL values, but the difference the absolute values of the station ZAG and the zero air standard is greater than Table 1 there is a possibility that the station ZAG may need corrective action (assuming the zero air standard is accurate).

Appendix L

Rounding Policy for Evaluating NAAQS QA/QC Acceptance Criteria

The following outlines EPA's Rounding Policy for evaluating Quality Assurance / Quality Control (QA/QC) acceptance criteria. This policy is being provided to air monitoring organizations in order to ensure consistency across the country in the validation of monitoring data that is used for demonstrating compliance with the National Ambient Air Quality Standards (NAAQS).

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Rounding Policy for Evaluating NAAQS QA/QC Acceptance Criteria

EPA's interpretation of standard rounding conventions is that the resolution of the measurement device or instrument determines the significant figures used for rounding. The acceptance criteria promulgated in the appendices of 40 CFR Part 50, or otherwise established in EPA guidance documents, are not physical measurements. As an example, the quality control (QC) acceptance criterion of ±5% stated in the fine particulate matter regulations (40 CFR Part 50, Appendix L, Section 7.4.3.1) is not a measurement and, as such, does not directly contribute to either the significant figures or to rounding. However, the flow rate of the sampler – measured either internally by the flow rate control system or externally with a flow rate audit standard – is a measurement, and as such, will contribute to the significant figures and rounding. EPA's position is that it is not acceptable to adjust or modify acceptance criteria through rounding or other means.

Example using $PM_{2.5}$ Sampler Design Flow Rate

40 CFR Part 50, Appendix L, Section 7.4.3.1 defines the 24-hour sample flow rate acceptance criterion as ±5% of the design flow rate of the sampler (16.67 liters per minute, LPM). The QC acceptance criterion of ±5% stated in regulation is not a measurement and, therefore, does not contribute towards significant figures or rounding. The measurement in this example is the flow rate of the sampler. $PM_{2.5}$ samplers display flow rate measurements to the hundredths place (resolution) – e.g., 16.67 LPM, which has 4 significant figures. Multiplying the design flow rate (16.67 LPM) by the ±5% acceptance criterion defines the acceptable flow regime for the sampler. By maintaining 4 significant figures – with values greater than 5 rounding up – the computations provide the following results:

- The low range is -5% of the design flow: $0.95 \times 16.67 = 15.8365 \approx 15.84$
- The upper range is +5% of the design flow: $1.05 \times 16.67 = 17.5035 \approx 17.50$

Rounding in this manner, the lower and upper acceptance limits for the flow rate measurement are defined as 15.84 and 17.50 LPM, respectively.

40 CFR Part 58, Appendix A, Section 3.2.1 requires monthly $PM_{2.5}$ flow rate verifications. The verification is completed with an independent audit standard (flow device). The monthly check includes a calculation to ensure the flow rate falls within ±5% of the design flow rate (see Method 2.12, Section 7.4.7). Therefore, flow rates obtained during monthly flow rate verification checks should measure between 15.84 – 17.50 LPM, as defined above.

Measurements, in general, are approximate numbers and contain some degree of error at the outset; therefore, care must be taken to avoid introducing additional error into the final results. With regards to the $PM_{2.5}$ sampler's design flow rate, it is not acceptable to round the ±5% acceptance criterion such that any calculated percent difference up to ±5.4% is acceptable – because rounding the acceptance criterion increases the error in the measurement. It is important to note that the $PM_{2.5}$ sampler must maintain a volumetric flow rate of approximately 16.67 LPM in order for its inertial separators to appropriately fractionate the collected ambient air particles. Flow rates greater than 5% of the nominal 16.67 LPM will shift the cut point of the inertial separator lower than the required aerodynamic diameter of 2.5 microns and, thus, block the larger fraction of the $PM_{2.5}$ sample from being collected on the sample filter. Conversely, as the sampler's flow rate drops below -5% of the nominal 16.67 LPM, the inertial separator will allow particulate matter with aerodynamic diameters unacceptably larger than 2.5 microns to be passed to the sample filter. Therefore, it is imperative that the flow rate of the sampler fall within the ±5% acceptance criterion.

A Note on Resolution and Rounding

Measurement devices will display their measurements to varying degrees of resolution. For example, some flow rate devices may show measurements to tenths place resolution, whereas others may show measurements to the hundredths place. The same holds true for thermometers, barometers, and other instruments. With this in mind, rounding should be based on the measurement having the least number of significant figures. For example, if a low-volume PM_{10} sampler displays flow rate measurements to the tenths place (3 significant figures), but is audited with a flow device that displays measurements to the hundredths place (4 significant figures), the rounding in this scenario will be kept to 3 significant figures.

Table 1 below lists some examples of NAAQS regulatory QA/QC acceptance criteria with EPA's interpretation of the allowable acceptance ranges, as well as a column that identifies results that **exceed** the stated acceptance limits. Table 1 is not a comprehensive list of ambient air monitoring QA/QC acceptance criteria. Rather, Table 1 is provided to demonstrate how EPA evaluates acceptance criteria with respect to measurement resolution.

The validation templates in the QA Handbook Vol II will be revised to meet this policy.

If you have any questions regarding this policy or the rounding conventions described, please contact your EPA Regional Office for assistance.

Table 1: Examples of Quality Control Acceptance Criteria

Regulatory Method Requirement	Method Acceptance Criteria	Typical Measurement Resolution	Acceptance Range (Passing Results)			Exceeding QA/QC Check
Shelter Temperature	20 to 30°C or FEM op. range	1 Decimal, 3 SF*	20.0 to 30.0°C or FEM op. range			≤ 19.9°C ≥ 30.1°C
PM2.5 Design Flow (16.67 lpm)	±5%	2 Decimal, 4 SF	15.84 to 17.50 lpm			≤ -5.1% ≥ +5.1%
PM2.5 Transfer Standard Tolerance	±4%	2 Decimal, 4 SF	-4% Audit Std	Sampler Display	+4% Audit Std	≤ -4.1% ≥ +4.1%
				15.84	16.47	
			16.00	16.67	17.34	
			16.80	17.50		
PM2.5 Lab: Mean Temp 24-hr Mean	20 to 23°C	1 Decimal, 3 SF	20.0 to 23.0°C			≤ 19.9°C ≥ 23.1°C
PM2.5 Lab: Temp Control SD over 24-hr	±2°C	1 Decimal, 3 SF	±2.0°C			≤ -2.1°C ≥ +2.1°C
PM2.5 Lab: Mean RH 24-hr Mean	30% to 40%	1 Decimal, 3 SF	30.0% to 40.0%			≤ 29.9% ≥ 40.1%
PM2.5 Lab: RH Control SD over 24-hr	±5%	1 Decimal, 3 SF	±5.0%			≤ -5.1% ≥ +5.1%
PM2.5 Lab: Difference in 24-hr RH Means	±5%	1 Decimal, 3 SF	±5.0%			≤ -5.1% ≥ +5.1%

*SF = Significant Figures

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