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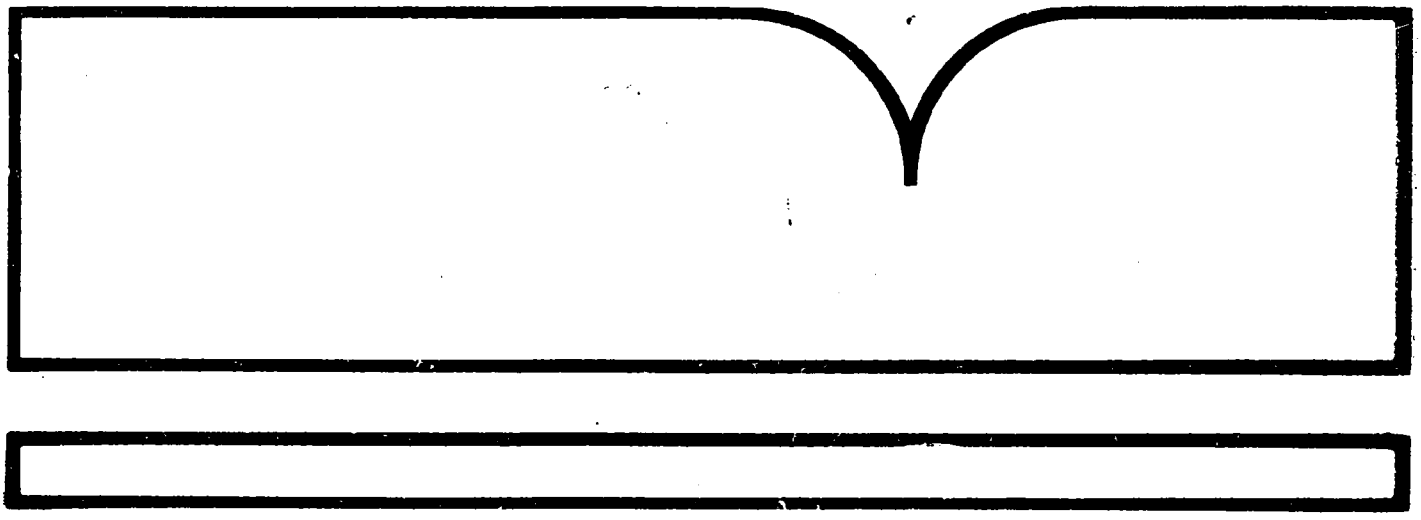
(U.S.) Environmental Monitoring Systems Lab.
Research Triangle Park, NC

Jun 83



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GUIDELINE ON THE MEANING AND USE OF PRECISION AND ACCURACY DATA REQUIRED BY 40 CFR PART 58, APPENDICES A AND B

by

Raymond C. Rhodes
Quality Assurance Division
Environmental Monitoring Systems Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL MONITORING SYSTEMS LABORATORY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate potential environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina, has the responsibility for: assessment of environmental monitoring technology and systems; implementation of agency-wide quality assurance programs for air pollution measurement systems; and supplying technical support to other groups in the Agency including the Office of Air, Noise and Radiation, the Office of Pesticides and Toxic Substances and the Office of Enforcement Counsel.

Knowledge of the quality of air pollution measurements from the national monitoring networks is important in determinating air quality trends, assessing compliance to air quality standards, and developing control strategies. Federal regulations for ambient air quality surveillance were revised May 10, 1979 to require the states to develop and conduct quality assurance programs approved by the EPA Regional Offices. In addition, the states are required to submit to EPA the results of specific tests and comparisons to assess the precision and accuracy of their measurement systems. This document is intended to help states and local agencies achieve the maximum benefits from the new requirements.

Thomas R. Hauser, Ph.D.
Director
Environmental Monitoring Systems Laboratory
Research Triangle Park, North Carolina

ABSTRACT

Federal regulations for ambient air quality surveillance were revised May 10, 1979, to include requirements that states perform certain specified tests to assess the precision and accuracy of their air pollution measurement systems and to report the results to EPA routinely.

This report discusses the concepts and definitions of precision and accuracy as they relate to ambient air pollution measurement systems. The rationale used in developing the specified procedures for acquiring precision and accuracy assessments is explained for both manual and automated measurement methods. The computational procedures specified for the handling of the precision and accuracy data and the development of the statistical assessments to be reported to EPA are reviewed.

Particular emphasis is given to the potential use of the precision and accuracy data by the states and local agencies as an adjunct to their routine quality assurance programs. A number of statistical quality control charts are recommended for routine use by the states and local agencies.

Finally, answers are provided for many questions concerning interpretation of the requirements of the regulation and procedures for handling special case situations not specifically detailed in the regulations.

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APPENDIX B: QUALITY ASSURANCE REQUIREMENTS FOR PREVENTION OF SIGNIFICANT DETERIORATION (PSD) AIR MONITORING

1. GENERAL BACKGROUND

1.1 Need for Mandatory Quality Assurance (QA)

Prior to the May 10, 1979 promulgation of the Regulations set forth in 40 CFR Part 58, (44 FR 27558-27604), the quality assurance and quality control practices of State and local agencies were strictly voluntary, although many forms of guidance and assistance had been provided by the EPA Regional Offices and the Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina (EMSL/RTP). Consequently, there was a wide diversity among the State and local agencies in the scope and effectiveness of their QA program. As described below, numerous indications pointed to the need for more extensive and more uniform QA programs of the state and local agencies.

1.2 Need for Quality Data

Many important EPA decisions are based on the nationwide monitoring data obtained by the State and local agencies. Data collected and reported to the National Aerometric Data Bank (NADB) in Durham, North Carolina are used by EPA to aid in planning the Nation's air pollution control strategy and to measure achievement toward meeting national air quality standards. In addition, the data are used locally for determining attainment of the standards. Further, the data in the NADB are made available to numerous requestors, who may use the data for various research projects, special studies, or other purposes.

Unfortunately, none of the data in the NADB prior to January 1, 1981 is accompanied by estimates of its quality. Although the capability (accuracy and precision) of the EPA-developed measurement methods have been determined in interlaboratory collaborative studies, those levels of method precision and accuracy are seldom achieved in the real world of day-to-day routine monitoring. To assure the most knowledgeable use of the data, the quality of the national monitoring data should be determined and made known to all data users.

Further, many of the monitoring methods used in the past by State and local agencies were not reference, equivalent, or approved methods, so designated by EPA after careful and thorough evaluation. Because of the likelihood of different methods producing differing results, all national monitoring should be performed using reference, equivalent, or approved methods.

1.3 Regulation of May 10, 1979

The ambient air monitoring regulations, as revised on May 10, 1979, contain a new Part 58 (1) that includes various requirements for the technical improvement of the national monitoring. Some of the new requirements are the specification of:

- Monitoring methods;
- Instrument siting and probe location;
- Scheduling of monitoring;
- Network design;
- Air quality reporting.

Part 58 contains several appendices, two of which specify requirements for quality assurance (QA) and data quality assessment:

1. Appendix A. Quality Assurance Requirements for State and Local Monitoring Stations (SLAMS);
2. Appendix B. Quality Assurance Requirements for Prevention of Significant Deterioration (PSD) Air Monitoring.

The QA requirements of these appendices involve two separate areas:

1. Documentation of each agency's Quality Control Program.
2. Assessment and reporting of the quality of each agency's air monitoring data.

Documentation of each agency's Quality Control Program is to cover, as a minimum, the following:

1. Selection of methods, analyzers, or samplers;
2. Installation of equipment;
3. Calibration;
4. Zero/span checks and adjustments of automated analyzers;
5. Control checks and their frequency;
6. Control limits for zero, span, and other control checks, and respective corrective actions when such limits are surpassed;
7. Calibration and zero/span checks for multiple range analyzers;
8. Preventive and remedial maintenance;
9. Quality control procedures for air pollution episode monitoring;
10. Recording and validation of data; and
11. Documentation of quality control information.

For the data quality assessment, specific procedures are delineated using special quantitative checks, to determine the precision and accuracy of each of the automated and manual methods used to measure the criteria pollutants.

These latter procedures were developed to measure the precision and accuracy under operating conditions as nearly typical as possible. Furthermore, the precision and accuracy (P and A) data are required to be reported to EPA for several important reasons. First, the P and A data are appropriately filed by EPA so that users of the routine monitoring data filed in the National Aerometric Data Bank (NADB) receive the corresponding P and A data for the particular network(s) and the particular time periods

involved. Second, the P and A data are evaluated from Regional and National standpoints to identify (a) regions, states, or local agencies that require improvement in their data quality (i.e., improvement in their QA system) and (b) pollutant measurement methods that may need remedial changes in the methodology to improve the precision and/or accuracy of the methods in the real monitoring world.

In addition to the above documentation and assessment requirements, the regulations require the following:

1. All criteria pollutant measurement calibration standards and flow measurement calibration standards must be traceable to National Bureau of Standards (NBS) Standard Reference Materials (SRM) or other primary standards;

2. All agencies must participate in National EPA performance audits and must permit EPA system audits of their monitoring and QA procedures.

3. All methods used for measurements of criteria air pollutants in SLAMS must be reference, equivalent, or approved methods.

A recent amendment to 40 CFR Part 58, promulgated on September 3, 1981 (46 FR 44159-44172) (2), makes the requirements for assessing precision and accuracy applicable to monitoring for lead (Pb) and includes several corrections to the 40 CFR Part 58 regulations. A separate EPA guideline document has been issued concerning the monitoring for Pb in the vicinity of point sources (3).

1.4 Measures of Data Quality

The quality of monitoring data can be expressed in terms of representativeness, comparability, completeness, precision and accuracy.

Aspects of representativeness have been strongly considered in the portions of Part 58 which deal with network design, siting, and probe location--factors that relate to the representativeness of the samples. The extent to which the samples represent the ideal locations, conditions,

and times of sampling are measures of representativeness, and have meaning with respect to the objective or purpose of the monitoring.

Comparability of data obtained across the entire Nation is achieved, to a large extent, by the use of the standardized (designated) sampling and analysis methods specified by the regulations, along with consistency in reporting units.

Completeness of data sets is an important concern in monitoring because of the adverse effects of gaps or "holes" in the data base. The statistical validity of sets of monitoring data is a direct function of the extent and pattern of missing data. Although the completeness of a given data set is a major concern to the data user, and its importance is emphasized in the regulation, the regulation does not require any special reporting with respect to data completeness. The number of individual data values reported to the NADB for each monitoring site can be determined and are reported with data for specific sites.

The measures of data quality which are required to be obtained and reported by the States and local agencies beginning January 1, 1981, are those for precision and accuracy. When one speaks of precision and accuracy of measurment data, one really means the precision and accuracy of the measurement process from which the measurement data are obtained. Precision is a measure of the "repeatability of the measurement process under specified conditions." Accuracy is a measure of "closeness to the truth." The definitions and concepts of precision and accuracy as they relate to the requirements of Appendices A and B of the regulation are discussed further in the next section.

1.5 Precision and Accuracy

As defined above, the accuracy of a measurement is its "closeness to the truth." Deviations from the truth result from both random errors and systematic errors. Precision, the repeatability of a measurement process, is associated with the random errors. The average inaccuracy, or bias, of a measurement process over some period of time or set of conditions is associated with the systematic error. Deviation that appears to be constant, or systematic, under one set of conditions may actually be random

under a set of conditions of wider scope. For example, the systematic error of a given instrument is associated with average accuracy for that instrument over some specified period of time. However, the variability of average inaccuracies from a number of instruments in a network may appear to be random and can, therefore, be associated with the "precision" for the network.*

1.5.1 Precision - Precision is used in 40 CFR Part 58, Appendices A and B, in the sense of "repeatability of measurement values under specified conditions." Since specified conditions may vary considerably, there are many levels of repeatability or precision. For example, with an automated continuous air pollution sensor, the random fluctuations in response over a short time, e.g., within a minute, when an instrument is measuring a gas of constant pollutant concentration is a very "local" measurement of precision. Another measure of repeatability would be the variability of span measurements made each day on an instrument over some longer period of time. The measure of precision (repeatability) used in 40 CFR Part 58, Appendices A and B, for automated methods is the variability of one-point precision checks made at biweekly intervals on the same instrument (Instrument Precision). Agency* precision, however, is the average repeatability of all the instruments of the agency during the calendar quarter. A given precision check may be considered as representative of an hourly average value that would have been obtained from the instrument if the air pollution concentration remained at the same level as that for the precision check.

*Throughout this guideline, agency or network is used in a general sense corresponding to the definition of a "reporting organization" as defined in Section 3 of Appendix A, 40 CFR Part 58, and as discussed in Section 1.6 of this guideline. A reporting organization may consist of one or more governmental air pollution agencies (networks), or in some special cases there may be more than one reporting organization in the same governmental air pollution agency (network).

Because the lack of precision from hour to hour is generally proportional to concentration, it may be further assumed without much error that the same percentage variation exists at other concentration levels, except for very low or very high concentrations.

1.5.2 Accuracy - Accuracy is used in Appendices A and B in the sense of "closeness to the truth." Although the ultimate truth cannot be known, accepted as the closest to the truth are the values determined by NBS or other nationally recognized measurement standards body. In assessing the accuracy of measurements of an air pollution monitoring agency, measurements are made through the mechanism or procedure of independent audits in which the measurement systems are challenged with standards (materials or devices) having traceability as directly as possible to NBS standards.

Some error or uncertainty exists even in NBS Standard Reference Materials (SRM's), which are labeled with computed tolerances based on empirical data and which are applicable only under certain specified conditions and procedures for use. Obviously, some errors are introduced in the use of secondary standards that have been prepared by reference against NBS SRM's. Further, if the use of secondary standards in conducting independent audits involves other measurements, such as flow measurements when diluting audit gases, additional errors are introduced.

Nevertheless, when measurements are made at State and local agencies, through the independent audits described in Appendices A and B, the auditors' assessed values are considered as the "truth." Their values are considered as "true" values in the metrology sense--not in any statistical sense. As described in sections 3.1.2 and 3.2.2 of Appendix A, periodic independent sample audits are made using known materials, or using devices having known properties. These independent audits are used as a check on the routinely-used calibration materials, equipment, and procedures. Because of the independence and infrequent and special nature of the audits, the audit materials and assessments must be considered as the "known" or true value and any consistent lack of agreement is due to bias of the routine calibration process and/or drift (change of bias) in the routine measurement process.

Measurements at a given agency may, on the average, be biased from the true audit values due to some systematic errors in the local routine calibration process. These average biases over a given time period (e.g., a calendar quarter) may be considered as the inaccuracy of the agency's measurement system for that calendar quarter. There will also be some variability in the inaccuracy of measurements* made at an agency during a calendar quarter. This variability of inaccuracy may be considered as a hgiher level of imprecision when considering a measurement chosen at random from the given agency during the quarter. Carrying the extension in time a step further, biases which exist from quarter to quarter at a given agency may also vary in a random way. Therefore, the annual average of the quarterly biases may be considered as the bias or average inaccuracy of the agency's measurement system for the year. And the variability of the bias from quarter to quarter may be considered a part of the overall within-year imprecision for the agency.

1.6 Reporting Organization

The Regulation, Section 3 of Appendix A, requires that measures of data quality, i.e., precision and accuracy, be "reported on the basis of 'reporting organization.' A reporting organization is defined as a State or subordinate organization within a State which is responsible for a set of stations which monitor the same pollutant and for which precision and accuracy assessments can be pooled. . . . and can be expected to be reasonably homogeneous as a result of common factors."

*The concept of a variable component of systematic error is discussed by Dr. Churchill Eisenhart's lengthy article, "Realistic Evaluation of the Precision and Accuracy of Instrument Calibration Systems," Journal of Research of the National Bureau of Standards, Vol. 67C, No. 2, April-June, 1963. See also "Systematic Measurement Errors", by Rolf B.F. Schumacher, Journal of Quality Technology, Vol. 13, No. 1, January 1981. pp. 10-24.

"Common factors which should be considered ... include:

"(1) operation by a common team of field operators,
(2) common calibration facilities, and
(3) support by a common laboratory or headquarters."

Several examples of reporting organizations are presented in Figures 1 through 4.

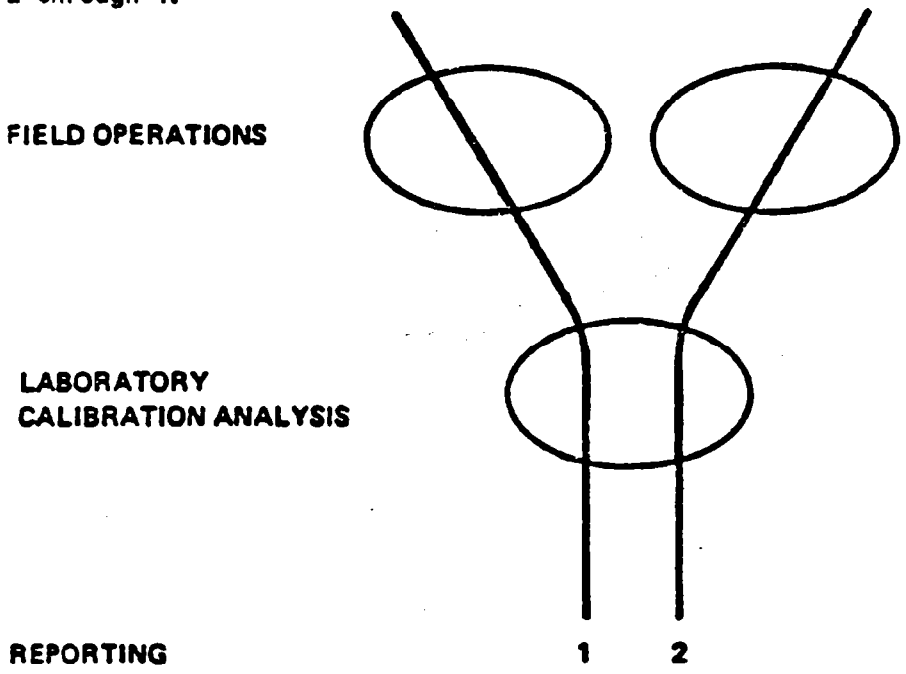

Figure 1. Multiple reporting organizations with central laboratory and separate field operations typical of manual methods.

In Figure 1, the field operations, which may be spread over a wide geographical area, are handled by two different working groups, each using their separate procedures, field calibration (flow) equipment and standards, preventive maintenance schedules, etc. The samples are analyzed, however, in a central laboratory with central laboratory personnel, procedures, calibration chemicals, calibrated balances, etc. In this example, there are two separate reporting organizations as indicated by lines 1 and 2.

Figures 2 and 3 illustrate situations where the field operations carried out by a single group; however, two different chemicals laboratories are involved, each of which performs all functions associated with calibration and analysis. Further data are analyzed and processed by separate units in Figure 2, but in Figure 3, the data handling is performed by one unit. In each case, there are two separate reporting organizations, defined by the two lines.

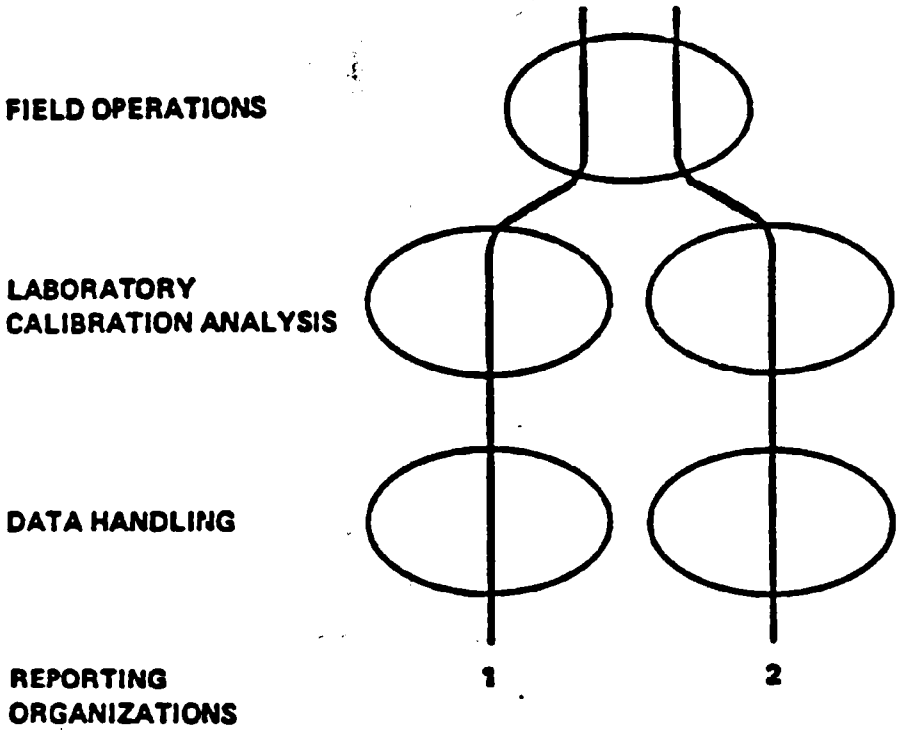

Figure 2. Multiple reporting organizations with central field operations and separate laboratories and data analysis functions for manual methods.

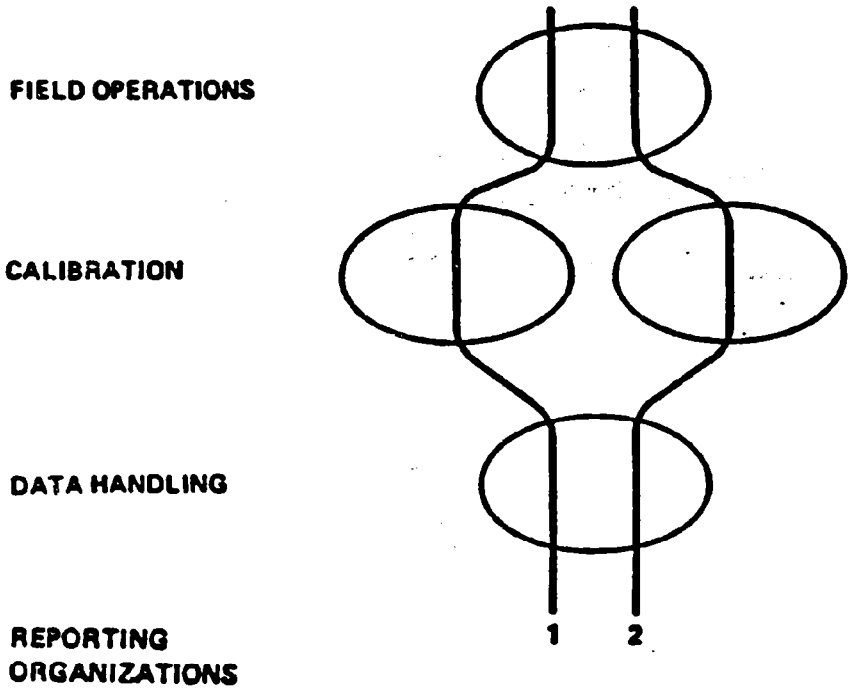

Figure 3. Multiple reporting organizations with central field operations and data analysis and with separate calibration systems for automated methods.

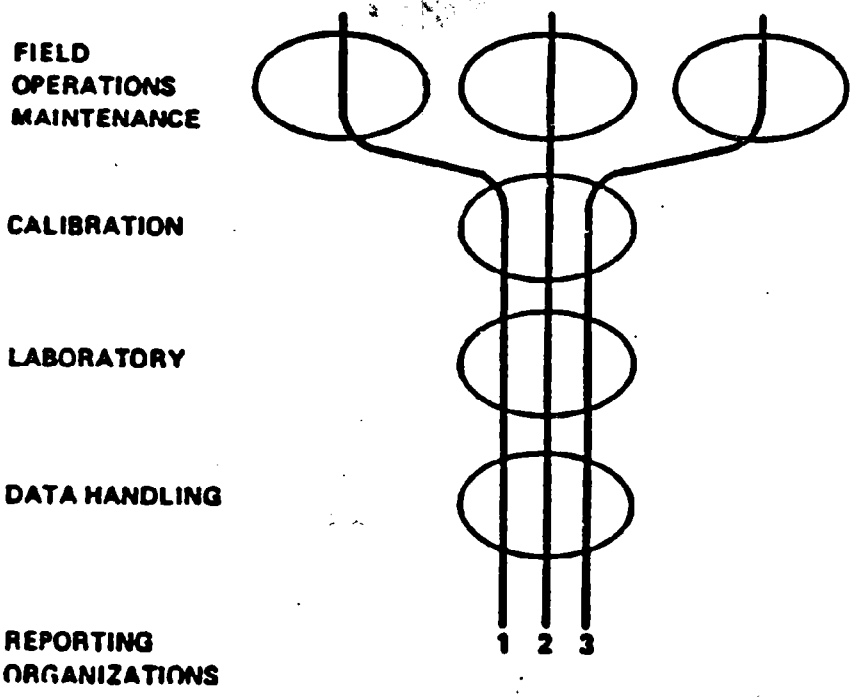

Figure 4. Multiple reporting organizations with separate field operations and central calibration and analysis laboratories and data analysis unit typical of large-scale automated methods.

Figure 4 represents three reporting organizations, each with its own field operations for sampling and instrument maintenance. In such a large operation, the field operation functions are performed by different sets of personnel at widely separated locations. However, each organization uses the same calibration and analysis laboratories and data handling facilities.

As can be deduced from these examples, the definition of reporting organization does not relate to which agency or organization reports the routine monitoring or to which agency or organization reports the precision and accuracy data, but rather to the total operational system involved in sampling, calibration, analysis, and reporting for routine monitoring for a specific pollutant.

It is important to emphasize that the definition of reporting organization is pollutant-specific. It is possible that a given sampling site may be identified with different reporting organizations for different pollutants. The concept or definition of reporting organization has no meaning, of course, for PSD monitoring. For PSD monitoring, the measurement and reporting of precision and accuracy data are accomplished for each site or sampling location.

2. OVERVIEW OF QUALITY ASSURANCE REQUIREMENTS

Before discussing the details of the requirements for precision and accuracy determination for SLAMS and PSD, it is desirable to summarize the general requirements of the regulations relative to quality assurance.

The precision and accuracy determinations are made by performing specified internal checks made by or for the reporting organization (SLAMS) or by the owner/operator (PSD). Closely related to these internal checks are the external performance audits and system audits conducted by EPA.

The responsibility for obtaining and reporting the precision and accuracy data belongs to the reporting organization and is therefore considered as "internal" to it. The conduct of the Performance Audit program by EMSL/RTP and the conduct of the Quality System Audit program by the EPA Regional Offices are considered as "external" to the reporting organization, because the programs are conducted by EPA, even though the reporting organizations are involved by their participation in the audits.

Precision for each of the manual methods (except for Pb) is determined from the results of collocated samplers located at two sites expected to have a measurable concentration of the pollutant. The precision checks for Pb are made by analyzing duplicate strips (or duplicate aliquots for equivalent methods) from a single site of expected high Pb concentration. Accuracy is determined from the results of local independent audits for the flow or analytical measurement portion of the methods. The accuracy checks are essentially internal-but-independent checks on the local routine calibration process.

The external audits for accuracy are EPA performance audits, in which reference samples or devices from EMSL/RTP are distributed as blinds on an annual or semi-annual frequency to the organizations involved. The results from these "unknowns" are transmitted to EMSL/RTP, which then sends the "true" value to the organizations. Each year an annual summary report, prepared by EMSL/RTP, provides an overall analysis by EMSL/RTP through the dissemination of (a) simulated bubbler samples for the SO_2 and NO_2 methods, (b) reference flow devices for the high-volume TSP method, and (c) reference flow devices and spiked high-volume filter strips for Pb. Note that only the chemical analysis portion of the bubbler methods is audited; the flow measurement is not audited. For the TSP method, only the flow measurement portion of the method is audited; the sample handling, sample conditioning, and weighing portions of the method are not audited. For Pb, the chemical analysis portion of the method is audited, and the flow measurement is audited.

Annual systems audits of each state agency may be conducted by the EPA Regional Offices. These audits should cover all the aspects of the State QA program, with particulate emphasis on the eleven items listed in Section 2.2 of Appendix A to Part 58 and repeated in Section 1.3 of this document. See also Section 2.0.11 of Reference 5.

2.2 Automated Analyzers

Precision of automated analyzers is determined from biweekly precision checks. The precision checks are actually measurements of the analyzer response at a concentration level near the national average for ambient air.

Accuracy is determined from the results of local audits using independently prepared standards. The accuracy checks are essentially internal-but-independent checks on the local routine calibration process.

The external performance and system audits for automated methods are similar to those for the manual methods, except that at the current time (December, 1982), reference materials are available only for the CO and SO_2 measurement systems. Audit materials/devices are being developed by EMSL/RTP for automated NO_2 and O_3 methods. When developed, the reporting organizations will be required to participate in these performance audits also.

2.3 PSD Requirements

The requirements for precision and accuracy assessment for PSD monitoring methods are very similar to those for SLAMS. In those instances where the requirements differ, special note will be made. Otherwise, the reader should assume that the requirements are the same. A separate section, Section 9, summarizes the major similarities and differences between the requirements for SLAMS and PSD. EPA has issued other guidance concerning the monitoring for PSD (6,7).

2.4 Reporting Precision and Accuracy Data

The procedures for obtaining precision and accuracy data, including the necessary computations, are included in Appendicies A and B of 40 CFR Part 58. For reference, a copy of the reporting form, Form 1 (front and back), is given on the following page.

3. CONDITIONS FOR PRECISION TESTS

3.1 Typical Conditions

It is very important that the estimates of precision for the above purposes be obtained under conditions that are as typical as possible. The measurements from which the estimates are made should be obtained under conditions of operation, maintenance, and calibration that are representative of normal routine activities of the monitoring agencies. The following precautions should be observed by the State and local agencies in obtaining the data used to estimate precision.

OMB No. 158-R0012
Expires

DATA ASSESSMENT REPORT

STATE	REPORTING ORGANIZATION	YEAR	QUARTER
1 2	3 4 5	6 7	8

SEND COMPLETED FORM TO REGIONAL OFFICE WITH COPY TO EMSL/RTP

NAME OF REPORTING ORGANIZATION _____

AUTOMATED ANALYZERS

PRECISION

		NO OF ANALYZERS[1]	NO OF PRECISION CHECKS	PROBABILITY LIMITS LOWER	PROBABILITY LIMITS UPPER
A. CO	C 4 2 1 0 1 (9-14)	(15-17)	(18-21)	+/- (22-27)	+/-
B. NO_2	C 4 2 6 0 2 (9-14)	(15-17)	(18-21)	+/- (22-27)	+/-
C. O_3	C 4 4 2 0 1 (9-14)	(15-17)	(18-21)	+/- (22-27)	+/-
D. SO_2	C 4 3 4 0 1 (9-14)	(15-17)	(18-21)	+/- (22-27)	+/-
E. ___	C (9-14)	(15-17)	(18-21)	+/- (22-27)	+/-

ACCURACY

	TRACEABILITY	SOURCE OF LOCAL PRIMARY STANDARD[2]	NO OF AUDITS	PROBABILITY LIMITS LEVEL 1 LOWER	LEVEL 1 UPPER	LEVEL 2 LOWER	LEVEL 2 UPPER	LEVEL 3 LOWER	LEVEL 3 UPPER	LEVEL 4 LOWER	LEVEL 4 UPPER	NO. OF AUDITS AT LEVEL 4
A. CO	C 4 2 1 0 1 (28-33)	(34)	(35)	(36-38) +/- (39-44)	+/-	+/- (45-50)	+/-	+/- (51-56)	+/-	+/- (57-62)	+/-	(63-65)
B. NO_2	C 4 2 6 0 2 (28-33)	(34)	(35)	(36-38) +/- (39-44)	+/-	+/- (45-50)	+/-	+/- (51-56)	+/-	+/- (57-62)	+/-	(63-65)
C. O_3	C 4 4 2 0 1 (28-33)	(34)	(35)	(36-38) +/- (39-44)	+/-	+/- (45-50)	+/-	+/- (51-56)	+/-	+/- (57-62)	+/-	(63-65)
D. SO_2	C 4 3 4 0 1 (28-33)	(34)	(35)	(36-38) +/- (39-44)	+/-	+/- (45-50)	+/-	+/- (51-56)	+/-	+/- (57-62)	+/-	(63-65)
E. ___	C (28-33)	(34)	(35)	(36-38) +/- (39-44)	+/-	+/- (45-50)	+/-	+/- (51-56)	+/-	+/- (57-62)	+/-	(63-65)

[1] COUNT ONLY REFERENCE OR EQUIVALENT MONITORING METHODS

[2] Identify according to the following code
A. NBS SRM
B. EMSL REFERENCE GAS
C. VENDER CRM
D. PHOTOMETER
E. BARS
F. Other: SPECIFY_____

FORM 1 (FRONT)

OMB No. 158-R0012
Expires

DATA ASSESSMENT REPORT

STATE	REPORTING ORGANIZATION	YEAR	QUARTER
1 2	3 4 5	6 7	8

SEND COMPLETED FORM TO REGIONAL OFFICE WITH COPY TO EMSL/RTP

NAME OF REPORTING ORGANIZATION _____

MANUAL METHODS

PRECISION

		NO. OF SAMPLERS [1] (16–17)	NO. OF COLLOCATED SITES (18–19)	NO. OF COLLOCATED SAMPLES < LIMIT (20–23)	PROBABILITY LIMITS (24–29)	LIMITS APPLICABLE TO BLOCKS 20–23	NO. OF VALID COLLOCATED DATA PAIRS (50–55)
A. TSP	110101 (8–14)				LOWER +/- UPPER +/-	TSP: 20 μg TSP/m³	
B. SO_2	142401 (8–14)				LOWER +/- UPPER +/-	SO_2: 40 μg SO_2/m³	
C. NO_2	142602 (8–14)				LOWER +/- UPPER +/-	NO_2: 30 μg NO_2/m³	
D. Pb	112128 (8–14)				LOWER +/- UPPER +/-	Pb: 0.15 μg Pb/m³	

ACCURACY

			NO. OF AUDITS (37–39)	PROBABILITY LIMITS LEVEL 1 (40–45)	LEVEL 2 (46–51)	LEVEL 3 (52–57)
A. TSP	110101 (30–35)	A (36)		LOWER +/- UPPER +/-	LOWER +/- UPPER +/-	LOWER +/- UPPER +/-
B. SO_2	142401 (30–35)	B (36)		LOWER +/- UPPER +/-	LOWER +/- UPPER +/-	LOWER +/- UPPER +/-
C. NO_2	142602 (30–35)	C (36)		LOWER +/- UPPER +/-	LOWER +/- UPPER +/-	LOWER +/- UPPER +/-
D. Pb	112128 (30–35)	D (36)		LOWER +/- UPPER +/-	LOWER +/- UPPER +/-	LOWER +/- UPPER +/-

[1] COUNT ONLY REFERENCE OR EQUIVALENT MONITORING METHODS.

In preparation for the performance of the precision checks, no special adjustments, calibrations, or maintenance of the instruments should be performed. For example, the biweekly precision checks should be made prior to any routine or special checks or adjustments made in connection with zero/span, calibration, or maintenance scheduled on the same day as the precision checks. If routine zero or span checks, adjustments, calibrations or maintenance are performed at some scheduled frequency, the biweekly precision checks should be made at various random times in between these scheduled operations. In other words, the special checks for precision should be made at times which, as a sample, are representative of the typical conditions existing within the calendar quarter. From practical, logistic considerations, the precision checks could be made just prior to (a) scheduled zero/span checks that may result in instrument adjustment, (b) scheduled calibrations, or (c) scheduled maintenance.

3.2 Manual Methods

As previously pointed out (Section 1.5.1), the conditions under which precision is determined must be very specifically stated. The intent of the regulation is to obtain precision estimates that reflect the repeatability of the entire measurement process. The best known way of measuring the repeatability of the entire process is through the use of collocated samplers. In this way, most of the variables acting throughout the entire measurement process are independently involved for each of the two separate samplers. Even so, there will be commonalities of conditions for the paired data from the collocated samplers that will enhance better agreement than would be achieved if the two samplers and samples were completely independent. For example, the paired samples will be handled under the same conditions, and will be analyzed under the same conditions in the laboratory. Because of such commonalities, the precision estimates obtained will be somewhat optimistic, i.e., they will tend to underestimate the true inherent variability (imprecision) of the total measurement process.

Internal (local) precision checks are made using collocated samplers at a minimum of two sites of high concentration. One of the collocated

samplers is randomly designated as the official sampler for routine monitoring; the other is considered the duplicate. After the designated sampler is so identified, its designation should not be changed. Results from the duplicate sampler are to be obtained each day the designated sampler is operated unless the samplers are operated more frequently than every sixth day, in which case at least one collocated sample is required each week.

Ideally, collocated samplers should also be required for Pb. However, because of the added expense of establishing duplicate samplers at Pb sites, resort has been made to analyses of duplicate strips or aliquots from filters from a single sampler at a high concentration Pb site. The estimates of precision from the duplicate strips will not include variabilities from sampler to sampler and thus will underestimate the imprecision of the total measurement process.

3.3 Automated Analyzers

For automated analyzers, the use of collocated analyzers would be best to measure repeatability; however, the cost would be prohibitive. The next most desirable technique is to perform response checks at approximately ambient concentration levels at random times between successive instrument adjustments. In this way, the precision is a measure of instrument drift from the time of the most recent instrument adjustment or calibration to the time of the precision check. The regulations require the precision checks to be made at two-week intervals or more frequently. Although not stated in the regulations, an average of the instrument output should be obtained over some relatively short period of time, e.g., five minutes following introduction of the "precision" gas and after reaching equilibrium. Thus, the precision estimates have meaning only with respect to the time-averaging period over which the average values are obtained. Precision estimates for other time-averaging periods would have to be determined by knowing or assuming a drift pattern between successive instrument adjustments and calibrations.

Precision checks are conducted at least biweekly and are made with concentrations of test gases in the following ranges:

0.08 - 0.10 ppm for SO_2, O_3, NO_2;

8 - 10 ppm for CO.

These precision checks may use the same materials, equipment, and personnel routinely used for instrument calibration or span checks.

4. CONDITIONS FOR ACCURACY AUDITS

4.1 Typical Conditions

Data for estimating accuracy should be obtained under conditions as typical as possible, i.e., under normal, routine activities of the monitoring agencies. Thus, consistent with the previous discussion under Section 3.1 for precision, no special adjustments, calibrations, or maintenance of the instruments should be performed immediately prior to the internal accuracy audits.

To measure the closeness of an observed measurement value to the truth, some material or condition of known (true) property (standard) must be measured by the measurement system being checked. The measurement system is "challenged" with the "known" to obtain the observed measurement. The difference between the observed value and the known value is a measure of the bias or inaccuracy of the observed value. Standard convention is to obtain a signed difference by subtracting the known value from the observed value so that the sign indicates the direction of the bias. More specific details concerning the conduct of accuracy audits is given in Reference 1.

4.2 Manual Methods

For manual methods, it is difficult to challenge the total measurement system with "knowns". Therefore, an accuracy audit is made of only a portion of the measurement system. The two major portions of manual measurement systems are the flow measurements and the analytical measurements. The flow measurement portion of the TSP and Pb reference methods,

and the analytical measurement portion of the Pb and the NO_2 and SO_2 bubbler methods are audited for accuracy. The flow rate audits for the TSP and Pb methods are made at a flow rate near the normal operating flow rate. Twenty-five percent of the combined total sites for TSP and Pb must be audited internally each quarter, so as to represent a random sample for the entire network. However, at least one site must be audited each quarter, and all sites must be audited internally each year.

For the NO_2 and SO_2 methods, analytical audit samples (standards) in the following ranges are used:

1. 0.2 - 0.3 µg/ml;
2. 0.5 - 0.6 µg/ml;
3. 0.8 - 0.9 µg/ml.

For the Pb method, the standards are spiked strips containing 100-300 µg/Pb strip and 800-1000 µg/Pb strip are used. An internal audit at each concentration level must be made on each day of analysis of routine monitoring samples, and the audits must be made at least twice each quarter.

4.3 Automated Analyzers

For automated analyzers, "known" gaseous pollutant standard concentrations, independently certified and obtained with equipment different from that used for routine calibration and spanning, are introduced into the measurement instruments. In this way, two different calibration systems are involved: the one used for routine monitoring and the one used to establish the audit standards. For SLAMS, the accuracy audits may be conducted by the same personnel who normally calibrate the instruments. However, in the case of PSD, different personnel must be used.

Automated analyzers are challenged (audited) with known pollutant concentration standards at three levels (four levels in the case of high-range analyzers) in accordance with Table III. The internal, independent accuracy audits are the responsibility of each reporting organization and can be performed by personnel of the reporting organization. However, the reporting organization could, if desired, have the accuracy audits conducted by a contractor, or they could, by mutual agreement, be performed by a Regional team, a contractor of EPA, or some other independent organization.

Table I. Automated Analyzer Audit Concentrations

Audit Level	Concentration range, ppm SO_2, NO_2, O_3	CO
1	0.03 - 0.08	3 - 8
2	0.15 - 0.20	15 - 20
3	0.35 - 0.45	35 - 45
4	0.80 - 0.90	80 - 90

External audits of automated analyzer measurement systems are conducted by EPA. Semiannual performance audits for CO and SO_2 automated methods are conducted by EMSL/RTP through the dissemination of small cylinders containing CO gas and through the dissemination of small cylinders containing SO_2 gas used in conjunction with a dilution system. Materials or devices for conducting performance audits for the measurement systems for NO_2 and O_3 are being developed by EMSL/RTP. Participation in these latter audits will be required of the State/local agencies when the audit materials become available.

The annual systems audits conducted by the EPA Regional Offices were previously discussed.

5. STATISTICS OF PRECISION

The choice of the particular statistics used for precision are described in the following section. However, it should be stated at this point that the statistical procedures and computations specified in 40 CFR Part 58, Appendices A and B represent a tradeoff or compromise between (a) the amount of effort and data that would be "nice to have" for statistical analysis, and (b) the amount of effort that can be reasonably expected and (c) the amount of data that can be efficiently and effectively handled by State and local agencies. Thus, the statistics of Appendices A and B represent a compromise between (a) theoretical statistical exactness, and (b) simplicity and uniformity in computational procedures.

5.1 Signed Percentage Differences

The reason for using percentage differences instead of actual differences is that errors in precision are generally proportional to concentration levels. In the case of the biweekly precision checks, which are made at one fixed level, either actual differences or percentage differences could be used. However, since other comparisons are made on a percentage basis, percentage differences are used throughout for simplicity and consistency. It is recognized that the percentage errors may be somewhat higher at very low concentrations.

To obtain signed differences, the measurement associated with one identified factor is always subtracted from the measurement associated with the other identified factor. For example, for collocated samplers the value from the designated sampler is always subtracted from the value for the duplicate sampler. Therefore, each difference will be either positive or negative in sign.

The reason for using signed percentage differences instead of absolute percentage differences is to obtain important information on the possible presence of systematic errors. The calculation of the average difference values using signed percentage differences reveals or highlights any systematic errors which may need investigation and corrective action to improve the precision of the monitoring data. Further, the statistical significance of these systematic errors can be determined with the average and the standard deviation of the signed percentage difference values. With absolute percentage differences, it would not be possible to separate the systematic errors from the random errors. Ideally, the average, signed percentage difference values obtained for each instrument or site should be zero. Where these values are significantly different from zero, the resulting probability limits will be noticeably asymmetrical about zero.

5.2 Manual Methods

For manual measurement methods, precision or repeatability is determined from the discrepancy between measurements from collocated samplers presumably sampling the same air parcel over the same time period (Instrument or Site Precision).

Because it is desired to obtain a measure of precision associated with a result from a single sampler, the variability (standard deviation) of percentage differences between the collocated instruments is divided by $\sqrt{2}$, since both instruments are assumed to be equally imprecise. The division by $\sqrt{2}$ compensates for the fact that the variability (standard deviation) of percentage differences from two measurement systems of equal imprecision is increased by a factor of $\sqrt{2}$ over the error variability of a single measurement system. After division by $\sqrt{2}$, the repeatability represents the variation in results which would be obtained if a large number of like instruments of the same imprecision as those at the collocation site were located at the same site sampling the same air over the same period.

Because of the additional cost of establishing collocated samplers for the estimation of precision for Pb, resort has been made to the measurement of agreement between the analysis of duplicate strips from a single filter or analyses of duplicate aliquots of the extracts. Whichever method is used, the $\sqrt{2}$ factor should be used in the calculation of the probability limits. The precision includes only the analytical portion of the method and does not include the sampling and flow measurement portions of the method.

5.3 Automated Analyzers

A given precision check may be considered as representative of an hourly average which would have been obtained from the instrument if the air pollution concentration were the same as the concentration level of the gas used for the precision check. Because the lack of precision is generally proportional to concentration, nearly the same percentage variation exists at other concentration levels, except for very low concentrations for a given measurement system and quality control system.

5.4 Probability Limits

Throughout Appendices A and B, "probability" limits* are computed to measure the expected spread or variability of the data from a particular

population. These expected limits are expressed simply as a mean plus or minus a constant (1.96) times the standard deviation as follows:

$$L = \bar{x} \pm ks \qquad (1)$$

where:

L = probability limits (upper limit, L_U; lower limit, L_L)
$\bar{x}$ = mean value
k = 1.96, a constant
s = standard deviation

Under the assumptions of (a) an underlying normal population, (b) the mean $\bar{x}$, being the estimate of the true mean, μ, of the underlying population, and (c) the standard deviation, s, being the estimate of the true standard devication, σ, of the underlying distribution, then $\bar{x} \pm 1.96s$ represents the expected limits which should include 95 percent of all the individual measurement of the population. Under the assemption given, $\bar{x} \pm 1.96s$ limits are the expected 95 percent probability limits, regardless of the sample size.**

The requirement for the computation of "probability" limits (rather than confidence limits) is to provide the State and local agencies with limits which will be of practical meaning and usefulness for internal control applications without involving overly complicated and sophisticated statistics. The selection of the 95 percent level was made because even for non-statisticians, the chance or probability of obtaining one value out of twenty exceeding the limits has practical meaning.

Note that the limits are not "confidence limits," which could be computed if one desired to determine limits that would include the true mean, μ, with a specified confidence probability. With a given average, $\bar{x}$, and standard deviation, s, confidence limits on the "true"* statistical mean would be:

$$\bar{x} \pm ts/\sqrt{n} \qquad (2)$$

*See O.L. Davies, "Statistical Methods in Research and Production," Oliver and Boyd (1949), p. 249 for a discussion of probability limits.

**See A. Hald, "Statistical Theory with Engineering Applications," Wiley (1952), pp. 311-312.

where: $t_{\alpha/2}$ = a value from the t-distribution

n = number of sample values

With the limits computed for an instrument, site, analysis-day, or agency, along with the appropriate sample size, confidence limits on the true mean could be computed, if so desired.

Note also that the limits, $\bar{x} \pm 1.96s$, are not "tolerance" limits according to the usual definition of "limits which will include at least a fraction P of the individual values of a population with a stated degree of confidence γ." Such two-sided tolerance limits are expressed in the same form as equation 1, $\bar{x} \pm ks$, but the value of k here is different from that in equation 1 and depends on the specified values of population fraction, P, and confidence coefficient, γ. Tabulated values for k are often given** for values of P of 0.75 and above, and values of γ of 0.75 and above. For example, for sample size, n, of 13, P = 0.95 and γ = 0.75, the k value is 2.424. Thus, the tolerance limits, $\bar{x} \pm 2.424s$, will include at least 95 percent of the individual values of the underlying normal distribution with a confidence of 75 percent.

In a sense, the $\bar{x} \pm 1.96s$ "probability" limits are a special type of tolerance limit where the confidence level is at the "expectation," or near the 50 percent confidence level. (It is not exactly the 50 percent confidence level because the distributions of $\bar{x} + ks$ and $\bar{x} - ks$ are not normal for small sample sizes.) In other words, approximately 50 percent of the time, the probability limits will include 95 percent of the individual values of the underlying distribution.

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*The "true" mean in the statistical sense is a quantity the confidence limits for which includes considerations for the variations due to random sampling and random measurement repeatability. The "true" mean in the statistical sense is not the same as the "true" mean in the meteorological sense.

**Handbook 91, "Experimental Statistics," U.S. Dept. of Commerce, National Bureau of Standards, pp. 2-13 through 2-15 and Table A-6; see also A. Hald, "Statistical Theory with Engineering Applications," pp. 313-315.

A summary of the various probability limits for precision, computed as outlined in Appendix A, is presented in Table 2 for manual methods and automated analyzers. Note that a condition and measure of bias or systematic error is always associated with the $\bar{d}_j$'s and the $\bar{D}$'s, and a condition and measure of repeatability or random error is associated with the $\pm$ 1.96 S_j and the $\pm$ 1.96 S_a terms of the limits.

5.5 Meaning of Precision

Table 3 summarizes and interprets the probability limits for precision. The $\bar{d}_j$'s and the S_j's are the means and standard deviations, respectively, for the calendar quarter for particular instruments, particular sites, particular instrument-site combinations, or particular analysis days.

S_j represents the variability of the measurement process under the most similar conditions and may be considered as the statistical "error." $\bar{d}_j$ can be considered in a statistical sense as a local, within-quarter instrument bias or inaccuracy. However, the $\bar{d}_j$'s may not necessarily be statistically different from zero. If the $\bar{d}_j$'s are significantly different from zero, a persistent drift in instrument response is occurring, and the cause must be identified and corrected. Whether or not the $\bar{d}_j$'s are significantly different from zero, for a particular instrument, site, or analysis day, the $\bar{d}_j$'s will probably vary in a random way among instruments, among sites, and among analysis days; therefore, the variability of the $\bar{d}_j$'s may be considered as another level of precision, when considering the agency monitoring system as an entity.

For a specific agency S_a represents the "averaged" or pooled within-instrument, within-site, or within-analysis-day variability. In other words, it is the agency estimate for the calendar quarter of the within-instrument, within-site, or within-analysis-day variability--an average error term.

The $\bar{D}$'s may be considered as a within-quarter <u>agency</u> bias or inaccuracy. However, the $\bar{D}$'s may not necessarily be statistically significant from zero. A part of the EPA analysis of the data includes a test for significance of the $\bar{D}$'s. (Such a test should also be performed by each agency.) If the $\bar{D}$'s are significantly different from zero, a persistent

Table 2. Computed Probability Limits for Precision for Manual Methods and Automated Analyzers

Manual methods			
Precision (from daily signed percentage differences between collocated instruments for SO_2, NO_2, and TSP, or from signed percentage differences between duplicate strips or duplicate analyses for Pb).			
Single Site*	d_j	$\pm$	$\frac{1.96\ S_j}{\sqrt{2}}$
	bias between samplers, strips or analyses (systematic error)		within-site variability, individual daily value basis (random error)
Agency	D	$\pm$	$\frac{1.96\ S_a}{\sqrt{2}}$
	agency bias (systematic error)		average within-site variability (random error)
Automated analyzers			
Precision (from biweekly precision checks at one fixed level)			
Single Instrument*	$\bar{d}_j$	$\pm$	$1.96\ S_j$
	instrument bias (systematic error)		within-instrument variability (random error)
Agency	$\bar{D}_j$	$\pm$	$1.96\ S_a$
	agency bias (systematic error)		average within-instrument variability (random error)

*Limits for each instrument, site, or analysis day are not required to be reported to EPA. However, they should be computed for internal agency use.

Table 3. Summary of 95 Percent Probability Limits for Precision and Their Meaning for Manual Methods and Automated Methods.

	95 percent probability limits	Meaning of limits
Manual methods		
Single site*	$\bar{d}_j \pm 1.96 \frac{S_j}{\sqrt{2}}$	Expected variability (imprecision) during the calendar quarter of an individual air pollution measurement from the particular site.
Agency	$\bar{D} \pm 1.96 \frac{S_a}{\sqrt{2}}$	Expected variability (imprecision) during the calendar quarter of an individual air pollution measurements from any site within the agency.
Automated analyzers		
Single Instrument*	$\bar{d}_j \pm 1.96\ S_j$	Expected variability (imprecision) during the calendar quarter of air pollution measurements at the precision check concentration from the particular instrument.
Agency	$\bar{D} \pm 1.96\ S_a$	Expected variability (imprecision) during the calendar quarter of air pollution measurements at the precision check concentration from any instrument operated by the agency.

*Limits for each instrument, site, or analysis day are not required to be reported to EPA. However, they should be computed for internal agency use.

drift in the same direction very likely exists for most of the instruments. Whether or not the $\bar{D}$'s are significant from zero, the $\bar{D}$'s may vary in a random way among quarters for the same agency; therefore, the variability of the $\bar{D}$'s may be considered as a third level of imprecision. The EPA analyses of the data for each calendar year include a test of $\bar{D}$, the average of the four quarterly $\bar{D}$'s for a given agency against zero, to detect any persistent drifts throughout the entire year for all instruments of the same type.

From the probability limits reported by an agency, one could back-calculate the agency average, $\bar{D}$, and the agency standard deviation, S_a. As discussed previously, if the computations were made using unsigned percentage differences, it would not be possible to determine the $\bar{D}$ and S_a values; thus, it would not be possible to determine the possibly significant systematic agency errors. In other words, it would not be possible to separate the systematic errors from the random errors.

Figure 5 graphically illustrates the meaning of the calculated values of $\bar{d}_j$, S_j, $\bar{D}$, S_a, and the 95 percent probability limits for precision. The individual x's represent the individual d values for each of four instruments or sites of the example. For each of the instruments or sites, the $\bar{d}_j$, the average of the d's, represents the bias from zero, and S_j represents the variability of the d values. The pair of short parallel lines in the tails of the distribution represent the 95 percent probability limits for the assumed underlying normal distribution of individual d values.

The normal distribution shown in Figure 5 under Quarterly Report shows $\bar{D}$ (the weighted average of the $\bar{d}_j$'s), and S_a, representing the pooled or weighted "average" of the individual S_j values. The short parallel lines in the tails of the distribution represent the corresponding 95 percent probability limits.

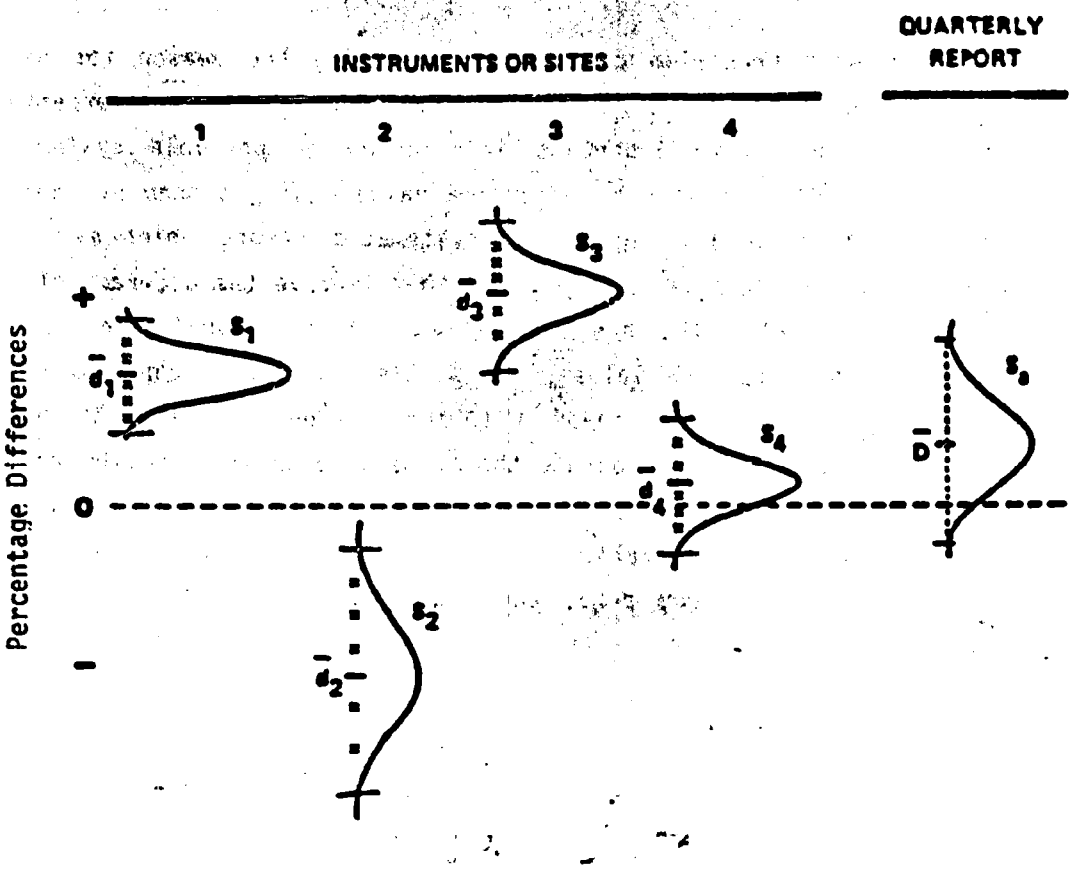

Figure 5. Graphical interpretation of precision data

6. STATISTICS OF ACCURACY

The statistics for accuracy employed in 40 CFR Part 58, Appendices A and B, are discussed.

6.1 Signed Percentage Differences

As with precision discussed previously, the reason for using percentage differences instead of actual differences is that actual errors in accuracy are generally proportional to concentration levels, except at very low concentrations, for a given measurement system and quality control system. Since accuracy comparisons are usually made on a percentage basis, for simplicity and consistency with the statistics for precision, percentage differences for accuracy are used throughout. The percentage errors may be somewhat higher at lower concentration levels.

Also, as with precision discussed previously, the reason for using signed percentage differences for accuracy instead of absolute percentage differences is to obtain important information on possible systematic errors. The calculation of the difference values using signed percentage differences reveals or highlights any systematic errors which may need investigation and corrective action to further improve the accuracy of the monitoring data. Using the average and the standard deviation of the signed percentage difference values, the statistical significance of these systematic errors can be determined. With absolute percentage differences, it would not be possible to separate the systematic errors from the random errors. Ideally, the average signed percentage difference values obtained for each analyzer should be zero. Where the average difference values are significantly different from zero, the resulting probability limits will be noticeably asymmetrical about zero.

6.2 Manual Methods

The accuracy of manual sampling methods is assessed by auditing a portion of the measurement process. For TSP and Pb, the flow rate during sampling is audited. For SO_2, NO_2, and Pb. the analytical measurement is audited. For single samplers, the accuracy is the signed percentage difference value, which is the observed or measured value minus the known value divided by the known value and converted to a percentage. For an agency, the accuracy is the mean of the signed percentage difference values from the samplers.

6.3 Automated Analyzers

The audit is performed by challenging the analyzer with known concentrations at three levels (four levels for analyzers with extended ranges). The accuracy at each level is calculated as described previously for the manual method (Section 6.2).

6.4 Probability Limits

The statistical concepts discussed previously for precision are also applicable to the computation of probability limits for accuracy.

Table 4 summarizes the various probability limits for accuracy computed as outlined in 40 CFR Part 58, Appendix A, for manual methods and automated analyzers. The bias or systematic error is associated with the single-instrument and agency signed percentage differences, $\bar{d}_j$'s and $\bar{D}$'s, respectively. Repeatability or random error is associated with the $\pm kS_a$ terms of the probability limits.

6.5 Meaning of Accuracy

Table 5 summarizes and interprets the aforementioned probability limits for accuracy for manual methods and automated analyzers. The $\bar{D}$'s and the S_a's are the means and standard deviations, respectively, for the calendar quarter for the agency.

For accuracy, S_a represents the variability of inaccuracies across instruments, sites, or analysis-days. In a sense, this S_a may be considered a precision estimate. For automated methods with a well-controlled calibration system, and with good linearity and stability over time, the S_a for accuracy and the S_a for precision should be approximately equal. (Whereas, the S_a for precision measures the average variation at a single concentration at biweekly intervals, the S_a for accuracy measures the variation at given concentration levels but at only one time each quarter for a given instrument). A part of the EPA analysis includes a comparison of the S_a for precision and the S_a for accuracy for continuous instruments. If the S_a for accuracy at the lowest concentration level is significantly larger than the S_a for precision, there is likely to be some uncontrolled variable existing within the calibration process, which should be investigated.

For integrated sampling methods, the logic of the comparison between the $S_a/\sqrt{2}$ for precision and the S_a for accuracy is not as straight-forward as for automated analyzers. For TSP, since the S_a for accuracy includes variation only from the flow rate portion of the measurement process, this S_a should be less than the $S_j/\sqrt{2}$ for precision, which includes variation from the entire measurement process. For the SO_2 and NO_2 bubbler methods, a similar situation exists as for the TSP, in that the S_a for accuracy includes variation only from the chemical analysis portion of the

Table 4. Computed Probability Limits for Accuracy For Manual Methods and Automated Analyzers

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Manual Methods

Accuracy (TSP and Pb) (from flow rate checks at a fixed level, once per quarter, 25% of sites each quarter)

Single Site d_1

sampler inaccuracy (combined systematic and random errors)

Agency $\bar{D} \pm 1.96\ S_a$

$\bar{D}$: agency bias (systematic error)

S_a: total variability including between sampler inaccuracies

Accuracy (NO_2, SO_2 and Pb), Each Level (from analytical checks at least twice per quarter)

Single Analysis Day d_1

daily inaccuracy (combined systematic and random errors)

Agency $\bar{D} \pm 1.96\ S_a$

$\bar{D}$: agency bias (systematic error)

S_a: total variability, including between-day inaccuracies

TABLE 4. (Contd.)

Automated Analyzers

Accuracy, Each Level (from calibration audits once per quarter, 25% of instruments each quarter)

Single Instrument		d_i	
		instrument inaccuracy (combined systematic and random errors)	
Agency	$\bar{D}$	±	1.96 S_a
	agency bias (systematic error)		total variability including between instrument inaccuracies

Table 5. Summary of 95 Percent Probability Limits for Accuracy and Their Meanings for Manual Methods and Automated Analyzers

Manual Methods		
TSP and Pb		
Single Site	d_1	Expected bias (inaccuracy) during the calendar quarter of flow rate portion of the measurement process for the particular site.
Agency	$\bar{D} \pm 1.96\ S_a$	Expected variation in bias (inaccuracy) during the calendar quarter of flow rate portion of the measurement process for all sites in the agency.
SO_2, NO_2, and Pb		
Single Analysis Day	d_1	Expected bias (inaccuracy) during the calendar quarter of the chemical analysis portion of the measurement process for the particular analysis day at each concentration level.
Agency	$\bar{D} \pm 1.96\ S_a$	Expected variation in bias (inaccuracy) during the calendar quarter of the chemical analysis portion of the measurement process for all analysis days at each concentration level.
Automated Analyzers		
Single Instrument	d_1	Expected bias (inaccuracy) during the calendar quarter of air pollution measurements at each audit concentration from the particular instrument.
Agency	$\bar{D} \pm 1.96\ S_a$	Expected variation in bias (inaccuracy) during the calendar quarter of air pollution measurements at each audit concentration from all instruments in the agency.

measurement method but the $S_j/\sqrt{2}$ includes variation from the entire measurement process. If S_a for accuracy significantly exceeds $S_a/\sqrt{2}$ for precision, the calibration process for the method involved is not well-controlled. For Pb, both the flow rate and analytical portions of the method are audited. But the flow rate audits are combined with the TSP data and not reported individually for lead.

Figure 6 graphically illustrates the meaning of the calculated values of d, $\bar{D}$, and S_a, and the 95 percent probability limits for accuracy. For accuracy at a given level, the individual audit results, d, for four instruments or sites are represented by the x's. In accordance with the minimum requirements of the regulations, only one audit value (for a given level) is shown for each instrument or site.

Under Quarterly Report is shown the same four individual x or d values, with the $\bar{D}$ and S_a calculated from the individual values. The 95 percent probability limits are shown by the short parallel lines in the tails of the distribution.

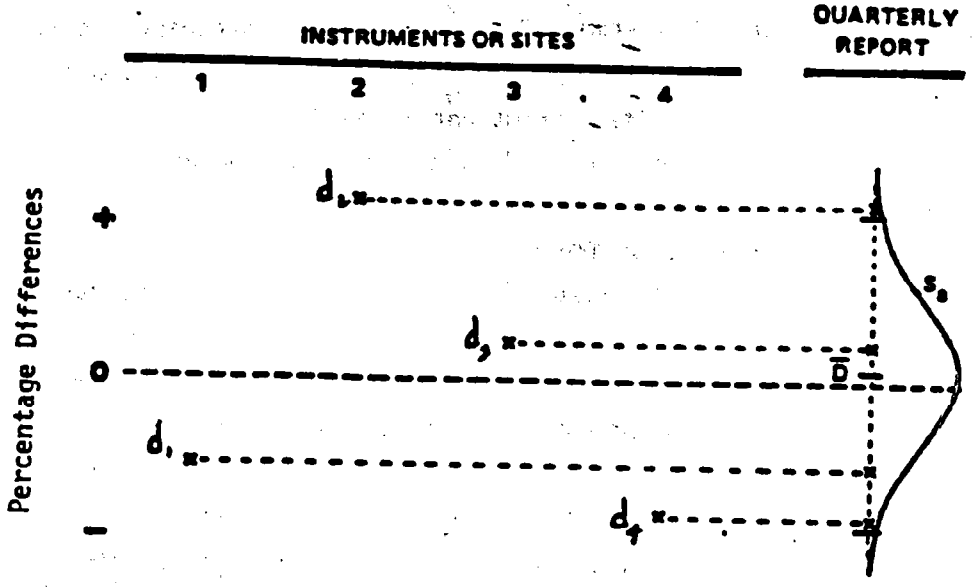

Figure 6. Graphical interpretation of accuracy data

7. USE OF PRECISION AND ACCURACY DATA

The precision and accuracy data obtained by the networks and reported to EPA are of considerable value to various organizations. These estimates will be helpful to the user of routine monitoring data by providing the user with information on the quality of the data with which he is working. The estimates are valuable to EPA in obtaining "real world" information on the precision and accuracy of the reference, equivalent, and approved methods. The data should also be of particular interest and value to the originating agencies as a supplement to the routine quality control system.

7.1 Originating Agencies

7.1.1 Supplement to Internal Quality Control - The measures of precision and accuracy are obtained by each network in the form of probability or control chart-type limits that can and should be used within each agency as supplementary information for internal quality control. The precision and accuracy information obtained within a network on a given site or instrument can be used for local quality control purposes for the particular site or instrument. It is important to emphasize, however, that the precision and accuracy checks required by Appendix A do not obviate the need to maintain a routine quality control system. The precision and accuracy checks are too infrequent to be adequate for day-to-day control. Furthermore, the precision and accuracy results should not normally be used to make any after-the-fact adjustments or corrections to the measurement system or to monitoring data. Excessive deviations, however, should not be ignored and should trigger investigative action.

7.1.2 Control Charts - The results of the precision and accuracy data can be plotted on various control charts. As stated above, the results of the precision and accuracy checks, if used in a timely way, can constitute a valuable supplement to normal routine internal quality control checks. With the increased installation and use of computers for acquisition and/or up-to-date storage of monitoring data, the computers could also be used for the acquisition and/or storage of the precision and accuracy data. Further, the computers could be programmed to perform the necessary calculations for precision and accuracy reporting and could also be programmed to plot the control charts in real (or near-real) time.

In general, the control chart limits will be similar to the computed probability limits except that the 1.96 value will be replaced by a 3.0. (The 1.96 corresponds to an expected 95 percent probability--the 3.0 corresponds to an expected 99.7 percent probability.) The ± 1.96 S_a limits could also be used as "2-sigma" warning limits along with the "3-sigma" control limits. In the case of manual method precision, the $\sqrt{2}$ factor is not included because the points to be plotted will be the percentage differences, which include variability from the imprecision of both samplers. Also, since the intuitively expected values for $\bar{d}_j$ and $\bar{D}$ are zero for precision and accuracy, the centerline for the control charts should be zero. Table 6 describes control charts which can be plotted for the individual precision checks and accuracy audits.

Although the prime objective of the precision and accuracy audits it to obtain an assessment of data quality, a number of statistical control charts can be maintained to provide some supplemental long-term internal control. With control limits established on the basis of past history (at least one quarter for precision, at least one year for accuracy), future data values can be plotted to detect significant changes from past experience. Control charts could be plotted with the $\bar{D}$ values to detect within quarter biases. Similarly, the quarterly values of S_a could be plotted to control or display the variability aspects of the measurement systems.

Consult Appendix H of the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I, Principles, EPA 600/9-76-005 for further details on the construction and use of control charts. Also, the analysis and interpretation of the results from individual accuracy audits are given on pages 86-9, Section 2.0.12 of Volume II, Ambient Air Specific Methods, EPA 600/4-77-027a.

7.2 States and Regional Offices

The precision and accuracy reports will be helpful to the states in comparing these measures of data quality from the networks within the States. Similarly, the EPA Regional Offices will be able to make

comparisons within and between States. These comparisons may point out particular organizations or States in need of further improvement in their quality assurance programs.

7.3 Environmental Protection Agency (EPA)

Evaluation of the precision and accuracy data is important to EPA (EMSL, Research Triangle Park, North Carolina) in its role of responsibility for quality assurance of air pollution measurements. The precision and accuracy data will be used to (a) determine possible needs for additional research efforts related to the technical or procedural aspects of particular measurement methods, (b) indicate measurement methods, or portions thereof, which may require improved quality control, and (c) indicate particular agencies, States, or Regions that may require technical assistance or improved quality control. In other words, the precision and accuracy information will enable comparisons to be made among measurement methods, and among networks or other organizational entities for purposes of identifying possible areas in need of improvement of data quality.

With knowledge of the precision and accuracy information, EPA could consider appropriate statistical allowances or risks in setting and enforcing the standards, and in developing control strategies.

7.4 The User

Users of monitoring data maintained in the National Aerometric Data Bank (NADB) receive, along with the monitoring data, the precision and accuracy data for the corresponding reporting organizations and time periods. Knowledge of the precision and accuracy data assists the users in their interpretation, evaluation, and use of the routine monitoring data.

8. SUMMARY OF ANALYSIS OF PRECISION AND ACCURACY DATA

To assist Regions and States in making the above comparisons and in performing other analyses of the reported precision and accuracy data, EMSL/RTP prepares evaluation and summary reports covering each calendar

Table 6. Recommended Control Charts and Control Limits for Precision Checks and Accuracy Audits for State and Local Agencies

Pollutant measurement method	Type of Control charts	Number of control charts	Control limits	Frequency of plotting and values to be plotted	Variability or inaccuracy to be controlled
Manual methods					
SO_2 NO_2 TSP Pb	Precision-Single Site	One control chart for each collocated site (the single site for Pb)	Zero ± 3 S_a	Each day, plot d_j for each site	Excessive lack of agreement between collocated samplers
TSP (flow rate) Pb (flow rate)	Accuracy-Single Site	One control chart per agency	Zero ± 3 S_a	After each audit, plot each individual d_j	Excessive inaccuracy of each instrument
SO_2 (analysis) NO_2 (analysis) Pb (analysis)	Accuracy for each audit level	One control chart for each audit level	Zero ± 3 S_a	After each audit, plot each individual d_j	Excessive inaccuracy for each audit
Automated methods	Precision-Single Site	One control chart for each instrument.	Zero ± 3 S_a	After each biweekly precision check, plot each individual d_j value	Excessive variability and drift of each instrument
SO_2 CO NO_2 O_3	Accuracy for each audit level	One control chart for each audit level	Zero ± 3 S_a	After each audit check, plot each individual d_j value	Excessive inaccuracy of each instrument

quarter, as well as an annual summary. Samples of these reports are available upon request.

9. COMPARISON OF SLAMS AND PSD REQUIREMENTS

Table 7 summarizes the major similarities and differences of the requirements for SLAMS and PSD.

As indicated, the requirements are the same in that both require:

(a) The development, documentation, and implementation of approved quality control programs.
(b) The assessment of data quality for precision and accuracy.
(c) The use of reference, equivalent, or approved methods.
(d) The use of calibration standards traceable to NBS SRM's or other primary standards.
(e) The participation in EPA performance audits and the permission for EPA to conduct system audits.

The monitoring and QA responsibilities for SLAMS are with the State or local agency, whereas for PSD they are with the source owner/operator seeking the permit. The monitoring duration for SLAMS is indefinite, whereas for PSD the duration is usually up to 12 months. Whereas, the reporting period for precision and accuracy data is on a calendar quarter basis for SLAMS, it is on a continuing sampling quarter basis for PSD, since the monitoring may not commence at the beginning of a calendar quarter. For example, the reporting quarters for PSD might be March, April, May; June, July, August; etc.

The performance audits for PSD must be conducted by personnel different from those who perform routine span checks and calibrations, whereas for SLAMS, it is the preferred but not the required condition. For PSD, the audit rate is 100 percent of the sites per reporting quarter, whereas for SLAMS it is 25 percent of the sites or instruments. Note that monitoring for SO_2 and NO_2 for PSD must be done with automated analyzers--the manual bubbler methods are not permitted.

Table 7. Comparison of QA Requirements for Appendix A (SLAMS) and Appendix B (PSD)

Topic	Appendix A	Appendix B
Requirements	1. Develop and implement an approved quality control program. 2. Assess data quality in terms of precision and accuracy. 3. Use reference, equivalent, or approved methods. 4. Use traceable standards. 5. Participate in EPA performance audits and permit EPA to perform system audits.	
Monitoring and QA Responsibility	State/Local Agency	Source Owner/Operator
Monitoring Duration	Indefinitely	Up to 12 months
QA Reporting Period	Calendar quarter	Sampling quarter
Accuracy Assessment Audits	Standards and equipment different from those used for spanning and calibration. Prefer different personnel.	Personnel, standards, and equipment different from those used for spanning and calibration.
Audit Rate -Automated -Manual	25% per quarter Hi-vol and Pb - 25% per quarter. SO & NO_2 - Each analysis day, at least twice per quarter.	100% per quarter 100% per quarter (No manual SO_2 or NO_2 permitted).
Precision Assessment		
-Automated (precision gas check)	One point precision check biweekly - more frequent encouraged. Independence not required.	
-Manual (collocated sampling)	Two sites, every sixth day, or at least once per week for NO_2, SO_2 and TSP. Duplicate strips or aliquots for Pb.	One site: at least once per week or every third day for daily monitoring (TSP and Pb).
Reporting	By reporting organization.	By site.

The requirements for precision assessment for the automated methods are the same for both SLAMS and PSD. However, for manual methods, only one collocated site is required for PSD and the frequency is once per week instead of every sixth day as is usual for SLAMS.

The precision and accuracy data for PSD is reported separately for each sampler (site), whereas for SLAMS, the report is by reporting organization.

It should be recognized that the requirements of Appendix A and Appendix B are minimum requirements. The permit-granting authority for PSD may require more frequent or more stringent requirements than stated in Appendix B. Also, the Regional Offices may require more frequent or more stringent requirements for SLAMS than those stated in Appendix A.

10.4 QUESTIONS AND ANSWERS

A series of workshops was conducted in each of the 10 EPA regions to review the background, rationale, and requirements of the May 10, 1979 regulation (40 CFR Part 58) with region, state and local agency personnel. During the conduct of the workshops numerous questions were raised by the regional, state and local agency personnel concerning interpretations of the requirements and guidance for implementing the requirements of the regulation in special cases and circumstances. This section presents the questions raised and the answers given.

1. Q. What is the relation between the Quality Assurance Criteria (QAC) program and the Precision and Accuracy Reporting System (PARS)?

A. The QAC program was designed as a qualitative means of "scoring" data quality from knowledge of siting, probe location, measurement method, etc. (i.e., technical criteria) with judgmental weights. The QAC program was intended as as interim method of judging data quality for past periods until the PARS system became effective, January 1, 1981. Unless required to be continued by the Regional Offices, the QAC program has been terminated.

2. Q. Are video tapes available of the Regional Workshops conducted by EPA (EMSL/RTP and OAQPS) on regulation 40 CFR Part 58?

A. Yes, a series of color video tapes on the regulation covering condensations of the material presented at workshops by members of the EMSL/RTP and OAQPS at each of the ten Regions is available on loan from the Air Pollution Training Institute, EPA (MD-17), Research Triangle Park, North Carolina 27711. These tapes provide a systematic review of the requirements of the regulations, including those portions dealing with the precision and accuracy reporting (7).

3. Q. The regulations (CFR Part 58, section 58.23) require that SLAMS be fully implemented, including the requirements of Appendix A, by January 1, 1983. The regulations (section 58.34) require that NAMS be

fully implemented, including the requirements of Appendix A, by January 1, 1981. Further, Appendix A specifies the minimum requirements for SLAMS.

Section 4.1.1 of Appendix A, requires precision data from all approved SLAMS analyzers. Section 4.1.2 of Appendix A requires accuracy data from all approved SLAMS analyzers. The instructions for Form 1 (Appendix A, Section 5.3, Block No. 15-17) state that only approved analyzers in the network be counted and reported. (1) What, if any, is the difference between approved and reference or equivalent methods?; (2) What analyzers/methods are to be included in the precision checks and accuracy audits and reported?; and (3) How does the difference in the implementation dates (January 1, 1983 for SLAMS and January 1, 1981 for NAMS) affect the requirements for precision checks and accuracy audits and the reporting thereof?

A. (1) An approved analyzer is a reference or equivalent method or an analyzer otherwise approved under 40 CFR Part 58, Appendix C.

(2) Reporting of precision and accuracy data is required for all reference, equivalent or approved methods used at designated, fully approved, and operational SLAMS sites.

(3) The results of the special checks for precision and accuracy for both automated analyzers and manual methods are intended to represent the precision and accuracy for the entire reporting organization for the SLAMS network. Since the NAMS is a part of SLAMS, the same precision and accuracy data represent the NAMS as well as SLAMS. Further, the intent of the regulation is that the documented QA system (see section 2.2, 40 CFR Part 58) applies equally to NAMS and SLAMS. In other words, the QA system for NAMS is to be no different from that for all other SLAMS. NAMS sites are to receive no special treatment with respect to QA.

4. Q. Will EPA certify commercial supplier cylinders or permation tubes for users?

A. Yes. EMSL/RTP currently provides a service of certifying gas cylinders, permeation tubes, and flow measurement devices at no cost.

5. Q. What quality assurance requirements apply to the meteorological monitoring systems used to obtain data for modeling purposes for PSD?

A. No requirements are given in the regulations. However, Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD) EPA-450/2-78-019, May 1978, includes some recommendations (6). The QA for the meteorology measurement systems should be included in the documented QA plan. A guideline document, "Quality Assurance Manual for Meteorological Monitoring Systems" is currently in preparation.

6. Q. Where in the regulation is the form for reporting PSD precision and accuracy data?

A. There is no special form included in the regulation. However, Form 1 could be modified for use. A separate form, however, would be required for each site. The permit-granting authority should specify the format for reporting PSD data.

7. Q. If SLAMS data are used for PSD purposes, must the precision and accuracy requirements for PSD (Appendix B) be met?

A. If it is planned in advance by the permit-granting authority to use data from a SLAMS site for PSD purposes, i.e., the same site is used for both SLAMS and PSD, then it must meet the precision and accuracy requirements for both. Special considerations or decisions may be made by the permit-granting authority to use data from SLAMS sites.

8. Q. (a) Can the flow rate audit for TSP be performed in the laboratory or must it be performed in the field? (b) Can the precision checks and audits for automated analyzers be performed in the laboratory?

A. (a) The flow rate audit must be performed <u>in the field</u> with different equipment than used for calibration. (b) All precision and accuracy data are to represent field monitoring results. Consequently, precision and accuracy checks for automated analyzers must be made <u>in the</u>

field under monitoring conditions.

NOTE: By definition, precision data for manual methods result from field sampling. Only the accuracy audits for the SO_2, NO_2, and Pb manual methods are performed in the laboratory.

9. Q. Can the results of the precision and accuracy checks be used as a basis for invalidating routine monitoring data?

A. The intended use of the precision and accuracy checks is not for use as data validation or invalidation checks. Each agency should have developed and implemented a separate system for routine use in performing the data validation function and which should include various types of checks with associated validation/invalidation criteria.

It is possible that after a sufficient history of precision and accuracy data (e.g., after a year) have been accumulated, these data could, with appropriate statistical analysis, provide a basis for being used as validation/invalidation criteria, as a part of (in addition to) the routine data validation system.

If, however, precision and accuracy data are used to invalidate routine monitoring data, all of the monitoring data from the particulat site or sites (instrument or instruments) involved should be invalidated back to the last "acceptable" check of the same type. In such a case, the results of the precision check or accuracy audit involved should not be included in the calculations for reporting precision and accuracy data.

10. Q. Precision checks and/or accuracy audits may have been performed during a period for which routine monitoring data have been invalidated for cause. Should the results of the precision checks and accuracy audits be reported?

A. Not if routine monitoring data obtained immediately before and after the precision checks and accuracy audits, were invalidated for reasons that could have adversely affected the precision and accuracy results. The audits should be repeated as soon as practical after the invalidation of the monitoring data.

11. Q. Although the regulations require only one accuracy audit for the selected automated analyzers each quarter, an agency may decide to audit a given analyzer more than once during a quarter. In equations 8 and 9 (section 4.1.2 of Appendix A of the regulation), k is indicated as the number of analyzers audited during the quarter. If more than one audit is performed on an analyzer, what is the value of k?

A. With more than one audit on a given analyzer, k is the number of audits performed. For example, if two analyzers are audited--one twice and the other three times--the total number of audits is five. Therefore, k is 5, which should be used in the calculations and reported in Blocks 36-38 on Form 1 (front). The same procedure would also be used for audits of manual methods.

12. Q. On Form 1, the upper portion of the leftmost block in each group of blocks used for the reporting of the probability limits contains small +/- signs. Are the + or - signs, whichever applies, to be circled, or should a larger + or - sign be written or typed in?

A. The intent of the +/- signs was to remind those completing the form that either a + or a - sign must be entered preceding the two digit value. On some of the forms, the +/- is very faint. It is best to enter a large + or - sign in the block, rather than to circle the appropriate sign, or to delete the inappropriate sign.

13. Q. Does EPA provide any guidance on the conduct of independent performance audits?

A. Yes. Details concerning the conduct of performance audits for the TSP flow measurement and for automated continuous methods for sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone are provided in the EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Section 2.0.12 (5).

14. Q. Exactly how are precision and accuracy data to be computed when the samplers or analyzers may be changed at a given site?

A. Precision Checks

Automated methods - Compute results individually for each analyzer-site combination in actual use to obtain monitoring data during each quarter. Determine $\bar{d}$ and s for each analyzer-site combination. Combine the results as specified by the formulas in Appendix A or B. In formulas 4, 4a, 5, and 5a, k is the number of analyzer-site combinations.

Manual methods - Compute results individually for each collocated site, whether or not changes or replacements have been made in the samplers during the quarter. Compute $\bar{d}$ and s for each collocated site. Combine the results as specified by the formulas in Appendix A or B. In formulas 4, 4a, 5, and 5a, k is the number of collocated sites.

Accuracy Checks

Automated methods - Ideally, each analyzer-site combination in actual use to obtain monitoring data during the calendar year should be audited. Due to changes of analyzers at given sites, this will result in more combinations than there are sites.

In practice, by the end of each calendar year, each analyzer which has been used for routine monitoring should have been audited and each site should have been audited.

In planning for auditing, the "25 percent rule" should take the above into account.

Manual methods (TSP) - Although samplers or motors may be changed at given sites during the calendar year, it is considered necessary only to audit 25 percent of the sites each quarter, as a minimum. Ideally, each sampler-motor combination used to obtain routine monitoring data during the year should be audited. Normally, because of motor brush wear, motors or brushes are replaced approximately 3 times per year, with a once-every-sixth-day schedule.

15. Q. In addition to the audit levels specified in the regulation, an agency desires, for its own purposes, to audit at other levels. Are the audit results at these other levels to be reported to EPA?

A. No. Only the results at the levels specified in the regulation are to be reported to EPA.

16. Q. How are the precision and accuracy data applicable to monitoring data with respect to compliance to the ambient air standards?

A. The precision and accuracy data (probability limits) reported to EPA cannot be used directly in relation to compliance to air quality standards or to attainment/non-attainment for several reasons. First, compliance standards are determined from site specific information. Any consideration of precision and accuracy data would be limited to the specific sites and time periods involved. Such data would be available only at the local agency.

Further, to be relatable to a standard, any precision and accuracy data would have to be appropriately transformed to (a) the same time-averaging basis as that of the air quality standard and (b) to the same pollutant concentration level as the standard on measurements obtained.

In the determination of attainment/non-attainment, other related information may need to be considered, such as

a. Time series history and continuity of the pollutant measurements at the site(s) involved
b. Aggregate frequency distribution of the pollutant measurements on the same time-averaging basis as the standards at the site(s) involved
c. Meteorology
d. Frequency of non-compliance to standards
e. Magnitude of exceedance of the monitoring data above the standard.

The requirements for quality assurance data on precision and accuracy were not established for purposes of relating the information to standards or to attainment/non-attainment, but rather to obtain some measure of data quality and to improve the data quality from the nation's monitoring networks, where indicated by the precision and accuracy data.

Until appropriate statistical procedures are developed, the probability limits on precision and accuracy can <u>not</u> be used directly with

relation to meeting standards or determining attainment/non-attainment. The probability limits for precision and accuracy are not confidence limits on true pollutant concentration levels.

17. Q. Section 5.2 of Appendix A of the regulation specifies that "simple unweighted arithmetic averages of the probability limits for precision and accuracy from the four quarterly periods of the calendar year" be computed and reported with the annual SLAMS report. Why are the results of the precision checks not weighted using formulas 4a and 5a of section 4.1.1 (b) as is required for quarterly reporting? Also, why are the results of the accuracy audits not weighted?

A. The major reason for computing the annual limits in this way was the simplicity of the computations--aimed particularly for agencies without sophisticated computing capability.

For annual precision limits, it may be more statistically correct to compute the limits weighting the results from each site or instrument for the entire year by the number of precision checks made on each site or instrument by using formulas 4a and 5a. However, it is doubtful that, from a practical standpoint, there will be appreciable differences between the limits calcualted by the more complicated weighted procedure and the limits calculated by simple averaging.

For the more complicated weighted procedure to be more correct statistically, it must be assumed that the ratios of the numbers of precision checks at given sites or instruments during the year to the number of ambient pollutant data values reported from the sites or instruments during the year, are essentially the same.

For the annual accuracy probability limits, it would be most correct statistically to compute the limits by using the results of all audit checks made during the year whether or not multiple audits have been made for a given instrument or site during the year. The computations would be made using equations 8 and 9 (not equations 4a and 5a) using all of the audit data for the year. Here again, it is doubtful that the results will be, from practical standpoints, appreciably different from those using the simple averaging method. The results of accuracy checks are aimed primarily at measuring the correctness of the calibration system

used throughout the reporting organization, even though during a given quarter, only about one-fourth of the instruments or sites may be audited. If multiple audits are made during a given quarter (as some reporting organizations may desire to do) presumably the multiple audits of the same instrument or site would not be performed during the same month, and therefore, the multiple audits would represent different audits in time of the reporting organization's calibration system.

Therefore, each audit is considered as a separate audit of the calibration system, whether or not multiple audits of the same site or instrument are performed during any given quarter, or during the year.

In effect, the sites or instruments which have been audited more than once are given additional weight by including the individual results of each audit.

Manual Methods

18. Q. For results of the manual methods, it is stated that at least 25 percent of the high-volume and Pb samplers (Section 3.2.2 (a) of Appendix A) be audited each quarter. Is it required that the duplicate sampler in the case of collocated sites be included in the accuracy audits?

A. No. It is not required that the duplicate sampler be audited. Since the designated sampler will be audited, paired data from the two samplers are available from the precision check for accuracy comparison. However, the local agency might consider it desirable to audit the duplicate sampler.

19. Q. Section 2.3.3, Appendix A, 40 CFR Part 58, states that flow measurement equipment must be traceable to an authoritative volume or other standard. Will the use of Class A volumetric glassware satisfy this requirement?

A. Yes, if it is of sufficient size. For example, when checking a wet test meter having a 1 liter per revolution dial, a 2 liter (or larger) volumetric flask should be used. Other means of satisfactory traceability are (a) commercial NBS-traceable bubble meters, or (b) mass

flowmeters calibrated with wet or dry test meters which are NBS-traceable.

20. Q. How are flow audits conducted for the TSP method when flow controllers are used? How are the results calculated?

A. A filter is used with the orifice plate or reference flow device. The flow rate determined by use of the flow transfer standard considered the true value (the X value), and the observed level (the Y value) is the flow rate indicated by the sampler's flow indicator or the flow rate setting (assumed flow rate) of the flow control device.

21. Q. Can the collocated high-volume samplers use the same timers for automatic start and stop?

A. Ideally, they should be operated as independently as possible to involve all of the variables in the measurement process. Some Regions require that the collocated samplers be independent to the degree that they are plugged into different electrical outlets. However, since timer variation should be small, a common timer may be permissible by the Regional office or permit-granting authority.

22. Q. In some cases, for PSD sampling, as many as 4 (or more) high-volume samplers may be used with automatic start-stop timers at a given site in order that the samplers may operate unattended for 4 (or more) successive days. Must the collocated (duplicate) sampler <u>always</u> be used with the same designated sampler?

A. No.

23. Q. Must the duplicate sampler, in such a case, always be the same sampler?

A. No, but it would be desirable. If different duplicate samplers are used during a report quarter, the results should be examined separately for each duplicate sampler.

24. Q. Can the collocated bubbler samplers use the same vacuum pump?

A. Ideally, they should have separate vacuum pumps and be independent to the degree that they are plugged into different electrical outlets. However, from practical considerations, a common vacuum pump may be permissible by the Regional office.

25. Q. For manual methods, Form 1 (back) requires the number of samplers of each type which are operational in the network to be reported in Blocks 15-17. Are the duplicate samplers for each collocated site included?

A. No, the duplicate samplers are not counted. The intent is to obtain the number of SLAMS sites at which the manual samplers (reference, equivalent, or approved methods) are being operated.

26. Q. Can the sites selected for collocation be changed at any time?

A. Yes, although it would be best to change only at the beginning of a calendar quarter or a calendar year. If a change is made within a calendar quarter, the new site, or sites, shall be treated separately for calculation and reporting purposes. Thus, if one of two collocated sites is changed during a quarter, the results shall be treated and calculated as three separate sites.

For local quality control purposes, different biases (and variabilities) might be expected at the new site compared to the old site. Therefore, the results should not be combined when calculating the averages and standard deviations for the quarter. Similarly, if quality control charts are maintained--as they should be--at the local agency, it may be necessary to establish new control limits for the results from the new site.

27. Q. In the case of collocated samplers, if either the designated or duplicate sampler gives results that are below the minimum detection limits, should the precision data be reported?

The minimum detection limits are:

TSP	1 µg/m³
NO_2	15 µg/m³ (TGS-ANSA)
	9 µg/m³ (sodium arsenite)
	9 µg/m³ (sodium arsenite with Technicon II)
SO_2	25 µg/m³ (for a 30 liter sample in 10 ml of TCM absorbent)
(Pb)	0.07 µg/m³

A. No, the precision data must not be reported if either the designated sampler result or the duplicate sampler result is below the detection limit. Also note that if a pair of values are not reported, it is not to be counted in the "No. of valid collocated data pairs" entered in blocks 58-60, Form 1 (back). Further, the entry for blocks 30-23 "No. of collocated samplers < limit" must include only those readings from the designated sampler that have been used in the computation for precision. precision. Note that the limits given on Form 1 in the block and applicable to data blocks 20-23 are not the detection limits.

The determination of the 95 percent probability limits for precision in no way changes the reporting requirements of SAROAD. All data, regardless of concentration, shall continue to be reported in the standard manner.

28. Q. If past precision results from collocated sites are used to establish data validation limits,* and the precision results for a given day exceed the established limits, should the precision data be reported?

A. If the established data validation limits are exceeded due to excessive lack of agreement between the results of the collocated samplers and the result from the designated sampler is not reported (i.e., the value has been invalidated), then the results must not be included in the computations for reporting precision. The monitoring data from both the designated sampler and the duplicate sampler should be invalidated, i.e., neither should be reported as routine monitoring data.

In some instances, the excessive difference may be due to a known cause affecting only the duplicate (or designated) sampler results, in which case the result from the designated (or duplicate) sampler may be reported as monitoring data.

29. Q. Is a high-volume sampler with an automatic flow controller a reference or equivalent method?

A. It is considered as a reference method.

30. Q. For collocated high-volume samplers, how should the roofs of the two instruments be oriented?

A. The high-volume reference method does not restrict or specify the orientation of the ridge of the roof with respect to compass direction, with respect to the direction of predominate wind, or with respect to any other reference. Unless the region, state, or local agency has stipulated some requirement on the roof orientation, as for any individual high-volume sampler, then the roof orientations of the collocated samplers should not be restricted. The roof orientations should occur in whatever (random) direction results from the installation. In other words, roof orientation variability is a part of the method variability, and the two collocated samplers should not be made more alike than would result if they were installed separately as individual samplers without regard to the other.

31. Q. Will EMSL/RTP supply excess bubbler solutions (QC reference samples used in EPA performance audits) for use as audit materials?

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*NOTE: Any such data validation limits should be specified in the agency's documented quality control program subject to approval by the EPA Regional Office. Further, the occurrence of an excessive lack of agreement should raise questions concerning the validity of data acquired previously, and should initiate some corrective action investigation.

A. Yes, but only if extra (spare) solutions are available. However, it is not EMSL's practice to procure a large number of excess QC reference samples for this purpose. Further, the concentrations may not be in the ranges required by the regulations.

32. Q. (a) When monitoring for lead in particulate matter, can the flow audits for TSP automatically be used as the flow audit data for lead? As an example, suppose a network has a total of 16 hi-vols, 12 of which are used for TSP and 4 of which are used for lead. Must one of the 4 hi-vols used to monitor lead be audited each quarter? Or could the 4 hi-vols used to monitor lead be grouped with the 12 hi-vols used to monitor TSP, so that each quarter, 4 of the total hi-vols are audited, the ones used for lead being audited randomly within the year?

(b) In some cases, the same hi-vol sampler may be used for both TSP and lead. Does this mean that such samplers must be audited at least twice each year, once for TSP and once for lead?

A. (a) According to Section 3.22 (d) of the Pb regulation (2), the Pb sites are to be grouped with the TSP sites. The sites audited should be selected at random from the entire group of sites, such that 25 percent of the sites are audited each quarter. The results obtained from these audits will be reported as for TSP but will be considered as representative measures of the precision of flow measurements for both TSP and Pb.

(b) No. If a sampler is used for both TSP and Pb, it need be considered only as a single site for auditing purposes.

33. Q. Since the requirements of the regulation are considered as minimum requirements, some agencies may decide, or some Regional Offices may require, the use of collocated samplers to estimate precision for Pb. If so, how will this fact be indicated?

A. It should be indicated by entering a written note on Form 1 beneath data blocks 24-29 (for Pb) stating "dup. samplers."

34. Q. Signed percentage differences of the results from collocated samplers are used for precision estimates for NO_2, SO_2, and TSP. How are the signs of the percentage differences for Pb results to be assigned?

A. For duplicate strips, one of the strips, by location of the strip within the filter, can be considered the "designated" value and the other, the duplicate. Once the designations are made, the same designations should continue to be used.

In the case of duplicate analyses of the extract from a single strip, the first analysis should be considered as the "designated" value, and the second, as the duplicate.

35. Q. For lead monitoring, some states and local agencies prepare and analyze composite samples formed by combining strips from a number of filters. In such cases how should the precision data be obtained?

A. The recommended procedure would be to prepare two separate composites and analyze each independently. The signed percentage differences would be obtained by subtracting the first analysis result from the second and dividing by the first value. The first analysis value would be considered as the designated and reportable value. Equations 10 and 11 of section 4.2.1(b), Appendix A, would be used in computing the appropriate probability limits. If such a compositing procedure is used, that fact should be indicated by entering a written note on Form 1 beneath data blocks 24 - 29 (for Pb) stating "duplicate composites".

36. Q. Some agencies have automated analyzers (O_3, SO_2, NO_2) with ranges as high as 5 ppm, and some use ranges as low as 0.5 ppm. At what levels should the precision check and the accuracy audits be performed?

A. The levels of the precision check and the accuracy audits must conform to the levels specified in the regulation. Therefore, if the range of O_3, SO_2, or NO_2 analyzers equals or exceeds 0.08 ppm (8 ppm for CO), the precision check can be performed within the specified 0.08 to 0.10 ppm level (8 to 10 ppm for CO).

It is assumed that most SLAMS sites for routine monitoring will have O_3, SO_2, and NO_2 analyzers with a full-scale range of 0.50 to 1.0 ppm (50-100 ppm for CO). It is further assumed that analyzers will be calibrated over their range (or ranges, if equipped with a range selector switch) of intended use. For example, if a SO_2 analyzer equipped with a range selector switch is operated with a 0.50 ppm range for routine monitoring and a 1.00 ppm range for episode monitoring and is intended to be used at both range settings, then the analyzer should be calibrated separately on each range setting. In this case, the analyzer is audited at three levels (0.03-0.08 ppm, 0.15-0.20 ppm, and 0.35-0.45 ppm) on the 0.50 ppm range setting and it will be audited at four levels (0.03-0.08 ppm, 0.15-0.20 ppm, 0.35-0.45 ppm, and 0.80-0.90 ppm) on the 1.00 ppm range setting. Thus, it will be audited at seven conditions, and the results will be reported accordingly. If the range for O_3, SO_2, or NO_2 exceeds 0.90 ppm (even as high as 5 ppm or 10 ppm), or if the range for CO exceeds 90 ppm, then the audits are required at the four levels specified. No audits are required to be reported at levels higher than 0.90 ppm for O_3, SO_2, or NO_2, or higher than 90 ppm for CO. However, it would seem reasonable that the local agency should for its own internal quality assurance, calibrate their high-range instruments and perform audits at higher levels of expected concentrations.

Automated Methods

37. Q. For automated analyzers, Form 1 (front) requires the number of analyzers of each type which are operational in the network to be reported in Blocks 15-17. If the state or local agency is operating a non-reference, non-equivalent, or non-approved analyzer at a special purpose site, should the results of this analyzer be reported?

A. No. The report applies only to SLAMS sites which, beginning on January 1, 1981, must use reference, equivalent, or approved methods. If, for some reason, a state or local agency is permitted by the Region to use a non-reference, non-equivalent, or non-approved analyzer at a SLAMS site, it should then be included. The same rules would apply to manual methods as well.

38. Q. When performing precision checks or performance audits for automated analyzers, the average output should be obtained over what time period of equilibrium response?

A. The time to reach equilibrium conditions and the time period over which the response should be averaged will depend upon the instrument and level of the standard being used. As a rule, it should be the same as is used to obtain calibration data points at the same levels.

39. Q. In some cases, due to instrument replacement or scheduled start-up at a given site, only one precision check may have been made on an automated instrument during the quarter. In such cases, the standard deviation is zero for that instrument. Should the zero be included in the calculation of the pooled standard deviation, S_a? How is the precision result reported?

A. It can be handled in one of two ways.

1. If precision checks are made on the instrument during the succeeding quarter, the single result can be held over and combined (calculated and reported) with the results of the succeeding quarter.
2. If, for some reason, no precision checks are performed or planned to be performed during the succeeding quarter, the single value could be included in the calculation of the average, D, but not included in the calculation of the pooled standard deviation, S_a.

40. Q. Auditing must be conducted with a different standard than that used for routine multipoint calibration. What relationship must exist between the standard used for accuracy auditing and the standard used for routine multipoint calibration?

A. The general rule is: The working standard used for the accuracy audit must be different from the working standards used for calibration, but both may be certified (referenced) against the same NBS SRM or CRM. A protocol for certifying the working calibration or audit

standard against an SRM or CRM is given in Section 2.0.7 in Reference 5. (CRM's were authorized for use as traceable standards by amendments to 40 CFR Parts 50 and 58 on January 20, 1983 (48 FR 2528-2530)).

41. Q. Can the NBS SRM traceability requirement be met if I use a NBS "traceable" cylinder gas or permeation tube from a commercial supplier?

A. Yes, but caution should be exercised and complete certification documentation should be received with the NBS-traceable items.

42. Q. The regulations state the "Direct use of an NBS SRM as a working standard is not prohibited but is discouraged because of their limited supply and expense." Should NBS SRM's be used for the accuracy audits?

A. No. As stated in the regulations, NBS SRM's are in limited supply, and should be used only sparingly as references to which working calibration standards (and accuracy audit standards) are assessed. CRM's may also be used in lieu of NBS SRM's; see answer to previous question.

43. Q. In some networks, the output from automated analyzers is fed into a data logger or minicomputer or transmitted by telemetry to a central station or computer. When conducting a performance audit, at what point in the total measurement system should the observed or measured value be obtained?

A. The observed or measured value should be obtained at the same point and in the same manner that routine monitoring data are obtained. In other words, the performance audit should be an audit of the entire routine measurement system--not just the analyzer. (The same conditions should apply for the calibration process.) If the normal output of an analyzer is measured and reduced by a computer in another location, the performance audit result (and calibration data) should be obtained in the same way. Since there is usually a major concern for the analyzer, however, it would be good practice to also check its output with a (digital) voltmeter or recorder. It is possible that the analyzer could be

functioning perfectly but the rest of the system could be malfunctioning, or vice versa.

44. Q. Some automatic instruments have daily (i.e., every 24-hours) automatic injections for zero. In the normal reduction of data, the data between successive automatic zero injection checks are corrected by the average of the "before" and "after" zero drifts. Since the regulations state that the precision check should be made prior to any adjustment, what should be the procedure for calculating the result of the precision check for this type of instrument?

A. The procedure is the same as that used for routine ambient measurements: the precision check reading should be processed exactly the same as it would be if it were an ordinary ambient reading. If the zero injections occur on a fixed schedule, then, to the extent possible, the precision checks should be randomly timed, i.e., at various times of day or at various times with respect to the automatic cycle. The same would also apply to automatic span cycles. See also the answer to the next question. In either case, do not make any adjustments to the instrument until after the above checks have been performed.

45. Q. Some instruments (Beckman 866) have built-in automatic electronic stabilizers which readjust zero and span every 8 hours based on the automatically performed zero and span checks. When should precision checks and accuracy audits be performed?

A. Ideally, the precision checks and accuracy audits should be performed at random times between instrument adjustments. If the schedule of the automatic adjustments is known to those performing the precision checks and accuracy audits, the precision checks and accuracy audits should be scheduled at random times between the adjustments. If the schedule of the automatic adjustments is not known to these persons, then the precision checks and accuracy audits could be performed at any time of the day. (See also the answer to the previous question.)

46. Q. Some ozone analyzers are operated only six months of the year. How shall precision and accuracy data be obtained and reported?

A. Precision checks will be made on all operating monitoring instruments on the minimum biweekly frequency specified; no special considerations need to be made, except in the unlikely case where only a single precision check is made in a quarter. Because the standard deviation cannot be computed from the single value, the result of the precision check should be held and combined with data for the previous or subsequent quarter, as appropriate. Therefore, if no precision check (or only one precision check) is made in a given calendar quarter, no precision data will be reported.

The purpose of obtaining the precision data is to relate it to scheduled monitoring data, there would be no purpose in obtaining precision data when no monitoring data are being obtained.

The regulations require that all operating analyzers be audited during the year. If ozone analyzers are operated only six months (e.g., two quarters), then 50 percent of the analyzers must be audited each quarter. If the six-month period covered more than two quarters (e.g., May through October), some analyzers could be scheduled for audit in each of the three quarters. If only one audit is performed in a given quarter, the audit results should be reported with audits of the previous or following quarter, since a standard deviation cannot be calculated for a single value.

47. Q. Philips SO_2 instruments require a new calibration whenever the reagent is changed--approximately every 90 days. When should accuracy audits be performed?

A. Accuracy audits (and precision checks) should be performed at random times between multipoint calibrations or other adjustments of the analyzer. Consequently, neither accuracy audits nor precision checks should be performed immediately <u>after</u> such calibrations or adjustments. To minimize costs, (i.e., to eliminate extra trips to sites) accuracy audits and precision checks could be performed just <u>before</u> such calibrations or adjustments. Since the Phillips SO_2 instrument may have has automatic

daily zero and span checks and adjustments, the precision checks and accuracy audits should be made at random times between such automatic adjustments (or immediately before such adjustments).

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16. ABSTRACT

The federal regulations for ambient air quality surveillance were revised May 10, 1979, to include requirements that states perform certain specified tests to assess the precision and accuracy of their air pollution measurement systems and report the results to EPA routinely. This guideline document discusses the concepts and definitions of precision and accuracy as they relate to ambient air pollution measurement systems. The rationale used in developing the specified procedures for acquiring precision and accuracy assessments is explained for both manual and automated measurement methods. The computational procedures specified for the handling of the precision and accuracy data and the development of the statistical assessments for reporting to EPA are reviewed. Particular emphasis is given to the potential use by the states and local agencies of the precision and accuracy data as an adjunct to their routine quality assurance programs. A number of statistical quality control charts are recommended for routine use by the states and local agencies. Answers are provided for many questions raised concerning interpretation of the requirements of the regulation and procedures for handling special case situations not specifically detailed in the regulations.

17. KEY WORDS AND DOCUMENT ANALYSIS

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