

2015 Annual Data Quality Report

Monitoring and Laboratory Division
Quality Management Branch
Primary Quality Assurance Organization

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2015

Annual Data Quality Report

California Air Resources Board's
Primary Quality Assurance Organization

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Quality Management Branch
Monitoring and Laboratory Division
Air Resources Board

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Executive Summary

The Code of Federal Regulations (CFR) defines the California Air Resources Board (ARB) as one of four primary quality assurance organizations (PQAO) in California responsible for monitoring air pollutants and assessing data quality. The purpose of this report is to provide ambient air quality data producers and users with a centralized review of the data quality within ARB's PQAO with respect to measurement quality objectives (MQO).

The MQOs reviewed include data capture (amount of ambient data reported), precision (the degree of mutual agreement among individual measurements of the same property), bias/accuracy (the degree of agreement between an observed value and an accepted known or reference value), and the amount of precision and bias/accuracy data collected and reported. The criteria by which the assessments are made are mostly dictated in CFR¹ and are listed in Appendix A of this report. Appendix B provides details on the instruments/samplers that did not meet certain criteria. Where appropriate, comparisons to other PQAOs in California and the national average² are also made. The other PQAOs in California include: Bay Area Air Quality Management District (BAAQMD), San Diego County Air Pollution Control District (SDCAPCD), and South Coast Air Quality Management District (SCAQMD). It is important to note that this assessment is solely based on data available in U.S. Environmental Protection Agency's (U.S. EPA) Air Quality System (AQS). PQAOs may have collected certain precision and/or bias/accuracy data that was not uploaded to AQS; in some cases, that particular data was not federally required to be uploaded.

The gaseous criteria pollutants assessed include: carbon monoxide (CO), ozone (O₃), nitrogen dioxide (NO₂), and sulfur dioxide (SO₂). The ambient data capture rate represents the percentage of ambient data collected and uploaded to AQS to that of the total amount of data possible. For gaseous pollutants, one-point quality control (QC) precision checks (mostly automated) are performed by the monitoring organizations to confirm the instrument's ability to respond to a known concentration of gas. Precision represents the degree of variability among the one-point checks. The one-point checks are also used to assess bias/accuracy for each instrument. This is done by comparing the difference between the instrument response and a reference gas.

Precision for most particulate matter (PM₁₀ and PM_{2.5}) samplers is assessed via collocated sampling whereby two identical or equivalent samplers are operated side-by-side.³ Bias for PM samplers is assessed by using the routine flow rate verifications performed by site operators. Note that while all PM samplers are required to undergo monthly flow rate verifications except for high-vol PM₁₀ samplers, where quarterly flow checks are required, only flow rate verification data for continuous PM₁₀

¹ Title 40 CFR Appendix A to Part 58.

² National average includes state, county, district, National Park Service, and tribal sites, including those in California.

³ Collocated sampling is required for all PM samplers except continuous PM₁₀.

samplers are required to be uploaded to AQS. Starting in April 2016, this requirement will apply to all PM samplers.

Accuracy for both gaseous instruments and PM samplers is further verified by the performance evaluation audit program using through-the-probe audit techniques on gaseous instruments and checking flow rates on particulate samplers. The ambient data capture rate and the accompanying precision and accuracy data for 2015 from both gaseous instruments and PM samplers are summarized below.

Gaseous Instruments

Key findings and recommendations pertaining to gaseous instruments are highlighted below.

- Ninety-eight percent of the gaseous instruments operating under ARB's PQAO achieved the ambient data capture rate of at least 75 percent in 2015.
- Ninety-seven percent of the gaseous instruments operating under ARB's PQAO reported at least 75 percent of the required QC checks submitted to AQS.
- CFR precision and bias/accuracy criteria (from one-point QC checks) were met at the PQAO level.
- Performance audit data indicate that, except for a few instruments, ARB's PQAO met the audit criteria. This finding is consistent with the bias information obtained from the one-point QC checks.
- These findings are consistent with those in 2014.

Recommendation – Gaseous Program

- Although MQOs associated with the gaseous instruments were met at the PQAO level, there were instances of analyzers not meeting the MQO (e.g., ambient data capture rate, submittal of required QC checks, etc.). Monitoring agencies should investigate why these objectives were not met for each analyzer in their respective jurisdictions and develop corrective actions, if appropriate, to meet them in subsequent years.

PM Samplers

Key findings and recommendations pertaining to PM instruments are highlighted below.

- Ninety-seven percent of the particulate samplers operating under ARB's PQAO achieved the ambient data capture rate of at least 75 percent in 2015.

- ARB's PQAO did not meet the required number of collocated sampling sites for PM10 and for one method of collecting PM2.5 in 2015, an improvement compared to previous years, when more than one method did not meet the requirement. A detailed assessment of this can be found in ARB's *Annual Network Plan Covering Operations in 25 California Air Districts, June 2016*.⁴
- For the thirteen pairs of collocated PM2.5 samplers that were present within ARB's PQAO in 2015, all reported at least 75 percent of the required precision data. (See Table B3 for more details.)
- For the PM collocated data that were collected and reported, ARB's PQAO met the precision criteria for PM10 except at one location. However, the precision for PM2.5 for all methods was not met. Compared to 2014, the coefficient of variation (CV) values in 2015 are about the same for most of the methods, indicating a persistent problem with PM2.5 precision. (See Table B3 for more details.)
- Although there is no specific MQO for bias between collocated PM samplers, an assessment of bias between collocated PM samplers was performed and showed some unusually high values. (See Table B4 for more details.)
- Flow rate verifications are required to be performed on all PM samplers, but only those from continuous PM10 are required to be uploaded to AQS (starting April 2016, all will be required to be in AQS). Data from several continuous PM10 samplers were not reported to AQS for 2015. Similar problems existed in 2014.
- The audit accuracy data indicates that ARB's PQAO met ARB criteria for flow rate audits. This finding is consistent with the limited bias information that can be ascertained from the routine flow rate verification data available in AQS.

Recommendations – PM Program

- ARB and the local air monitoring agencies within ARB's PQAO should continue to work in collaboration to ensure that the entire ARB PQAO meets the federal collocation requirement for monitoring PM. This includes, but is not limited to, deploying additional samplers and clearly defining in AQS the primary and secondary samplers.
- High CV values between collocated PM2.5 samplers have been observed within the ARB PQAO and at a national level. Although ARB has conducted an assessment of the potential causes behind low PM2.5 precision and the large bias between some of the collocated PM2.5 samplers within the ARB PQAO, no definitive source of the issue has been identified. Some of the observations from

⁴<http://www.arb.ca.gov/aqd/amnr/amnr2016.pdf>

our assessment include: 1) ambient PM_{2.5} values in California are somewhat higher than the rest of the nation; 2) CV values tend to be higher among collocations of non-identical methods (i.e. FEM collocated with FRM) than those of identical methods; 3) empirically, due to the inherent nature of percent differences being magnified in the low concentration range, CV values would decrease if the cut-off limits were raised from 3 ug/m³; 4) sites that meet the CV criteria are not consistent from year to year.

- Air monitoring agencies within ARB's PQAO are encouraged to upload flow rate verification data to U.S. EPA's AQS for all PM sampling methods. Although only data from continuous PM₁₀ samplers are required to be uploaded, to enhance consistency in regulation and avoid any confusion, starting in April 2016, U.S. EPA requires that data on flow rate checks be uploaded to AQS for all PM sampler methods.⁵ Such information will allow for a more comprehensive assessment of PM accuracy.
- Aside from the above recommendations, there were instances of samplers not meeting the MQOs (e.g., ambient data capture rate, submittal of required collocated measurements, etc). Monitoring agencies should investigate why these objectives were not met for each sampler in their respective jurisdictions and develop corrective actions, if appropriate, to meet them in subsequent years.

In an effort to compare 2015 data quality results across geographic areas within California, Table ES-1 presents results for both gases and PM in one composite table. To make a fair comparison, we divided the geographic areas into three categories according to monitoring activities: 1) gas only; 2) gas and PM without collocation; and 3) gas and PM with collocation. Below are some key observations from Table ES-1 (they are similar to results from 2014):

- There are two areas that monitored gases only, and both achieved all MQOs.
- Among nineteen areas that monitored gases and PM without collocation, thirteen met all MQOs, three did not meet the MQOs for ozone only, one did not meet the MQOs for PM only, and two did not meet for both ozone and PM.
- Among nine areas that monitored gases and PM with collocation, none achieved all MQOs, mainly due to high CVs associated with PM_{2.5}.

The statistics reported herein are intended as assessment tools for the data producers and users to identify areas where program improvements can be made to achieve all MQOs set by U.S. EPA or the data producers themselves. Although CFR criteria for precision and accuracy are generally applied and evaluated at the PQAO level, assessments at the district or site level may differ and can be important as well. However, it is important to note that when certain CFR criteria are not met, it does not necessarily mean that the corresponding air quality data should not be used, but rather,

⁵https://www3.epa.gov/ttn/amtic/files/ambient/pm25/Summary_of_Appendix_A_Changes_%203_25_2016.pdf

the data should be used with the knowledge of the quality behind it. The 2015 ambient data in AQS for ARB's PQAO have been certified and are considered suitable for comparison to federal standards.

In addition, data producers are encouraged to review their monitoring networks to ensure that AQS accurately reflects the number of sites/samplers operating and that all required ambient, precision, and accuracy data collected are continually reported to AQS in a timely manner (within 90 days of the end of each quarter per CFR).

Table ES-1. Composite Table of Ambient and QA Results (Both Gas and PM) for Local Districts Within ARB’s PQAO

Geographic (Area)*	All Gaseous Inst. Achieve ≥ 75% Data Capture Rates?	All Gaseous Inst. Reported ≥ 75% QC Checks?	All Gaseous Inst. Attained CFR Precision Criteria?	All Gaseous Inst. Attained CFR Bias Criteria?	All Gaseous Inst. Audited?	Did All Meet ARB Perf. Audit Criteria?	All PM Samplers Achieve ≥ 75% Data Capture Rates?	Were ≥ 75% of Precision Data Reported from Collocated Sites?	Did Collocated Sites Achieve CFR Precision Criteria?	FRV Data Reported for Continuous PM10?	All PM Samplers Audited?	Did All Audited Samplers Meet Flow Rate Audit Criteria?
Amador County	✓	✓	✓	✓	✓	✓	N/A	N/A	N/A	N/A	N/A	N/A
Antelope Valley	X	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	X	✓
Butte County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Calaveras County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Colusa County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Eastern Kern	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	X	✓
El Dorado County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Feather River	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Glenn County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓

Table ES-1 (cont'd). Composite Table of Ambient and QA Results (Both Gas and PM) for Local Districts Within ARB's PQAO

Geographic (Area)*	All Gaseous Inst. Achieve ≥ 75% Data Capture Rates?	All Gaseous Inst. Reported ≥ 75% QC Checks?	All Gaseous Inst. Attained CFR Precision Criteria?	All Gaseous Inst. Attained CFR Bias Criteria?	All Gaseous Inst. Audited?	Did All Audited Inst. Meet ARB Perf. Audit Criteria?	All PM Samplers Achieve ≥ 75% Data Capture Rates?	Were ≥ 75% of Precision Data Reported from Collocated Sites?	Did Collocated Sites Achieve CFR Precision Criteria?	FRV Data Reported for Continuous PM10?	All PM Samplers Audited?	Did All Audited Samplers Meet Flow Rate Audit Criteria?
Great Basin	✓	X	✓	✓	✓	✓	✓	✓	X	✓	✓	✓
Imperial County	✓	✓	X	✓	✓	✓	✓	✓	X**	✓	✓	✓
Lake County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Mariposa County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Mendocino County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Mojave Desert	X	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓
Monterey Bay	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓
North Coast	X	✓	✓	X	✓	X	✓	N/A	N/A	✓	X	✓
Northern Sierra	✓	✓	✓	✓	✓	X	X	✓	X	✓	✓	✓
Northern Sonoma County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Placer County	✓	✓	✓	✓	✓	✓	X**	✓	✓	✓	X**	✓

Table ES-1 (cont'd). Composite Table of Ambient and QA Results (Both Gas and PM) for Local Districts Within ARB's PQAO

Geographic (Area)*	All Gaseous Inst. Achieve ≥ 75% Data Capture Rates?	All Gaseous Inst. Reported ≥ 75% QC Checks?	All Attained CFR Precision Criteria?	All Attained CFR Bias Criteria?	All Inst. Audited?	Did All Audited Inst. Meet ARB Perf. Audit Criteria?	All PM Samplers Achieve ≥ 75% Data Capture Rates?	Were ≥ 75% of Precision Data Reported from Collocated Sites?	Did Collocated Sites Achieve CFR Precision Criteria?	FRV Data Reported for Continuous PM10?	All PM Samplers Audited?	Did All Audited Samplers Meet Flow Rate Audit Criteria?
Sacramento Metropolitan	X	X	✓	✓	X	✓	X	✓	X	✓	X	✓
San Joaquin Valley	✓	✓	✓	✓	✓	X**	X	✓	X**	✓	X**	✓
San Luis Obispo County	✓	✓	✓	✓	X***	✓	✓	N/A	N/A	✓	✓	✓
Santa Barbara County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Shasta County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Siskiyou County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Tehama County	✓	✓	✓	✓	✓	✓	✓	N/A	N/A	✓	✓	✓
Tuolumne County	✓	✓	✓	✓	✓	✓	N/A	N/A	N/A	N/A	N/A	N/A
Ventura County	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓
Yolo-Solano	✓	✓	X**	✓	✓	✓	✓	N/A	N/A	✓	✓	✓

* Geographic (Area): geographic area covered by a district. Sites within a given district may be operated by the district, ARB, or both.

** Impacted site operated by ARB.

*** Atascadero-Lewis Avenue was in operation until 2/23/2015; not audited prior to relocation. The new site met all audit requirements.

FRV: flow rate verification.

X: Did not meet criteria.

I. INTRODUCTION

The California Air Resources Board (ARB) is the governmental agency delegated under State law with the authority and responsibility for collecting ambient air quality data as directed by the federal Clean Air Act of 1977 and Clean Air Act Amendments of 1990. ARB and local air pollution control agencies operate ambient monitoring stations throughout the State. As stated in the Code of Federal Regulations (CFR), the U.S. Environmental Protection Agency (U.S. EPA) has defined ARB as the Primary Quality Assurance Organization (PQAO) for all of California with the exception of the Bay Area Air Quality Management District (BAAQMD), the South Coast Air Quality Management District (SCAQMD), and the San Diego County Air Pollution Control District (SDCAPCD). In addition, the National Park Service (NPS) is its own PQAO at the national level; this report will not discuss NPS as a PQAO.

A PQAO is a local air district or a coordinated aggregation of such organizations that is responsible for a set of stations that monitors the same pollutants and for which data quality assessments can logically be pooled. Each criteria pollutant sampler/monitor at a monitoring station in the State and Local Air Monitoring Station (SLAMS) Network must be associated with one, and only one, PQAO.⁶

Factors defining a PQAO include:

- Operation by a common team of field operators according to a common set of procedures.
- Use of a common quality assurance project plan or standard operating procedures.
- Common calibration facilities and standards.
- Oversight by a common quality assurance organization.
- Support by a common management, laboratory, or headquarters.

The purpose of this report is to provide ambient air quality data producers and users with a centralized review of the data quality within ARB's PQAO. Specifically, data from instruments measuring criteria gaseous and particulate pollutants are compared to measurement quality objectives (MQO). Where appropriate, comparisons to the national average and other PQAOs in California are also made. (The national average includes agencies defined as "state," "county," "district," "National Park Service," or "tribal.") In addition, when auditing gaseous and particulate samplers, ARB also conducts performance audits of meteorological sensors (if present). Details on such audits can be found in Appendix C of this report.

⁶ Samplers may also be identified as Special Purpose Monitors (SPM) or Industrial (ID) monitors. There are a limited number of SPM and ID monitors in California. The statistics reported in this report are predominantly the result of SLAMS monitors but also include a small number of SPM and ID monitors as well.

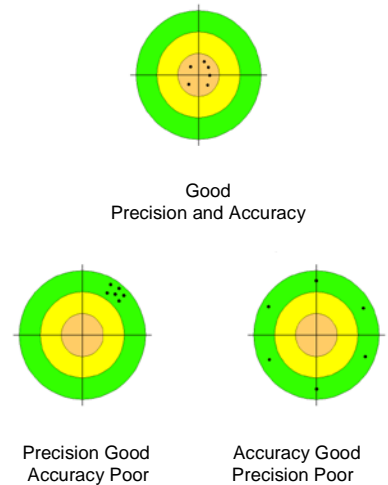
II. QUALITY ASSURANCE

Quality assurance is an integrated system of management activities that involves planning, implementing, assessing, and assuring data quality through a process, item, or service that meets users' needs for quality, completeness, and representativeness. Known data quality enables users to make judgments about compliance with air quality standards, air quality trends, and health effects based on sound data with a known level of confidence.

Quality assurance is composed of two main activities: quality control (QC) and quality assessment. QC is composed of a set of internal tasks performed routinely at the instrument level that ensures accurate and precise measured ambient air quality data. QC tasks address sample collection, handling, analysis, and reporting. Examples include calibrations, routine service checks, chain-of-custody documentation, duplicate analyses, development and maintenance of standard operating procedures, and routine preparation of QC reports.

Quality assessment is a set of external, quantitative tasks that provide certainty that the QC system is satisfactory and that the stated quantitative programmatic objectives for air quality data are met. Staff independent of data generators performs these external tasks, which include conducting regular performance audits, on-site system audits, inter-laboratory comparisons, and periodic evaluations of internal QC data.

The objective of quality assurance is to provide accurate and precise data, minimize data loss due to malfunctions, and to assess the validity of the air monitoring data to provide representative and comparable data of known precision and accuracy. The illustration to the right shows the relationship between precision and accuracy.



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

Bias is the systematic or persistent distortion of a measurement process which causes error in one direction. It is determined by estimating the positive and negative deviation from the true value as a percentage of the true value. When a certain bias is detected, the measurement process is said to be "inaccurate." The term "bias" is used to describe accuracy in CFR.⁷ In this report, the two terms are used interchangeably.

⁷ <http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=cd262bfedc5072c4808c47832bf484bb&ty=HTML&h=L&n=40y6.0.1.1.6&r=PART%20-%2040:6.0.1.1.6.7.1.3.34>

Precision is based on one-point QC checks for gaseous instruments and paired measurements from collocated samplers for particulate matter (PM). For precision, the statistic is the upper bound of the coefficient of variation (CV), which reflects the highest estimate of the variability in the instrument's measurements. One-point QC checks for gaseous instruments are also used to estimate bias. For PM, bias can be estimated from flow rate verifications; however, only flow rate verifications from continuous PM10 analyzers are required to be uploaded to AQS. Available tools for assessing precision and bias are summarized in Appendix A of this report (while details on cases where the criteria for precision or bias are not met can be found in Appendix B). Detailed descriptions of the coefficient of variation and the bias estimator, including the formulae behind the calculations, can be found in Appendix D.

Accuracy of the instruments is further validated or assessed by the through-the-probe performance audits conducted via the annual performance evaluation program for gaseous pollutants or via the semi-annual flow rate audits for PM. Appendix A lists ARB's audit performance criteria, which were developed to closely match the National Performance Audit Program.⁸

Consistent with the goals of assessing precision and accuracy of the instruments/samplers, this report also assesses the amount of ambient air quality data produced by the instruments or samplers. Depending on the sampling frequency of each respective instrument or sampler, data capture is compiled as a percentage of the ambient data collected over the total amount of data possible.

Air Quality Data Actions (AQDA) are a key tool used by the Quality Management Branch (QMB) of the Monitoring and Laboratory Division to identify and correct issues which would adversely affect the quality of the ambient data generated by the samplers. An AQDA is initiated by ARB auditors upon a failed audit. After an AQDA has been issued, an investigation into the causes of the failure will determine an outcome on the affected data. The data in question can be affected in three ways: released, corrected, or invalidated. Data that are released meet compliance criteria and can be used in all aspects of decision making. In some cases, data are flagged with qualifier codes as they are released. Corrected data pertains to when a calculated correction value is applied, rendering the data as meeting the established control criteria. Invalidated data are considered not for record, meaning the data set will not be utilized in any designation, enforcement, or regulatory decisions. As such, null codes are associated with invalidated data. Outside of the AQDA process, data could also be flagged if monitoring agencies determine and EPA concurs that the collected data were influenced by an exceptional or natural event. Additionally, there are informational flags that do not impact the usage of the data.

The implementation of a comprehensive corrective action system throughout ARB's PQAO is an essential component for improving data quality and facilitating continuous process improvement. To meet this need, QMB implemented the Corrective Action

⁸ <http://www3.epa.gov/ttn/amtic/npepqa.html>

Notification (CAN) process in late 2013. The CAN process documents issues that impact, or potentially impact, data quality, completeness, storage, or reporting. The goal of the CAN process is to investigate, correct, and reduce the recurrence of these issues. As such, the CAN process will identify issues not addressed by AQDAs, improves data quality, and helps ensure compliance with state, federal, and local requirements.

ARB's Quality Assurance Program is outlined in a six-volume Quality Assurance Manual, which guides the operation of the quality assurance programs used by ARB, local air districts, and private industry in California. The six-volume Quality Assurance Manual is available at <http://www.arb.ca.gov/aqgm/qa/qa-manual/qa-manual.htm>.

There are more than 250 air monitoring sites among the four California PQAOs in 15 separate air basins operating in California. Within ARB's PQAQO, there are 21 local air districts operating sites under ARB's guidance. Information about each air monitoring station audited by QMB is available at <http://www.arb.ca.gov/qaweb>.

III. DATA QUALITY - STATISTICAL SUMMARY RESULTS

The results are presented for two groups of pollutants: gases and particulate matter. For each group, the amount of ambient data collected (or captured) is discussed first, followed with an assessment of the quality behind the data. Statistical results presented in this report reflect the current information in AQS, with the exception of 2015 data, which is also updated to reflect corrections of data quality issues noted in Appendix B. These minor changes to 2015 data are not reflected in AQS since the data have already been certified and changing the data would require recertification. Data for 2013 and 2014 directly reflect the current information in AQS, and as such, they will reflect changes that occurred to past data since the 2014 Annual Data Quality Report was prepared. For example, "begin" and "end" dates for monitors may have been corrected, and parameter or method codes may have been updated to reflect the correct status of monitors in AQS. These changes may result in 2013 or 2014 data that differ from those published in the 2014 report.

A. Gaseous Criteria Pollutants

The gaseous pollutants assessed in this report are carbon monoxide (CO), ozone (O₃), nitrogen dioxide (NO₂), and sulfur dioxide (SO₂).

Ambient Data Capture: Data capture, as described in this report, is derived from the AQS completeness report AMP 430. The calculated number in AMP 430 represents the average of the monthly data capture rates for the calendar year and may not always be

indicative of whether the 75 percent regulatory completeness requirement⁹ is met for a particular pollutant, considering the operational period in the year. Note that while this report discusses the data capture rate of at least 75 percent, ARB’s goal is to have the most complete data in AQS.

Table A1 and Figure A1 present the percentage of instruments that reported at least 75 percent of the possible ambient data for each gaseous pollutant for each PQAQO. Table A2 displays similar information for ARB and each local air district operating within ARB’s PQAQO. Monitoring sites within each geographic area may be operated by the district, ARB, or both. As shown in the tables, very few instruments within ARB’s PQAQO reported a data capture rate of less than 75 percent. Compared to previous years, 2015 had about the same number of instruments reporting at least 75 percent of the ambient gaseous data.

Table A1. 2015 Ambient Gaseous Pollutant Data Capture Results

Pollutant	PQAQO	Year	# of Instruments	# of Instruments Reporting ≥ 75% Ambient Data Capture	% of Instruments Reporting ≥ 75% Ambient Data
CO	ARB	2015	27	25	93
		2014	27	26	96
		2013	30	27	90
	BAAQMD	2015	14	14	100
		2014	14	14	100
		2013	13	13	100
	SCAQMD	2015	27	26	96
		2014	27	27	100
		2013	28	27	96
	SDCAPCD	2015	4	4	100
		2014	4	4	100
		2013	3	3	100
	U.S. NATIONAL	2015	281	272	97
		2014	299	285	95
		2013	294	286	97

⁹ 40 CFR Part 50 states that the ambient data from a given instrument or sampler, in a calendar year, must be at least 75% complete to be included in making regulatory decisions, such as determinations of attainment of the ambient air quality standards. The State of California defines data “completeness” in a similar way, also using 75% as its criteria. However, unlike the federal definition, the State requirement factors in the high season of the pollutant in the completeness criteria (e.g. only months within the high ozone season are considered for ozone standard).

Table A1 (cont'd). 2015 Ambient Gaseous Pollutant Data Capture Results

Pollutant	PQAO	Year	# of Instruments	# of Instruments Reporting \geq 75% Ambient Data Capture	% of Instruments Reporting \geq 75% Ambient Data
NO ₂	ARB	2015	53	51	96
		2014	52	49	94
		2013	52	48	92
	BAAQMD	2015	17	17	100
		2014	17	16	94
		2013	16	16	100
	SCAQMD	2015	27	27	100
		2014	26	25	96
		2013	26	20	77
	SDCAPCD	2015	9	9	100
		2014	10	10	100
		2013	8	8	100
	U.S. NATIONAL	2015	437	420	96
		2014	421	399	95
		2013	387	365	94
O ₃	ARB	2015	107	107	100
		2014	105	105	100
		2013	105	102	97
	BAAQMD	2015	20	20	100
		2014	19	19	100
		2013	20	20	100
	SCAQMD	2015	29	29	100
		2014	30	30	100
		2013	31	30	97
	SDCAPCD	2015	9	9	100
		2014	11	11	100
		2013	9	9	100
	US-NATIONAL	2015	1153	1133	98
		2014	1176	1154	98
		2013	1180	1149	97

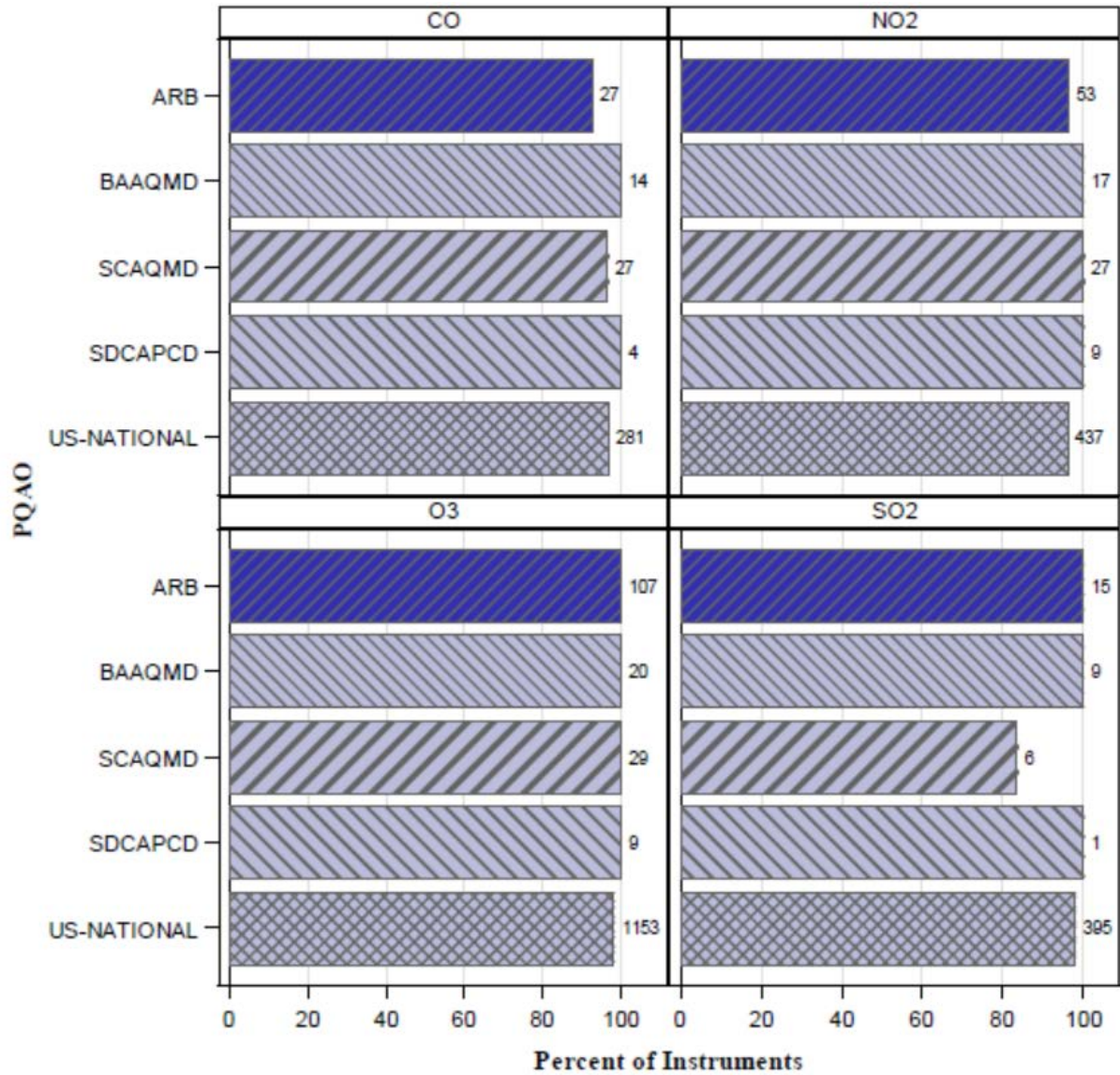
Table A1 (cont'd). 2015 Ambient Gaseous Pollutant Data Capture Results

Pollutant	PQAO	Year	# of Instruments	# of Instruments Reporting ≥ 75% Ambient Data Capture	% of Instruments Reporting ≥ 75% Ambient Data
SO ₂	ARB	2015	15	15	100
		2014	14	14	100
		2013	15	14	93
	BAAQMD	2015	9	9	100
		2014	9	9	100
		2013	10	10	100
	SCAQMD	2015	6	5	83
		2014	7	6	86
		2013	8	8	100
	SDCAPCD	2015	1	1	100
		2014	2	2	100
		2013	1	1	100
	US-NATIONAL	2015	395	387	98
		2014	402	389	97
		2013	409	393	96

- Further details on instruments not reporting ≥ 75% ambient data can be viewed Appendix B.
- Source: Air Quality System, AMP 430 Data Completeness Report, run September 2016, except as noted in Appendix B.
- Results reflect current information in AQS from September 2016, including changes to past data since the 2014 Annual Data Quality Report. Therefore, results for 2014 and 2013 might differ from those in the 2014 DQ report.

Figure A-1. Percent of Gaseous Instruments Meeting Seventy-Five Percent Ambient Data Capture Rate

(Total Instruments in Network Indicated Next to the Bars)



- National average includes state, county, district, National Park Service, and tribal sites, including those in California;
- Source AMP 430 Data Completeness Report, run September 2016, except as noted in Appendix B.

Table A2. 2015 Ambient Gaseous Pollutant Data Capture Results for Local Air Districts Within ARB's PQA0

Pollutant	Geographic Area	Motoring by (District=D, ARB=A, or Both=B)	# of Instruments	# of Instruments Reporting ≥ 75% Ambient Data	% of Instruments Reporting ≥ 75% Ambient Data
CO	Antelope Valley AQMD	D	1	1	100
	Butte County AQMD	A	1	1	100
	Imperial County APCD	B	2	2	100
	Mojave Desert AQMD	D	2	1	50
	Monterey Bay Unified APCD	D	1	1	100
	North Coast Unified AQMD	D	2	2	100
	Sacramento Metropolitan AQMD	D	4	3	75
	San Joaquin Valley Unified APCD	B	8	8	100
	Santa Barbara County APCD	B	6	6	100
NO ₂	Antelope Valley AQMD	D	1	0	0
	Butte County AQMD	A	1	1	100
	Feather River AQMD	A	1	1	100
	Imperial County APCD	B	2	2	100
	Mojave Desert AQMD	D	3	3	100
	Monterey Bay Unified APCD	D	1	1	100
	North Coast Unified AQMD	D	2	1	50
	Placer County APCD	A	1	1	100
	Sacramento Metropolitan AQMD	B	7	7	100
	San Joaquin Valley Unified APCD	B	16	16	100
	San Luis Obispo County APCD	D	4	4	100
	Santa Barbara County APCD	B	11	11	100
	Ventura County APCD	D	2	2	100
Yolo-Solano AQMD	A	1	1	100	
O ₃	Amador County APCD	A	1	1	100
	Antelope Valley AQMD	D	1	1	100
	Butte County AQMD	A	2	2	100
	Calaveras County APCD	A	1	1	100
	Colusa County APCD	A	1	1	100
	Eastern Kern APCD	D	1	1	100
	El Dorado County AQMD	A	2	2	100
	Feather River AQMD	A	2	2	100
	Glenn County APCD	A	1	1	100
	Great Basin APCD	D	1	1	100
	Imperial County APCD	B	4	4	100
	Lake County APCD	D	1	1	100
	Mariposa County APCD	A	1	1	100

Table A2 (cont'd). 2015 Ambient Gaseous Pollutant Data Capture Results for Local Air Districts Within ARB's PQAO

Pollutant	Geographic Area	Motoring by (District=D, ARB=A, or Both=B)	# of Instruments	# of Instruments Reporting ≥ 75% Ambient Data	% of Instruments Reporting ≥ 75% Ambient Data
O ₃	Mendocino County AQMD	D	1	1	100
	Mojave Desert AQMD	B	6	6	100
	Monterey Bay Unified APCD	D	5	5	100
	North Coast Unified AQMD	D	2	2	100
	Northern Sierra AQMD	B	2	2	100
	Northern Sonoma County APCD	D	1	1	100
	Placer County APCD	B	5	5	100
	Sacramento Metropolitan AQMD	B	7	7	100
	San Joaquin Valley Unified APCD	B	23	23	100
	San Luis Obispo County APCD	B	8	8	100
	Santa Barbara County APCD	B	12	12	100
	Shasta County AQMD	A	3	3	100
	Siskiyou County APCD	D	1	1	100
	Tehama County APCD	B	3	3	100
	Tuolumne County APCD	A	1	1	100
	Ventura County APCD	D	5	5	100
Yolo-Solano AQMD	B	3	3	100	
SO ₂	Great Basin Unified APCD	D	1	1	100
	Imperial County APCD	A	1	1	100
	Mojave Desert AQMD	D	2	2	100
	North Coast Unified AQMD	D	2	2	100
	Sacramento Metropolitan AQMD	D	1	1	100
	San Joaquin Valley Unified APCD	A	1	1	100
	San Luis Obispo County APCD	B	1	1	100
	Santa Barbara County APCD	D	6	6	100

- Further details on instruments not reporting ≥ 75% ambient data can be viewed in Appendix B.
- Source: Air Quality System, AMP 430 Data Completeness Report, run September 2016, except as noted in Appendix B.

Precision and Bias: One-point QC checks (mostly automated) are performed by the monitoring organizations to confirm the instrument's ability to respond to a known concentration of gas. The degree of variability in each of these measurements is computed as the precision of that instrument's measurements. For precision, the statistic defined in Title 40, CFR Part 58 Appendix A, is the upper bound of the coefficient of variation (CV), which reflects the highest tolerable variability in the data. This CV upper bound is not to exceed 7 percent for O₃, 10 percent for CO and SO₂, and 15 percent for NO₂.

These one-point QC checks are also used to estimate the bias inherent in the sampling system associated with each instrument. Appendix A to Part 58 outlines how bias is calculated based on one-point QC checks for gaseous pollutants. The bias estimator is the upper bound on the mean absolute value of the percent differences between the instrument's response and the true value of the gas concentration. A sign (positive/negative) is applied when the 25th and 75th percentiles are of the same sign. In other words, when at least 75 percent of the differences are all positive or negative, the bias estimate has a sign. Otherwise, the bias is denoted with "±." For bias, the CFR criteria are: ±7 percent for O₃, ±10 percent for CO and SO₂, and ±15 percent for NO₂.¹⁰ A detailed description of the bias estimator, including the formulae behind the calculations, can be found in Appendix D of this report.

Bias estimates are further verified via the through-the-probe performance audits. ARB acceptance criteria for performance audits for 2015 were: ±10 percent for O₃ (with warning at ±7 percent) and ±15 percent for CO, NO₂, and SO₂ (with warning at ±10 percent) for each audit point. ARB's policy is to audit 100 percent of local air districts' sites within its PQAQ each year and audit non-ARB PQAQ monitoring sites at least once every five years. Non-ARB PQAQs perform some audits on their own as part of the annual performance evaluation program.

CFR requires that the one-point QC checks be performed at least once every two weeks on each automated instrument, which translates to a minimum of 26 checks per year for an instrument that operates year-round. During data certification, EPA flags instruments that do not have at least 75 percent of the required QC checks in AQS; thus, 75 percent is the criterion used in Table A3 and Figure A2. CV upper bound and bias are displayed in Figures A3 and A4. A complete listing of all MQOs set forth by U.S. EPA under Title 40 CFR and the Quality Assurance (QA) Handbook Volume II can be found in Appendix A of this report.

For gaseous pollutants required by 40 CFR (CO, NO₂, O₃, and SO₂), ARB's PQAQ (as well as other California PQAQs) met the precision and bias criteria in 2015, as shown in Table A3. Information for years 2013 and 2014 are provided for a historical perspective. Three-year averages for each PQAQ are also included. In general, 2015 precision data are consistent with those in the previous two years. In addition, the required number of QC checks was achieved at most stations. Table A3 and Figure A2 include the number of instruments with at least 75 percent of the required precision data reported for 2015.

¹⁰The MQO goal for NO₂ was established in guidance in 2006 as 10% and was updated in 2014 to 15%. The goal of 15% was established in regulation in 2010. Prior to 2010, there was no goal in regulation.

Table A3. 2013-2015 Gaseous Pollutant Instrument Precision and Bias Results

Pollutant	PQAO	Year	# of Instruments	# of Instruments with ≥ 75% of Required Q/C checks	Upper Bound of Coefficient of Variation	CFR Criteria for Precision Met?	Bias	CFR Criteria for Bias Met?
CO	ARB	2015	27	25	4.27	Yes	+/- 2.85	Yes
		2014	27	25	3.71	Yes	+/- 2.51	Yes
		2013	30	29	4.81	Yes	+/- 3.88	Yes
		Avg			4.35	Yes	+/- 2.99	Yes
	BAAQMD	2015	14	14	1.44	Yes	+ 1.37	Yes
		2014	14	14	1.31	Yes	+ 1.16	Yes
		2013	13	14	1.45	Yes	+ 1.29	Yes
		Avg			1.39	Yes	+ 1.26	Yes
	SCAQMD	2015	27	26	3.45	Yes	+/- 2.73	Yes
		2014	27	27	3.48	Yes	+/- 2.79	Yes
		2013	28	26	3.66	Yes	+/- 2.92	Yes
		Avg			3.48	Yes	+/- 2.75	Yes
	SDCAPCD	2015	4	4	3.97	Yes	+/- 3.39	Yes
		2014	4	4	3.34	Yes	+/- 2.97	Yes
		2013	3	3	2.72	Yes	+/- 2.15	Yes
		Avg			3.36	Yes	+/- 2.75	Yes
	U.S. NATIONAL	2015	278	263	3.46	Yes	+/- 3.50	Yes
		2014	299	287	3.39	Yes	+/- 3.46	Yes
		2013	294	274	3.51	Yes	+/- 3.70	Yes
	NO ₂	ARB	2015	53	51	5.18	Yes	+/- 4.16
2014			52	49	4.82	Yes	+/- 3.87	Yes
2013			52	48	5.80	Yes	+/- 4.16	Yes
Avg					5.28	Yes	+/- 4.03	Yes
BAAQMD		2015	17	17	1.66	Yes	+/- 1.28	Yes
		2014	17	16	1.56	Yes	+/- 1.22	Yes
		2013	16	16	1.89	Yes	+/- 1.50	Yes
		Avg			1.72	Yes	+/- 1.32	Yes
SCAQMD		2015	27	27	5.36	Yes	+/- 4.55	Yes
		2014	26	26	4.78	Yes	+/- 4.01	Yes
		2013	26	24	5.50	Yes	+/- 4.38	Yes
		Avg			5.17	Yes	+/- 4.23	Yes

Table A3 (cont'd). 2013-2015 Gaseous Pollutant Instrument Precision and Bias Results

Pollutant	PQAO	Year	# of Instruments	# of Instruments with $\geq 75\%$ of Required Q/C checks	Upper Bound of Coefficient of Variation	CFR Criteria for Precision Met?	Bias	CFR Criteria for Bias Met?
NO ₂	SDCAPCD	2015	9	9	2.99	Yes	- 4.22	Yes
		2014	10	10	4.50	Yes	+/- 3.45	Yes
		2013	8	8	3.74	Yes	+/- 2.93	Yes
		Avg			3.80	Yes	+/- 3.54	Yes
	U.S. NATIONAL	2015	421	398	4.18	Yes	+/- 4.26	Yes
		2014	418	381	4.01	Yes	+/- 4.07	Yes
		2013	382	344	4.62	Yes	+/- 4.49	Yes
O ₃	ARB	2015	107	106	3.18	Yes	+/- 2.24	Yes
		2014	105	104	3.21	Yes	+/- 2.36	Yes
		2013	105	103	3.74	Yes	+/- 2.70	Yes
		Avg			3.37	Yes	+/- 2.41	Yes
	BAAQMD	2015	20	20	1.72	Yes	+/- 1.41	Yes
		2014	19	19	1.41	Yes	+/- 1.24	Yes
		2013	20	20	1.33	Yes	+/- 1.10	Yes
		Avg			1.51	Yes	+/- 1.23	Yes
	SCAQMD	2015	29	29	2.55	Yes	+/- 2.03	Yes
		2014	30	30	2.58	Yes	+/- 2.10	Yes
		2013	31	30	2.56	Yes	+/- 2.06	Yes
		Avg			2.53	Yes	+/- 2.03	Yes
	SDCAPCD	2015	9	7	1.78	Yes	+/- 1.36	Yes
		2014	11	7	2.08	Yes	+/- 1.71	Yes
		2013	9	9	2.17	Yes	+/- 1.68	Yes
		Avg			1.98	Yes	+/- 1.52	Yes
	U.S. NATIONAL	2015	1125	1086	2.59	Yes	+/- 2.42	Yes
		2014	1162	1120	2.16	Yes	+/- 2.18	Yes
		2013	1165	1110	2.24	Yes	+/- 2.31	Yes
	SO ₂	ARB	2015	15	14	5.33	Yes	+/- 3.37
2014			14	14	4.75	Yes	+/- 3.76	Yes
2013			15	14	3.82	Yes	+/- 2.86	Yes
Avg					4.66	Yes	+/- 3.27	Yes
BAAQMD		2015	9	9	1.77	Yes	+/- 1.48	Yes
		2014	9	9	1.59	Yes	+/- 1.39	Yes
		2013	10	10	1.35	Yes	+/- 1.09	Yes
		Avg			1.56	Yes	+/- 1.29	Yes

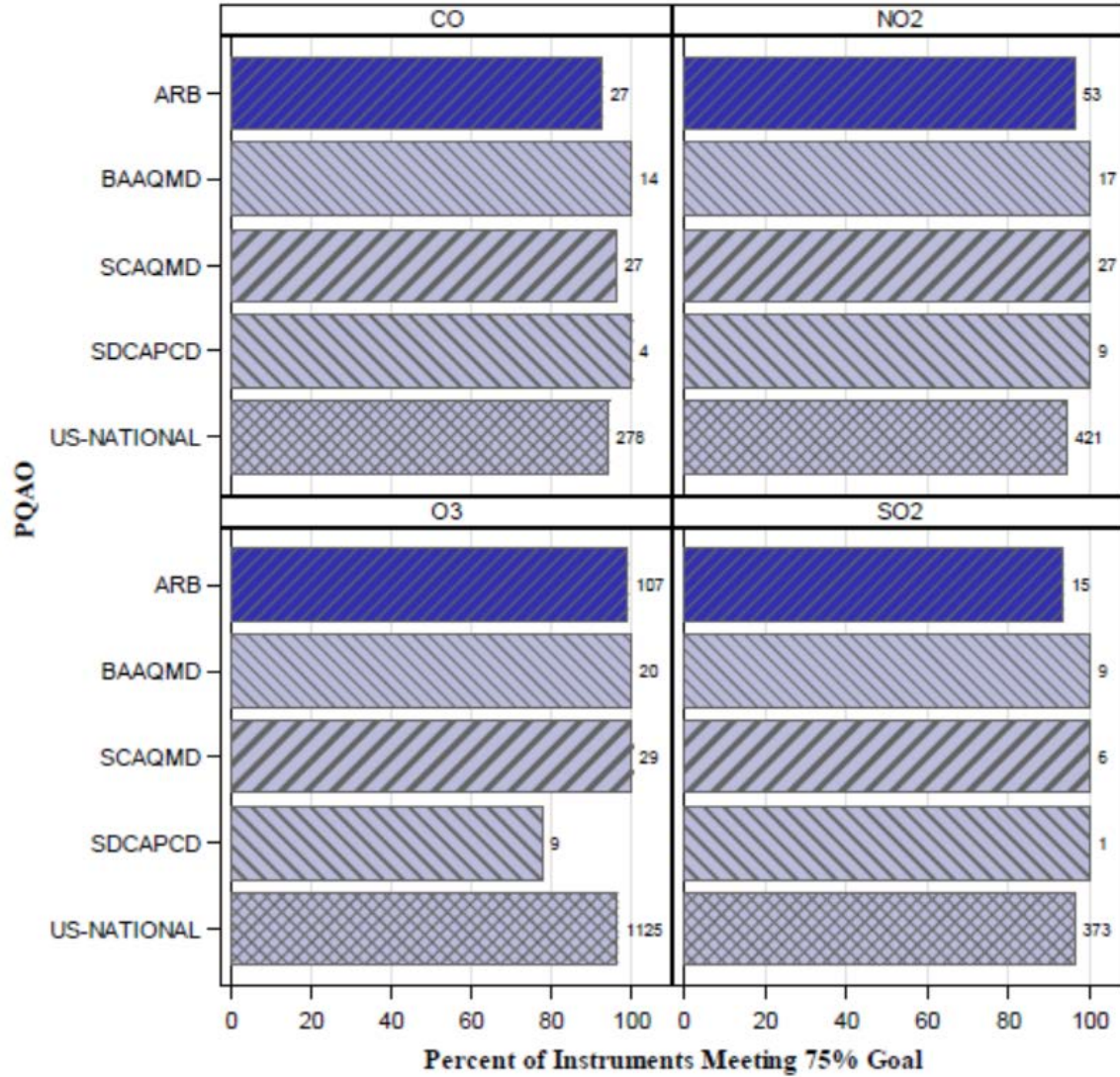
Table A3 (cont'd). 2013-2015 Gaseous Pollutant Instrument Precision and Bias Results

Pollutant	PQAO	Year	# of Instruments	# of Instruments with $\geq 75\%$ of Required Q/C checks	Upper Bound of Coefficient of Variation	CFR Criteria for Precision Met?	Bias	CFR Criteria for Bias Met?
SO ₂	SCAQMD	2015	6	6	3.92	Yes	- 5.46	Yes
		2014	7	7	4.44	Yes	- 5.57	Yes
		2013	8	6	4.30	Yes	+/- 5.23	Yes
		Avg			4.10	Yes	- 5.25	Yes
	SDCAPCD	2015	1	1	2.64	Yes	- 3.04	Yes
		2014	2	2	3.85	Yes	- 4.74	Yes
		2013	1	1	1.85	Yes	- 5.70	Yes
		Avg			2.81	Yes	- 4.60	Yes
	U.S. NATIONAL	2015	373	360	2.85	Yes	+/- 3.07	Yes
		2014	401	383	3.19	Yes	+/- 3.43	Yes
		2013	406	375	3.46	Yes	+/- 4.01	Yes

- CFR limits for precision (CV): 7% for O₃, 15% for NO₂, 10% for CO and SO₂; for bias: $\pm 7\%$ for O₃, $\pm 15\%$ for NO₂, $\pm 10\%$ for CO and SO₂. Both are based on QC checks required to be performed every two weeks, and EPA AMP 600 report flags instruments that do not have at least 75% of the required QC checks (unlike ARB's goal of 100% as stated in previous DQ reports).
- Further details on instruments not meeting these criteria can be viewed in Appendix B.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016.
- National average includes state, county, district, National Park Service, and tribal sites, including those in California; AMP 256 Data Quality Indicator Report, run September 2016. Note: discrepancies may exist in #of instruments listed in Table A3 compared to Table A1 due to different report sources, AMP256 and AMP430.
- Results reflect current information in AQS, including changes to past data since the 2014 Annual Data Quality Report. Therefore, results for 2014 and 2013 might differ from those in the 2014 DQ report.

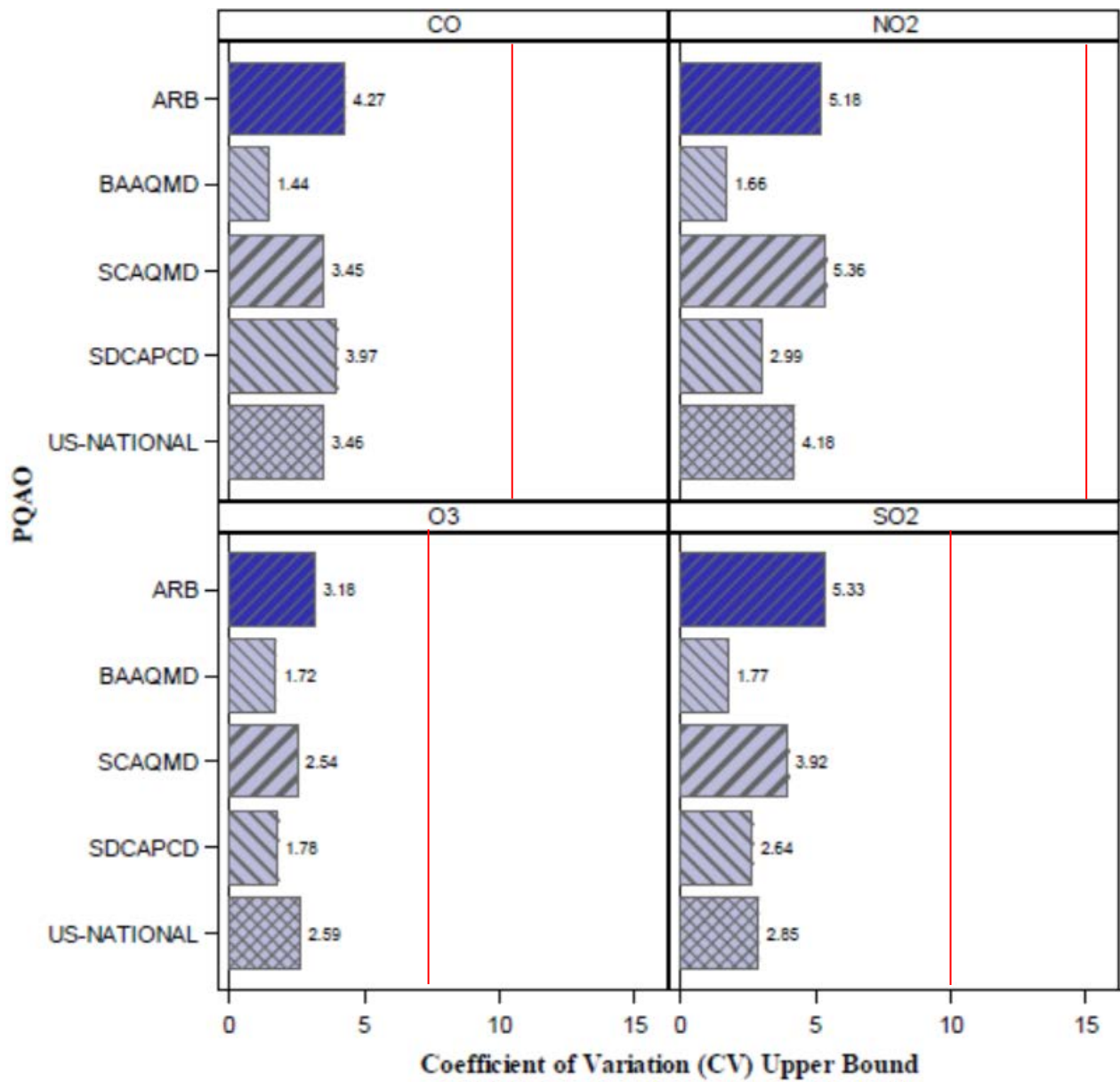
Figure A-2. 2015 1-Pt Quality Control Check Completeness – Gaseous Instruments

(Total Instruments in Network Indicated Next to the Bars)



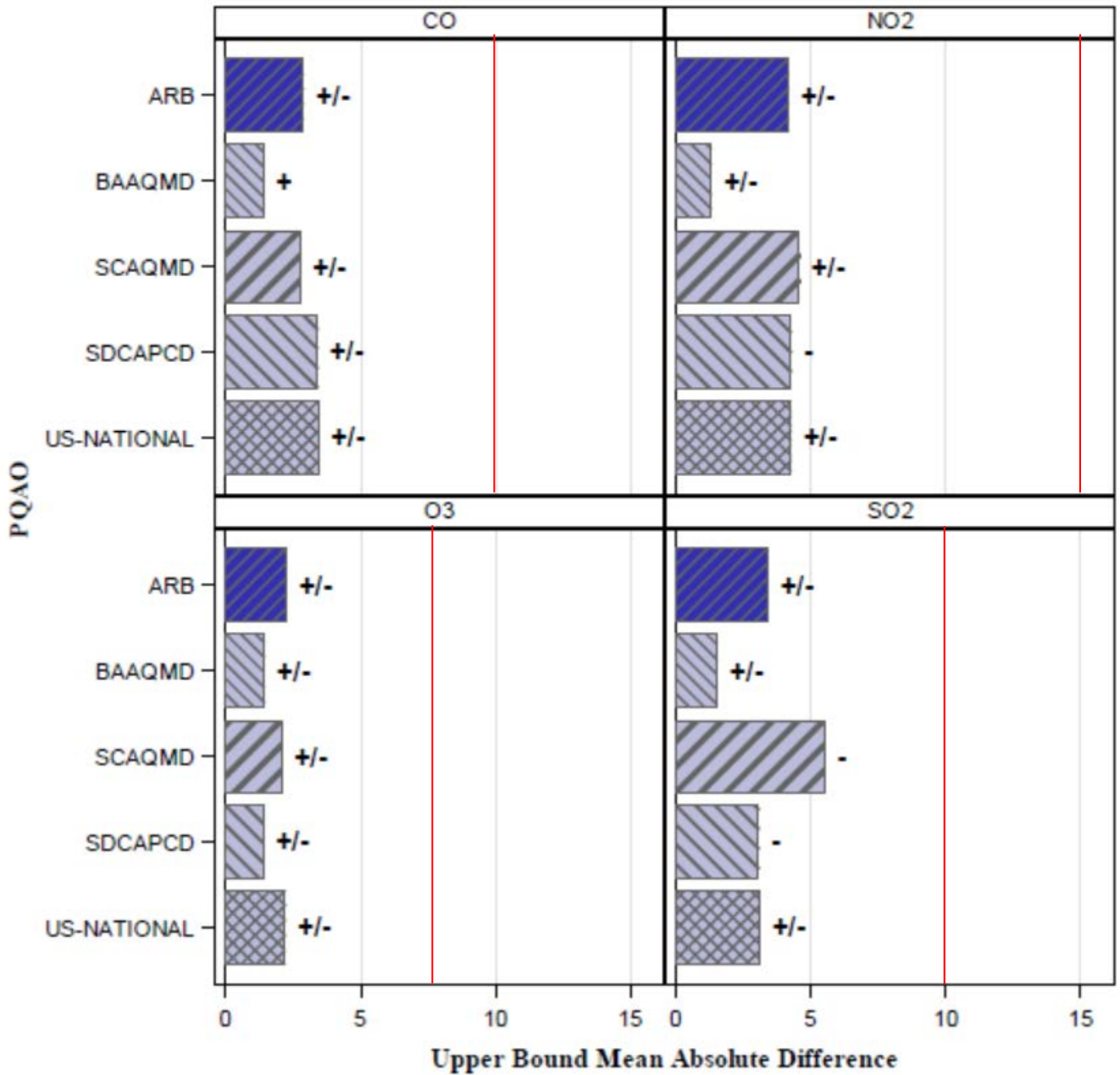
- National average includes state, county, district, National Park Service, and tribal sites, including those in California;
- Source AMP 430 Data Completeness Report, run September 2016, except as noted in Appendix B.

Figure A-3. 2015 Precision via 1-Pt Quality Control Checks – Gaseous Instruments



- US-National average includes state, county, district, and tribal sites, including those in California; AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.
- The 2015 CFR limit for precision was $\pm 10\%$ for CO and SO₂, $\pm 7\%$ for O₃, and $\pm 15\%$ for NO₂.
- Further details on instruments not meeting these criteria can be viewed in Appendix B.

Figure A-4. 2015 Bias via 1-Pt Quality Control Checks – Gaseous Instruments



- US-National average includes state, county, district, and tribal sites, including those in California; AMP 256 Data Quality Indicator Report, run September 2016.
- The 2015 CFR limit for bias was $\pm 10\%$ for CO and SO₂, $\pm 7\%$ for O₃, and $\pm 15\%$ for NO₂.
- Further details on instruments not meeting these criteria can be viewed in Appendix B.

Table A4 displays precision data for each local air district within ARB’s PQAQ in which sites are operated, with CV averaged across sites within each district. Monitoring sites within these areas may be operated by the district, ARB, or both. As shown in the table, all districts met the CV requirement and had very few instruments with less than 75 percent of required QC data reported.

In order to provide decision makers with data of known quality, U.S. EPA provides a tool for assessing data quality in terms of three data quality indicators in graphical format¹¹. At this link, U.S. EPA’s graphs provide detailed information on precision (CV), bias, and the number of one-point QC checks performed at each monitoring station in a given year.

Table A4. 2015 Gaseous Pollutant Instrument Precision Results for Local Air Districts Within ARB’s PQAQ

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	# of Instruments	# of Instruments with ≥ 75% of Required QC checks	Upper Bound of Coefficient of Variation
CO	Antelope Valley AQMD	D	1	1	2.25
	Butte County AQMD	A	1	1	2.70
	Imperial County APCD	B	2	2	5.16
	Mojave Desert AQMD	D	2	2	3.25
	Monterey Bay Unified APCD	D	1	1	2.17
	North Coast Unified AQMD	D	2	2	4.95
	Sacramento Metropolitan AQMD	D	4	2	3.35
	San Joaquin Valley Unified APCD	B	8	8	2.35
	Santa Barbara County APCD	B	6	6	1.66
NO ₂	Antelope Valley AQMD	D	1	1	1.95
	Butte County AQMD	A	1	1	3.76
	Feather River AQMD	A	1	1	4.84
	Imperial County APCD	B	2	2	6.36
	Mojave Desert AQMD	D	3	3	3.24
	Monterey Bay Unified APCD	D	1	1	1.35
	North Coast Unified AQMD	D	2	2	5.67
	Placer County APCD	A	1	1	2.29
	Sacramento Metropolitan AQMD	B	7	5	5.56
	San Joaquin Valley Unified APCD	B	16	16	4.28
	San Luis Obispo County APCD	D	4	4	2.73
	Santa Barbara County APCD	B	11	11	4.19

¹¹ <https://www.epa.gov/outdoor-air-quality-data/single-point-precision-and-bias-report>

Table A4 (cont'd). 2015 Gaseous Pollutant Instrument Precision Results for Local Air Districts Within ARB's PQAQ

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	# of Instruments	# of Instruments with ≥ 75% of Required QC checks	Upper Bound of Coefficient of Variation
NO ₂	Ventura County APCD	D	2	2	2.74
	Yolo-Solano AQMD	A	1	1	4.77
O ₃	Amador County APCD	A	1	1	1.58
	Antelope Valley AQMD	D	1	1	1.41
	Butte County AQMD	A	2	2	3.72
	Calaveras County APCD	A	1	1	3.52
	Colusa County APCD	A	1	1	1.96
	Eastern Kern APCD	D	1	1	2.80
	El Dorado County AQMD	A	2	2	1.85
	Feather River AQMD	A	2	2	3.90
	Glenn County APCD	A	1	1	2.72
	Great Basin Unified APCD	D	1	0	3.58
	Imperial County APCD	B	4	4	4.27
	Lake County APCD	D	1	1	1.14
	Mariposa County APCD	A	1	1	2.56
	Mendocino County AQMD	D	1	1	2.51
	Mojave Desert AQMD	B	6	6	1.92
	Monterey Bay Unified APCD	D	5	5	1.63
	North Coast Unified AQMD	D	2	2	3.90
	Northern Sierra AQMD	B	2	2	1.69
	Northern Sonoma County APCD	D	1	1	2.17
	Placer County APCD	B	5	5	1.07
	Sacramento Metropolitan AQMD	B	7	7	3.34
	San Joaquin Valley Unified APCD	B	23	23	2.48
	San Luis Obispo County APCD	B	8	8	1.28
	Santa Barbara County APCD	B	12	12	1.79
	Shasta County APCD	A	3	3	1.98
	Siskiyou County APCD	D	1	1	2.90
	Tehama County APCD	B	3	3	1.16
	Tuolumne County APCD	A	1	1	3.72
	Ventura County APCD	D	5	5	1.25
	Yolo-Solano AQMD	B	3	3	3.45
SO ₂	Great Basin APCD	D	1	0	5.58
	Imperial County APCD	A	1	1	8.04
	Mojave Desert AQMD	D	2	2	3.15

Table A4 (cont'd). 2015 Gaseous Pollutant Instrument Precision Results for Local Air Districts Within ARB's PQAO

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	# of Instruments	# of Instruments with ≥ 75% of Required QC checks	Upper Bound of Coefficient of Variation
SO ₂	North Coast Unified AQMD	D	2	2	3.43
	Sacramento Metropolitan AQMD	D	1	1	3.95
	San Joaquin Valley Unified APCD	A	1	1	6.47
	San Luis Obispo County APCD	B	1	1	0.89
	Santa Barbara County APCD	D	6	6	1.46

- NDA= No Data Available from AQS.
- AQMD – Air Quality Management District
- APCD – Air Pollution Control District
- CFR Limit for precision CV: 7% for O₃, 15% for NO₂, 10% for CO and SO₂, based on QC checks required to be performed every two weeks, and EPA AMP 600 report flags instruments that do not have at least 75% of the required QC checks (unlike ARB's goal of 100% as stated in previous DQ reports).
- Further details on instruments not meeting these criteria can be viewed in Appendix B.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016.

Accuracy Validation Via Performance Audits: To further validate bias estimates from one-point QC checks, CFR requires that independent performance audits be conducted and the average percent differences be evaluated against pre-determined criteria. In addition, auditing results should be assessed as to whether they are in agreement with the one-point QC checks.

Table A5 and Figures A5-A6 summarize the 2015 performance audit results for the gaseous criteria pollutants. Accuracy is represented as an average percent difference. The average percent difference is the arithmetic mean of the combined differences from the known value of all the individual audit points. Audit results show that, in general, all gaseous instruments met ARB criteria for bias at the PQAO level. Table A6 shows similar data for local air districts within ARB's PQAO.

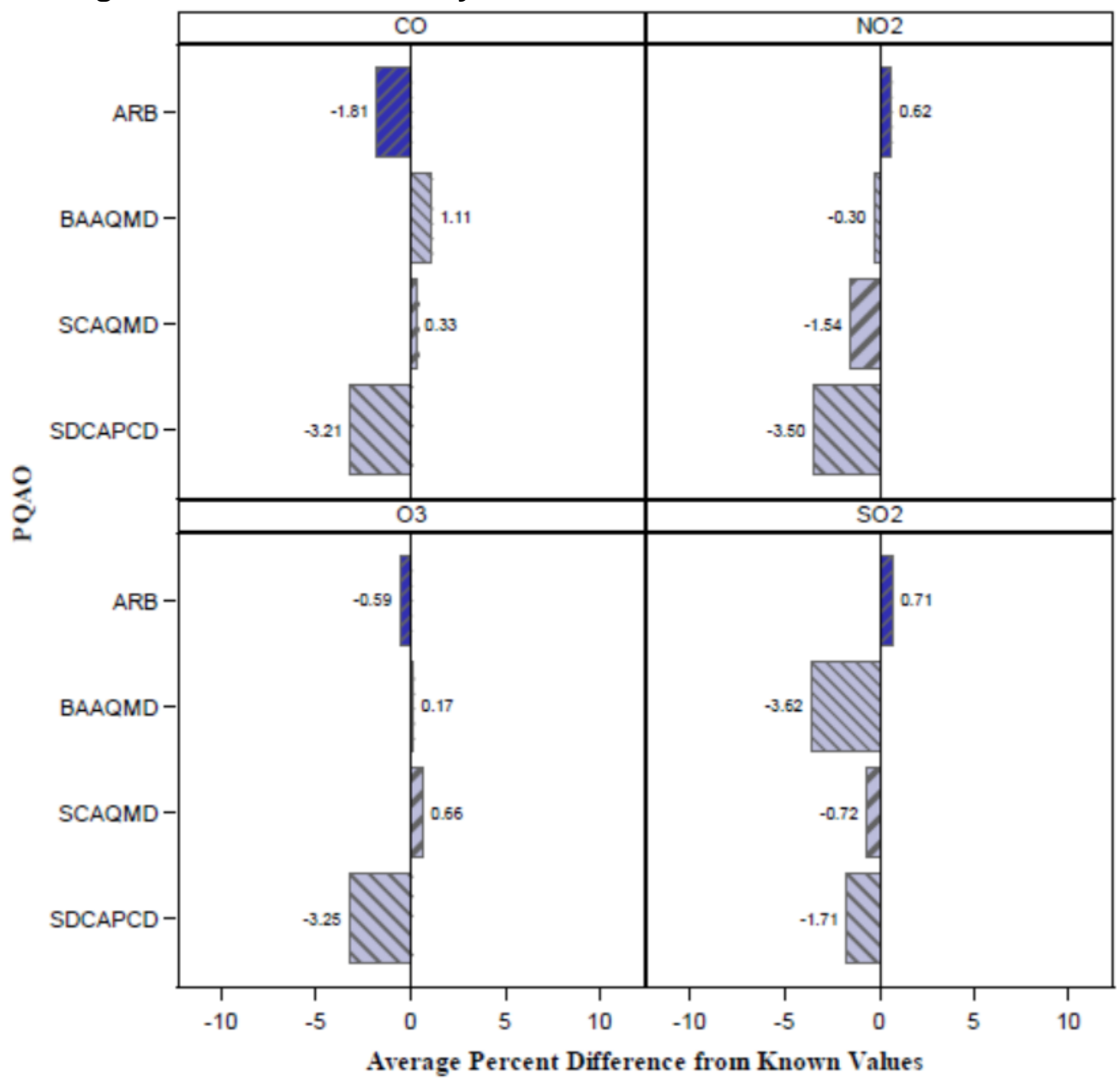
Performance audit results in 2015 corroborate what the QC checks revealed: that ARB's PQAO is providing accurate data for all gaseous pollutants. The average percent differences at the PQAO level were well below the audit criteria (± 10 percent for ozone, ± 15 percent for other gases) for all gaseous pollutants. This fact is further strengthened by the small number of audits that did not meet ARB performance audit criteria.

Table A5. 2015 Results for Performance Audits of Gaseous Pollutant Instruments

Pollutant	PQAO	# of Samplers	# of Samplers Audited	# of Audits Not Meeting ARB Criteria	Average Percent Difference
CO	ARB	27	26	0	-1.81
	BAAQMD	14	14	0	1.11
	SCAQMD	27	27	1	0.33
	SDCAPCD	4	4	0	-3.21
NO ₂	ARB	53	51	1	0.62
	BAAQMD	17	17	0	-0.30
	SCAQMD	27	27	0	-1.54
	SDCAPCD	9	9	0	-3.50
O ₃	ARB	107	106	1	-0.59
	BAAQMD	20	20	0	0.17
	SCAQMD	29	28	0	0.66
	SDCAPCD	9	9	1	-3.25
SO ₂	ARB	15	15	2	0.71
	BAAQMD	9	9	0	-3.62
	SCAQMD	6	6	0	-0.72
	SDCAPCD	1	1	0	-1.71

- The ARB performance audit criteria for 2015 were: $\pm 10\%$ for O₃ and $\pm 15\%$ for CO, NO₂, and SO₂ for each audit point. Only audits conducted by ARB were subjected to the AQDA process.
- Further details on instruments not meeting these criteria can be viewed in Appendix B.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016.

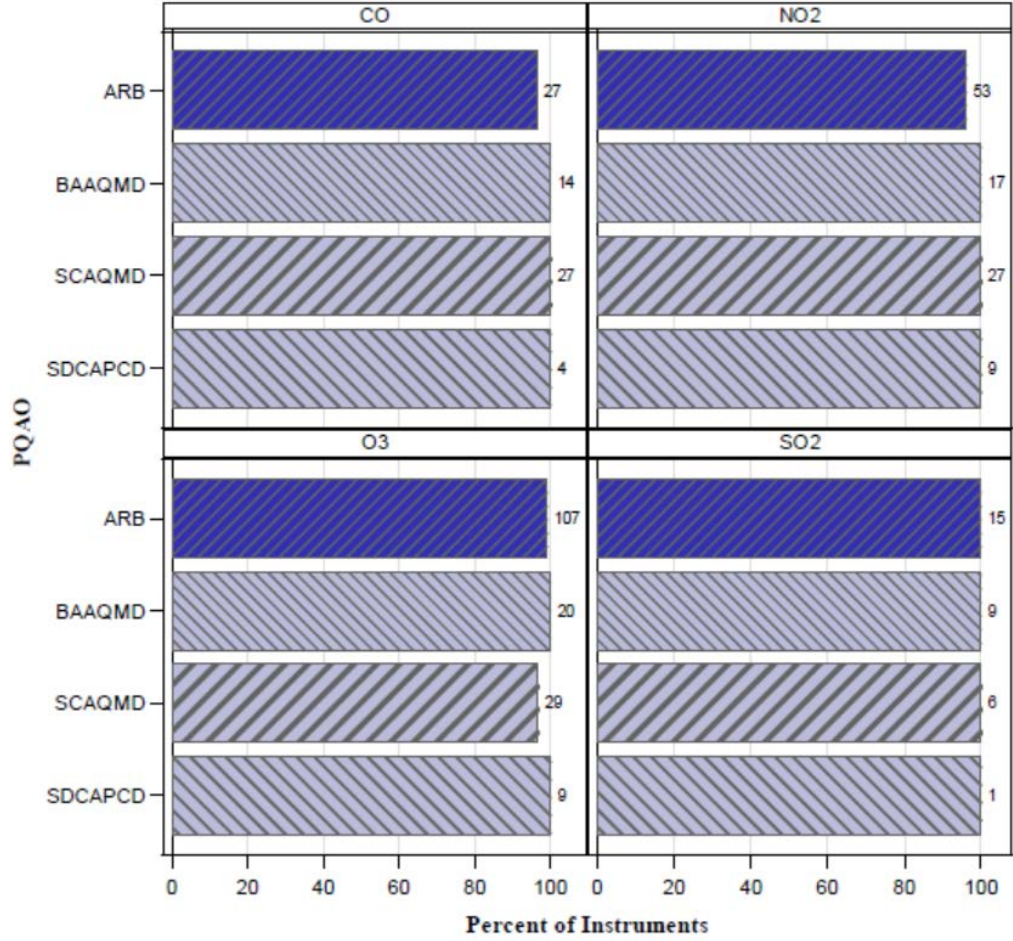
Figure A-5. 2015 Accuracy via Audits – Gaseous Instruments



- US-National average includes state, county, district, and tribal sites, including those in California; AMP 256 Data Quality Indicator Report, run September 2016.
- The ARB performance audit criteria for 2015: $\pm 15\%$ for CO and SO₂, $\pm 10\%$ for O₃, and $\pm 15\%$ for NO₂.
- Only audits conducted by ARB were subjected to the AQDA process.
- Further details on instruments not meeting these criteria can be viewed in Appendix B.

Figure A-6. Percent of Gaseous Instruments Meeting the Required Number of Performance Audits

(Total Instruments in Network Indicated Next to Bars)



- CFR requires that gaseous instruments be audited once per year. Further details on instruments not meeting these criteria can be viewed in Appendix B.
Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.
- National average includes state, county, district, National Park Service, and, including those in California.

Table A6. 2015 Results for Performance Audits of Gaseous Pollutant Instruments for Local Air Districts within ARB's PQAO

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	Number of Instruments	Number of Instruments Audited	Average Percent Difference
CO	Antelope Valley AQMD	D	1	1	-9.16
	Butte County AQMD	A	1	1	-3.26
	Imperial County APCD	B	2	2	-3.87
	Mojave Desert AQMD	D	2	2	-7.55
	Monterey Bay Unified APCD	D	1	1	-2.31
	North Coast Unified AQMD	D	2	2	-0.97
	Sacramento Metropolitan AQMD	D	4	3	-4.11
	San Joaquin Valley Unified APCD	B	8	8	-1.42
	Santa Barbara County APCD	B	6	6	-1.46
NO ₂	Antelope Valley AQMD	D	1	1	-6.17
	Butte County AQMD	A	1	1	6.29
	Feather River AQMD	A	1	1	-2.95
	Imperial County APCD	B	2	2	-4.28
	Mojave Desert AQMD	D	3	3	-2.09
	Monterey Bay Unified APCD	D	1	1	7.11
	North Coast Unified AQMD	D	2	2	5.41
	Placer County APCD	A	1	1	0.97
	Sacramento Metropolitan AQMD	B	7	6	0.93
	San Joaquin Valley Unified APCD	B	16	16	-0.81
	San Luis Obispo County APCD	D	4	3	1.07
	Santa Barbara County APCD	B	11	11	0.97
	Ventura County APCD	D	2	2	-0.23
Yolo-Solano AQMD	A	1	1	-3.34	
O ₃	Amador County APCD	A	1	1	-2.45
	Antelope Valley AQMD	D	1	1	-1.36
	Butte County AQMD	A	2	2	-4.17
	Calaveras County APCD	A	1	1	-8.90
	Colusa County APCD	A	1	1	-2.18
	Eastern Kern APCD	D	1	1	-3.63
	El Dorado County AQMD	A	2	2	-4.65
	Feather River AQMD	A	2	2	-2.96
	Glenn County APCD	A	1	1	-6.62
	Great Basin APCD	D	1	1	-3.04
	Imperial County APCD	B	4	4	-0.94
	Lake County APCD	D	1	1	1.36
	Mariposa County APCD	A	1	1	-7.14

Table A6 (cont'd). 2015 Results for Performance Audits of Gaseous Pollutant Instruments for Local Air Districts within ARB's PQAO

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	Number of Instruments	Number of Instruments Audited	Average Percent Difference
O ₃	Mendocino County AQMD	D	1	1	4.67
	Mojave Desert AQMD	B	6	6	-1.27
	Monterey Bay Unified APCD	D	5	5	-1.97
	North Coast Unified AQMD	D	2	2	-5.96
	Northern Sierra AQMD	B	2	2	-6.27
	Northern Sonoma County APCD	D	1	1	-0.76
	Placer County APCD	B	5	5	-3.64
	Sacramento Metropolitan AQMD	B	7	7	-0.62
	San Joaquin Valley Unified APCD	B	23	23	0.39
	San Luis Obispo County APCD	B	8	7	-0.39
	Santa Barbara County APCD	B	12	12	0.88
	Shasta County AQMD	A	3	3	-2.06
	Siskiyou County APCD	D	1	1	-1.73
	Tehama County APCD	B	3	3	-0.72
	Tuolumne County APCD	A	1	1	-7.61
	Ventura County APCD	D	5	5	1.02
Yolo-Solano AQMD	B	3	3	-2.48	
SO ₂	Great Basin APCD	D	1	1	-1.57
	Imperial County APCD	A	1	1	6.40
	Mojave Desert AQMD	D	2	2	-2.55
	North Coast Unified AQMD	D	2	2	-13.80
	Sacramento Metropolitan AQMD	D	1	1	0.00
	San Joaquin Valley Unified APCD	A	1	1	12.73
	San Luis Obispo County APCD	B	1	1	0.48
	Santa Barbara County APCD	D	6	6	-1.03

- The ARB performance audit criteria for 2015 were: ±10% for O₃ and ±15% for CO, NO₂, and SO₂ for each audit point. Only audits conducted by ARB were subjected to the AQDA process.
- Further details on instruments not meeting these criteria can be viewed in Appendix B.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016.

B. Particulate Matter



Particulate matter (PM) monitoring is conducted using both manual and continuous type samplers. Manual samplers are operated on a one-in-six-day or one-in-three-day sampling schedule for PM₁₀, and a similar, or more frequent schedule, for PM_{2.5}. Continuous samplers report hourly values. (ARB's PQAQO particulate program also includes total suspended particulates (TSP), sulfate, and lead monitoring.)

Similar to the discussion of gaseous pollutants, ambient data capture is discussed first, followed with an assessment of the quality of the data captured.

Ambient Data Capture: Data capture, as described in this report, is derived from the AQS completeness report AMP 430. The calculated number in AMP 430 represents the average of the monthly data capture rates for the calendar year and may not always be indicative of whether the 75 percent regulatory completeness requirement¹² is met for a particular pollutant. Note that while this report discusses the data capture rate of at least 75 percent, ARB's goal is to have the most complete data in AQS.

Table B1 and Figure B1 present the percentage of samplers that reported an ambient data capture rate of at least 75 percent for each PQAQO. Table B2 displays similar information for each local air district within ARB's PQAQO in which a PM sampler was operated. As can be seen in these tables, very few PM samplers within ARB's PQAQO failed to report at least a 75 percent data capture rate for the indicated ambient PM data. Compared to previous years, more ambient data were captured in 2015.

Precision and Bias: PM is subject to formal measurement quality objectives (MQOs) in federal and State regulations. Appendix A of this report lists the MQOs stated in CFR and U.S. EPA guidance. For all methods of collecting PM₁₀ and PM_{2.5}, Title 40 CFR Part 58 Appendix A specifies using the upper bound of CV to assess precision. This CV upper bound is not to exceed 10 percent. Collocated sampling is required to assess precision for manual PM₁₀ and both manual and continuous PM_{2.5} sampling. Each PQAQO is required to have a certain number of collocated sites to represent its monitoring network. From each pair of collocated samplers, a minimum of 75 percent of ambient data is required to be in AQS.

¹² 40 CFR Part 50 states that the ambient data from a given instrument or sampler, in a calendar year, must be at least 75% complete to be included in making regulatory decisions, such as determinations of attainment of the ambient air quality standards. The State of California defines data "completeness" in a similar way, also using 75% as its criteria. However, unlike the federal definition, the State requirement factors in the high season of the pollutant in the completeness criteria.

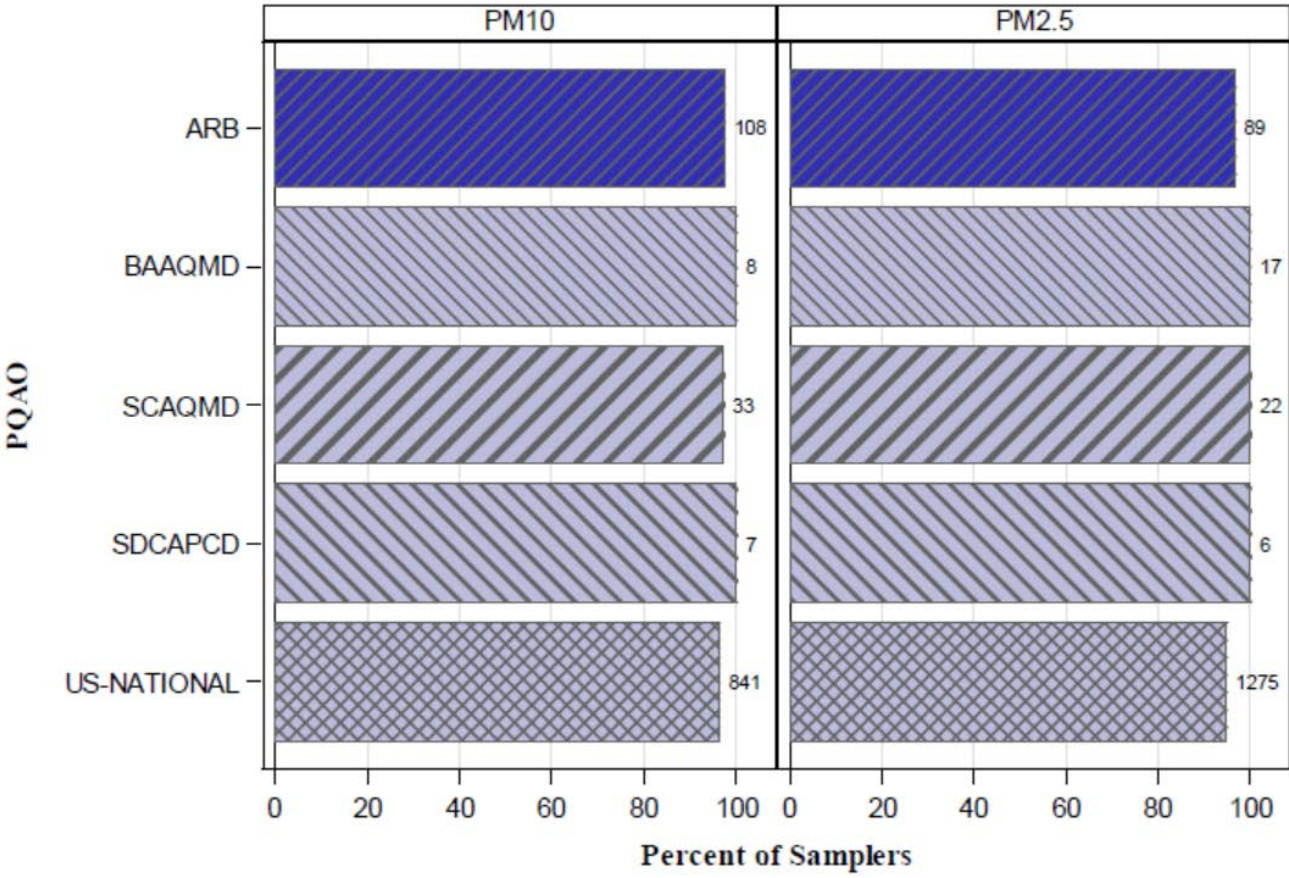
Table B1. 2015 Ambient PM Data Capture Results

Pollutant	PQAO	Year	# of Samplers	# of Samplers Reporting ≥ 75% Data Capture	% of Samplers Reporting ≥ 75% Data Capture
PM10	ARB	2015	108	105	97
		2014	108	104	96
		2013	109	103	94
	BAAQMD	2015	8	8	100
		2014	8	8	100
		2013	8	8	100
	SCAQMD	2015	33	32	97
		2014	35	35	100
		2013	36	36	100
	SDCAPCD	2015	7	7	100
		2014	8	8	100
		2013	7	7	100
	U.S. NATIONAL	2015	841	806	96
		2014	849	816	96
		2013	839	819	98
PM2.5	ARB	2015	89	86	97
		2014	80	75	94
		2013	74	69	93
	BAAQMD	2015	17	17	100
		2014	17	17	100
		2013	17	17	100
	SCAQMD	2015	22	22	100
		2014	23	22	96
		2013	23	23	100
	SDCAPCD	2015	6	6	100
		2014	15	15	100
		2013	11	11	100
	U.S. NATIONAL	2015	1275	1206	95
		2014	1250	1137	91
		2013	1150	1090	95

- Further details on samplers not reporting ≥ 75% ambient data can be viewed in Appendix B.
- Source: Air Quality System, AMP 430 Data Completeness Report, run September 2016, except as noted in Appendix B.
- Results reflect current information in AQS, including changes to past data since the 2014 Annual Data Quality Report. Therefore, results for 2014 and 2013 might differ from those in the 2014 DQ report.

Figure B1. Percent of Particulate Samplers Meeting Seventy-Five Percent Ambient Data Capture Rate

(Total Samplers in Network Indicated Next to Bars)



- Source: Air Quality System, AMP 430 Data Completeness Report, run September 2016, except as noted in Appendix B.

For continuous PM10 samplers, bias is assessed using the monthly flow rate verifications and comparing the absolute bias upper bound against CFR criterion of four percent difference. Detailed calculations are explained in section D.5 of Appendix D. Although monthly flow rate verifications are available in AQS for some PM2.5 instruments as well, CFR does not require that this data be uploaded. In 2014, flow rate data from some of PM2.5 samplers within ARB's PQAO was collected and reported.

The accuracy of all particulate samplers is assessed via the semi-annual flow rate audit by comparing the instrument's flow rate to a certified orifice (PM10 and TSP), or a calibrated mass flow meter (TEOM, PM2.5, and BAM samplers) that is certified against a National Institute of Standards and Technology traceable flow device or calibrator. As listed in Appendix A of this report, ARB's 2015 performance criteria, based on the average percent difference during a semi-annual flow rate audit, were ± 7 percent for PM10 Hi-Vol, and ± 4 percent for PM10 Low-Vol and PM2.5.

Precision of the data is based on the standard deviation of the percent differences of the mass concentrations of the two identical or equivalent collocated samplers. At low concentrations, precision based on the measurements of collocated samplers may be relatively poor. For this reason, collocated measurement pairs are selected for use in the precision calculations only when both measurements are equal to or above the following limits: (1) TSP: $20 \mu\text{g}/\text{m}^3$; (2) PM10 (Hi-Vol): $15 \mu\text{g}/\text{m}^3$; (3) PM10 (Lo-Vol): $3 \mu\text{g}/\text{m}^3$; and (4) PM2.5: $3 \mu\text{g}/\text{m}^3$. The collocated pairs of data that meet these limits are then used to calculate the upper bound of CV as an estimate of precision at each site. Title 40 CFR requires that this upper bound of the CV not exceed 10 percent for both PM10 and PM2.5 at the PQAO level. A detailed description of CV, including formulae for calculating it, can be found in Appendix D.

Table B2. 2015 Ambient PM Data Capture Results for Local Air Districts Within ARB's PQAQ

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	# of Samplers	# of Samplers Reporting ≥ 75% Data	% of Samplers Reporting ≥ 75% Data
PM10	Antelope Valley AQMD	D	1	1	100
	Butte County AQMD	A	1	1	100
	Calaveras County APCD	A	1	1	100
	Colusa County APCD	A	1	1	100
	Eastern Kern APCD	B	3	3	100
	El Dorado County AQMD	A	1	1	100
	Feather River AQMD	A	1	1	100
	Glenn County APCD	A	1	1	100
	Great Basin Unified APCD	D	17	17	100
	Imperial County APCD	D	9	9	100
	Mariposa County APCD	A	1	1	100
	Mendocino County AQMD	D	1	1	100
	Mojave Desert AQMD	D	5	5	100
	Monterey Bay Unified APCD	D	2	2	100
	North Coast Unified AQMD	D	1	1	100
	Northern Sonoma County APCD	D	3	3	100
	Placer County APCD	B	2	1	50
	Sacramento Metropolitan AQMD	B	8	7	88
	San Joaquin Valley Unified APCD	B	23	22	96
	San Luis Obispo County APCD	D	8	8	100
	Santa Barbara County APCD	D	7	7	100
	Shasta County AQMD	D	3	3	100
Siskiyou County APCD	D	1	1	100	
Tehama County APCD	D	2	2	100	
Ventura County APCD	D	2	2	100	
Yolo-Solano AQMD	B	3	3	100	
PM2.5	Antelope Valley AQMD	D	1	1	100
	Butte County AQMD	A	1	1	100
	Calaveras County APCD	A	1	1	100
	Colusa County APCD	A	1	1	100
	Eastern Kern APCD	D	2	2	100
	Feather River AQMD	A	1	1	100
	Great Basin Unified APCD	D	3	3	100
	Imperial County APCD	D	6	6	100
	Lake County APCD	D	1	1	100
	Mendocino County AQMD	D	2	2	100
	Mojave Desert AQMD	D	2	2	100
	Monterey Bay Unified APCD	D	7	7	100
	North Coast Unified AQMD	D	2	2	100
	Northern Sierra AQMD	D	6	4	67

Table B2 (cont'd). 2015 Ambient PM Data Capture Results for Local Air Districts Within ARB's PQAO

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	# of Samplers	# of Samplers Reporting ≥ 75% Data	% of Samplers Reporting ≥ 75% Data
PM2.5	Placer County APCD	B	3	3	100
	Sacramento Metropolitan AQMD	B	7	6	86
	San Joaquin Valley Unified APCD	B	25	25	100
	San Luis Obispo County APCD	D	5	5	100
	Santa Barbara County APCD	D	4	4	100
	Shasta County AQMD	D	1	1	100
	Siskiyou County APCD	D	1	1	100
	Ventura County APCD	D	6	6	100
	Yolo-Solano AQMD	B	1	1	100

- Further details on samplers not reporting ≥ 75% ambient data can be viewed in Appendix B.
- Source: Air Quality System, AMP 430 Data Completeness Report, run September 2016, except as noted in Appendix B.

ARB's PQAO is short of meeting the required amount of collocated sampling for one method of collecting PM2.5. Also, based on the number of manual PM10 sites, ARB's PQAO also does not meet the required amount of collocated sampling for PM10. A detailed assessment can be found in ARB's *Annual Network Plan Covering Monitoring Operations in 25 California Air Districts, June 2016*.¹³ This plan assumes all the conversions to "very sharp cut cyclones" for PM2.5 samplers while our report reflects data as shown in AQS; thus, the reader can expect some differences. Table B3 shows the number of sites with collocated precision data reported in respective years. Note that due to limited data¹⁴ for ARB's PQAO in 2015, lead is not discussed herein.

Precision Results: For the reported collocated sites, CFR requires that 30 paired observations per year be collected from each site with collocated samplers operating the entire year. Table B3 displays precision percent completeness (measured as a percent of the collected samples over the required number of observations and graphed in Figure B2) in addition to the CV upper bound. Information for years 2013 and 2014 are provided for historical perspectives. Three-year PQAO averages are also included. Summary precision info is displayed in Figures B3 and B4. A few highlights include:

- For the four PM10 and thirteen PM2.5 pairs of collocated samplers that were present within ARB's PQAO, all except one reported at least 75 percent of the required precision data in 2015.
- For PM10, with the exception of one collocated site, the CV was below 10 percent in ARB's PQAO (as well as other California PQAOs).
- For PM2.5, ARB's PQAO did not meet the 10 percent CV requirement at the PQAO level for all methods of collection for which data are available (except one based on incomplete data). Compared to 2014, the CV values were comparable.

¹³ <http://www.arb.ca.gov/aqd/amnr/amnr2016.pdf>

¹⁴ In 2014, there are two lead samplers in ARB's PQAO: Fresno-Garland and Callexico-Ethel. Neither has a collocated sampler.

Table B3. 2013-2015 Precision Results Based on Available Collocated PM Samplers

Pollutant	PQAO	Year	Method Code	# Pairs of Collocated Samplers Reported	% Precision Completeness	Upper Bound of Coefficient of Variation	CFR Criteria for Precision Met?
PM10	ARB	2015	All	4	100	11.52	No
		2014	All	5	100	10.30	No
		2013	All	5	100	6.38	Yes
		Avg	All	-	100	9.25	Yes
	BAAQMD	2015	All	1	100	15.62	No
		2014	All	1	100	3.69	Yes
		2013	All	1	100	2.65	Yes
		Avg	All	-	100	8.57	Yes
	SCAQMD	2015	All	3	100	10.11	No
		2014	All	3	100	4.27	Yes
		2013	All	3	100	5.28	Yes
		Avg	All	-	100	6.70	Yes
	SDCAPCD	2015	All	1	100	2.53	Yes
		2014	All	1	100	2.49	Yes
		2013	All	1	100	4.15	Yes
		Avg	All	-	100	3.11	Yes
	US-NATIONAL	2015	All	128	95	9.00	Yes
		2014	All	143	97	9.35	Yes
2013		All	147	97	9.29	Yes	
PM2.5	ARB	2015	117	1	100	36.79	No
		2014	117	1	100	23.03	No
		2013	117	2	100	26.30	No
		2015	NDA	NDA	NDA	NDA	NDA
		2014	118	3	100	16.37	No
		2013	118	2	100	14.55	No
		2015	143	1	100	4.08	Yes
		2015	145	4	74	17.56	No
		2014	145	4	100	12.63	No
		2013	145	4	100	14.31	No
		2015	170	6	100	18.00	No
		2014	170	4	100	18.06	No
		2013	170	3	100	17.60	No
		2015	181	1	100	17.34	No
		2014	181	1	100	23.24	No
		2013	181	1	100	23.94	No
		Avg	-	-	-	100	19.35

Table B3 (cont'd). 2013-2015 Precision Results Based on Available Collocated PM Samplers

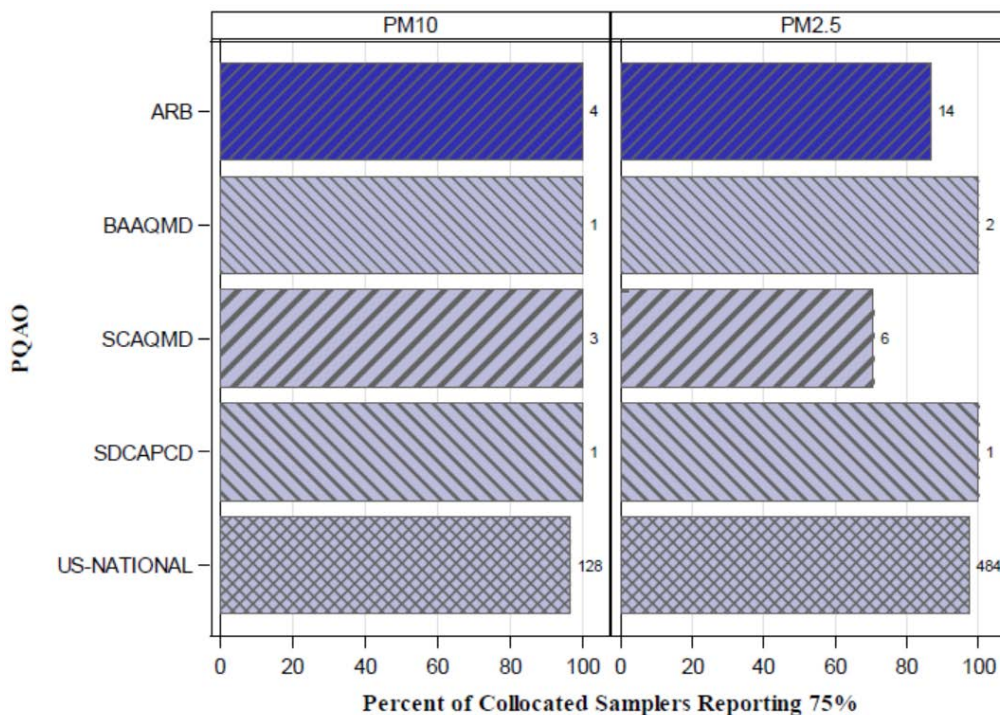
Pollutant	PQAO	Year	Method Code	# Pairs of Collocated Samplers Reported	% Precision Completeness	Upper Bound of Coefficient of Variation	CFR Criteria for Precision Met?
PM2.5	BAAQMD	2015	170	2	100	16.36	No
		2014	170	2	100	16.44	No
		2013	170	2	100	17.26	No
		Avg	-	-	100	16.43	No
	SCAQMD	2015	145	3	100	10.07	No
		2014	145	NDA	NDA	NDA	NDA
		2013	145	NDA	NDA	NDA	NDA
		2015	120	3	41	34.04	No
		2014	120	3	100	8.80	Yes
		2013	120	3	100	9.01	Yes
		Avg	-	-	100	11.68	No
	SDCAPCD	2015	145	1	100	7.93	Yes
		2014	145	1	100	5.18	Yes
		2013	145	1	100	4.39	Yes
		2015	170	NDA	NDA	NDA	NDA
		2014	170	1	100	18.99	No
		2013	170	NDA	NDA	NDA	NDA
		Avg	-	-	100	13.70	No
	US-NATIONAL	2015	117	3	100	16.93	No
		2014	117	4	98	16.03	No
		2013	117	5	100	14.20	No
		2015	118	61	100	8.10	Yes
		2014	118	68	97	10.66	No
		2013	118	67	99	8.76	Yes
		2015	120	7	72	14.50	No
		2014	120	12	92	13.10	No
		2013	120	9	93	10.34	No
		2015	143	11	89	10.69	No
		2014	143	10	93	9.41	Yes
		2013	143	10	95	7.35	Yes
2015		145	84	96	8.94	Yes	
2014		145	73	95	9.71	Yes	
2013		145	64	99	8.86	Yes	

Table B3 (cont'd). 2013-2015 Precision Results Based on Available Collocated PM Samplers

Pollutant	PQAO	Year	Method Code	# Pairs of Collocated Samplers Reported	% Precision Completeness	Upper Bound of Coefficient of Variation	CFR Criteria for Precision Met?
PM2.5	US-NATIONAL	2015	170	43	99	19.57	No
		2014	170	44	100	18.3	No
		2013	170	35	97	18.99	No
		2015	181	3	100	13.95	No
		2014	181	3	100	18.53	No
		2013	181	4	100	17.59	No

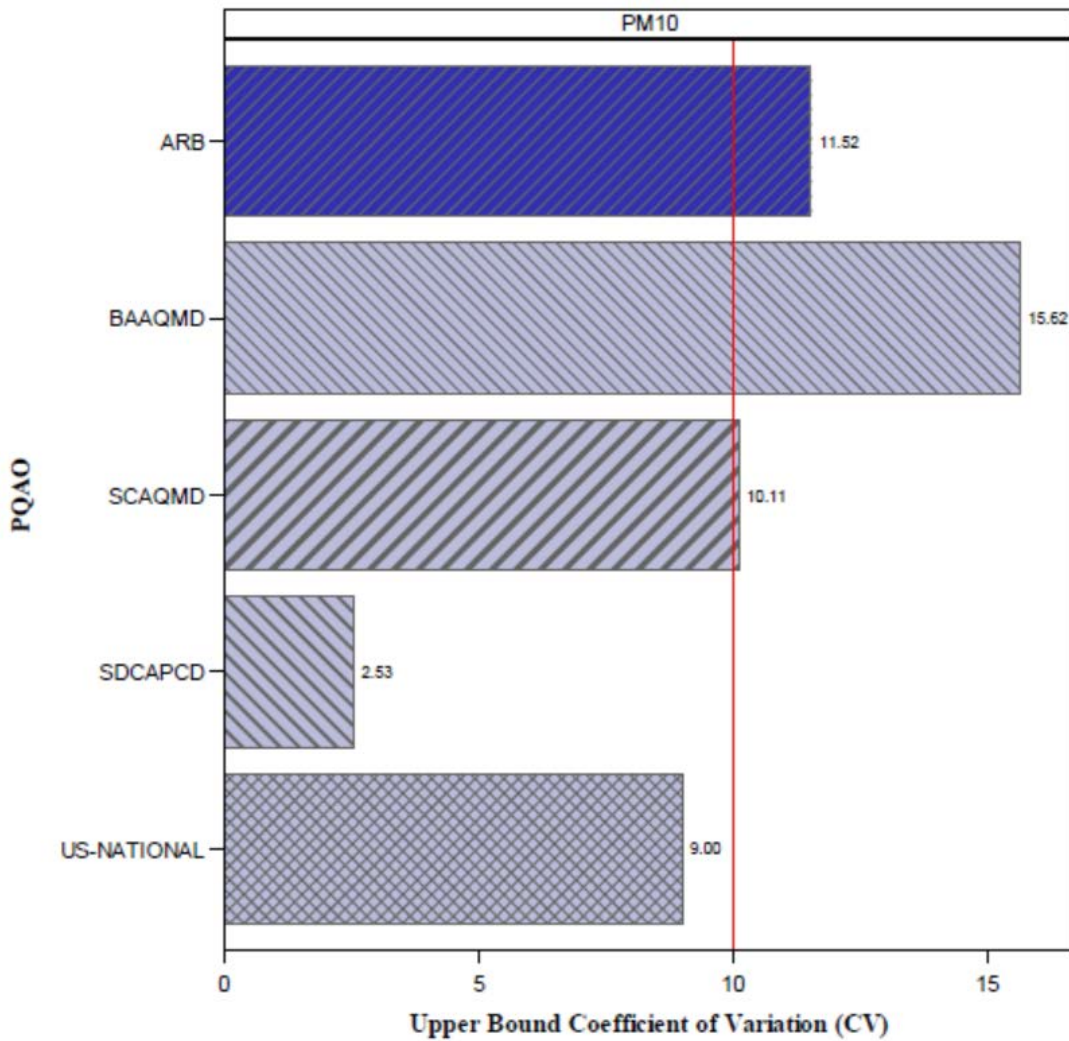
- CFR Limit is a coefficient of variation of $\leq 10\%$ for PM. Percent precision completeness is based on data collected from collocated samples. Further details on samplers not meeting these criteria can be found in Appendix B.
- Method 117 = R & P Model 2000 PM2.5 Sampler w/WINS; Method 118= R & P Model 2025 PM2.5 Sequential w/WINS; Method 120= Andersen RAAS2.5-300 PM2.5 SEQ w/WINS; Method 143= R & P Model 2000 PM2.5 Sampler w/VSCC; Method 145= R & P Model 2025 PM2.5 Sequential Air Sampler w/VSCC; Method 170= Met One BAM-1020 Mass Monitor w/VSCC; Method 181=Thermo TEOM 1400a FDMS.
- ***Bold italicized*** font indicates CV greater than 10% in 2014 while underlined font indicates CV greater than 10% in 2014 or 2013.
- NDA= No collocated data available from AQS, but ambient data were reported to AQS.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report (Collocation Summary), run September 2016.
- National average includes state, county, district, National Park Service, and tribal sites, including those in California; AMP 256 Data Quality Indicator Report, run September 2016
- Results reflect current information in AQS, including changes to past data since the 2014 Annual Data Quality Report. Therefore, results for 2014 and 2013 might differ from those in the 2014 DQ report.

Figure B2. 2015 Precision Completeness - PM



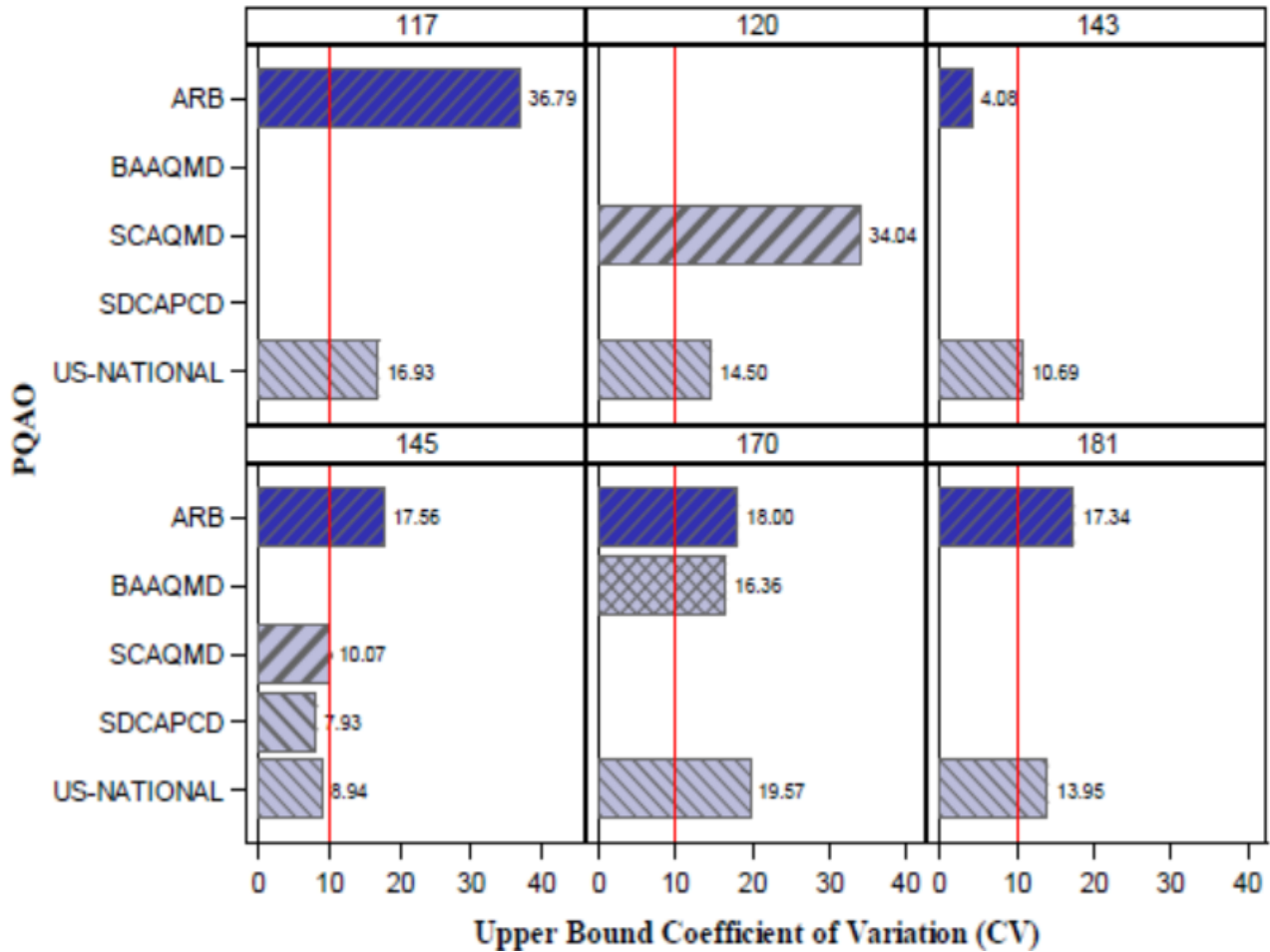
- Source: Air Quality System, AMP 430 Data Completeness Report, run September 2016, except as noted in Appendix B.

Figure B3. 2015 Precision via Collocated Samplers – PM10



- Precision for manual PM10 samplers is based on collocated samples;
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016. Further details on samplers not meeting criteria can be viewed in Appendix B.
- National average includes state, county, district, National Park Service, and tribal sites, including those in California; AMP 256 Data Quality Indicator Report, run September 2016.

Figure B4. 2015 Precision via Collocated Samplers – PM2.5



- PM2.5 precision criteria are based on collocated measurements; further details on samplers not meeting criteria can be viewed in Appendix B.
Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.
- National average includes state, county, district, National Park Service, and tribal sites, including those in California; AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.
- Method 117 = R & P Model 2000 PM2.5 Sampler w/WINS; Method 118= R & P Model 2025 PM2.5 Sequential w/WINS; Method 120= Andersen RAAS2.5-300 PM2.5 SEQ w/WINS; Method 145= R & P Model 2025 PM2.5 Sequential Air Sampler w/VSCC; Method 170= Met One BAM-1020 Mass Monitor w/VSCC; Method 181= Thermo TEOM 1400a FDMS.

Table B4 breaks down the statistics displayed in Table B3 under ARB's PQAO by local air districts. Monitoring sites within these areas may be operated by the district, ARB, or both. All areas reported at least 75 percent of the required precision data. The upper bound CV was met in all districts for PM10 with the exception of one location. However, the CV for PM2.5 is exceeded at all districts except Placer County Air Pollution Control District. However, the CV for this district was based on incomplete data. Detailed info in Table B4 is graphically displayed in Figures B5-1 for PM10 and Figure B5-2 for PM2.5.

To further compare the performance of the collocated samplers, an assessment of bias between the collocated samplers was conducted. While there is no requirement for this analysis, 40 CFR Appendix A to Part 58, section 4.3, recommends that this assessment be performed when the primary monitor is a federal equivalent method and the collocated monitor is a federal reference method. In this report, the bias calculations are provided for all collocated samplers in ARB's PQAO network (for informational purposes only). The bias (average difference between "primary" and "secondary" or "collocated" samplers) was estimated using the same procedure for calculating PM2.5 absolute bias, as outlined in Appendix D, section D.4. As shown in the far-right column of Table B4, the results reveal some large biases between the paired PM2.5 samplers within ARB's PQAO.

It is noteworthy that the high CV problem exists at the national level as well as within the ARB PQAO. Although ARB has conducted an assessment of the potential causes behind low PM2.5 precision and the large bias between some of the collocated PM2.5 samplers within the ARB PQAO, no definitive source of the issue has been identified. Some of the observations from our assessment include: 1) ambient PM2.5 values in California are somewhat higher than the rest of the nation; 2) CV values tend to be higher among collocations of non-identical methods (i.e. FEM collocated with FRM) than those of identical methods; 3) empirically, CV values would decrease if the cut-off limits were raised from 3 $\mu\text{g}/\text{m}^3$; 3) the frequency of flow rate verifications or other operational practices based on the limited data gathered do not suggest that they play a big role in influencing the high CVs.

Table B4. 2015 Precision Results for Districts within ARB's PQAO

Pollutant	Geographic Area	Method Code (Primary/Secondary)	Monitoring by (District=D, ARB=A)	% Precision Completeness	Upper Bound of Coefficient of Variation (CV)	Bias Between Collocated Samplers (%)
PM10	Great Basin Unified APCD	All	D	93	24.91	- 22.21
	Sacramento Metro AQMD	All	D	100	5.51	+/- 7.82
	San Joaquin Valley Unified APCD	All	D	100	3.43	- 7.81
			A	100	4.10	+ 3.11
PM2.5	Great Basin Unified APCD	181/145	D	100	17.34	+ 32.16
	Imperial County APCD	145/145	A	87	22.75	+/- 34.75
	Mojave Desert AQMD	117/117	D	100	36.79	+/- 82.68
	Monterey Bay Unified APCD	170/117	D	100	16.16	+/- 18.85
	Placer County APCD	143/143	A	100	4.08	+/- 5.12
	Sacramento Metro AQMD	145/145	D	93	12.93	- 14.47
		170/170	D	100	22.30	+/- 37.23
	San Joaquin Valley Unified APCD	145/145	A	100	10.48	+/- 12.46
		145/145	A	100	28.83	+/- 20.46
		170/145	D	100	17.04	+ 30.60
		170/170	A	100	15.12	+/- 18.47
		170/143	A	80	16.51	- 19.10
	Ventura County APCD	170/170	D	100	13.53	- 19.13

- CFR Limit for CV is 10% for PM. Further details on samplers not meeting these criteria can be viewed in Appendix B.
- **Bold italicized** font indicates CV greater than 10% in 2015.
- Bias between collocated samplers: positive number indicates primary > secondary (collocated).
- Great Basin uploaded data for 2014 and 2015 from Keeler; data for 2014 did not exist in 2014 DQ Report.
- Placer County PM2.5 collocation of method 143/143 began in July 2015; 100% of required data reported for the period.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report (Collocation Detail Report), run September 2016.

Figure B5-1. 2015 Precision Based on Collocated Samplers (PM10)

Site Name:	Fresno-Drummond	Keeler	Bakersfield	Sacramento-Del Paso
Primary POC:	1	6	1	1
CV Value:	3.43	24.91	4.10	5.51
Bias*:	- 7.81	- 22.21	+ 3.11	+/- 7.82
Observations:	54	28	54	36

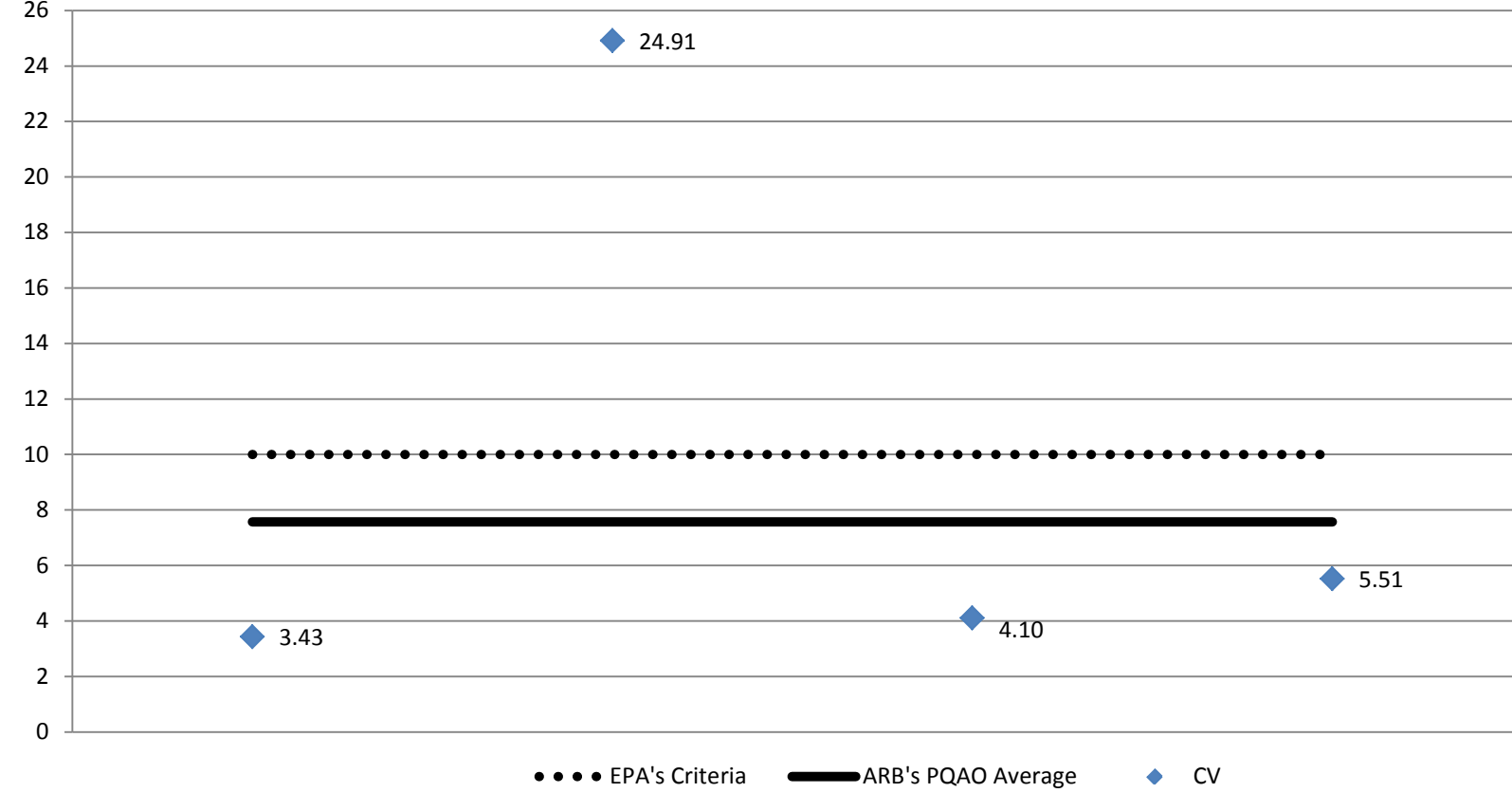


Figure B5-2. 2015 Precision Based on Collocated Samplers (PM2.5)

Site Name:	Roseville	Sac-Del Paso	Folsom	Victorville	Stockton	Modesto	Simi-Valley
Poc:	1	1	3	1	3	3	3
CV Value:	4.08	12.93	22.30	36.79	15.12	16.51	13.53
Bias*:	+/- 5.12	- 14.47	+/- 37.23	+/- 82.68	+/- 18.47	+/- 19.10	- 19.13
Method*:	143/143	145/145	170/170	117/117	170/170	170/143	170/170
Obs:	12	27	118	45	318	20	267

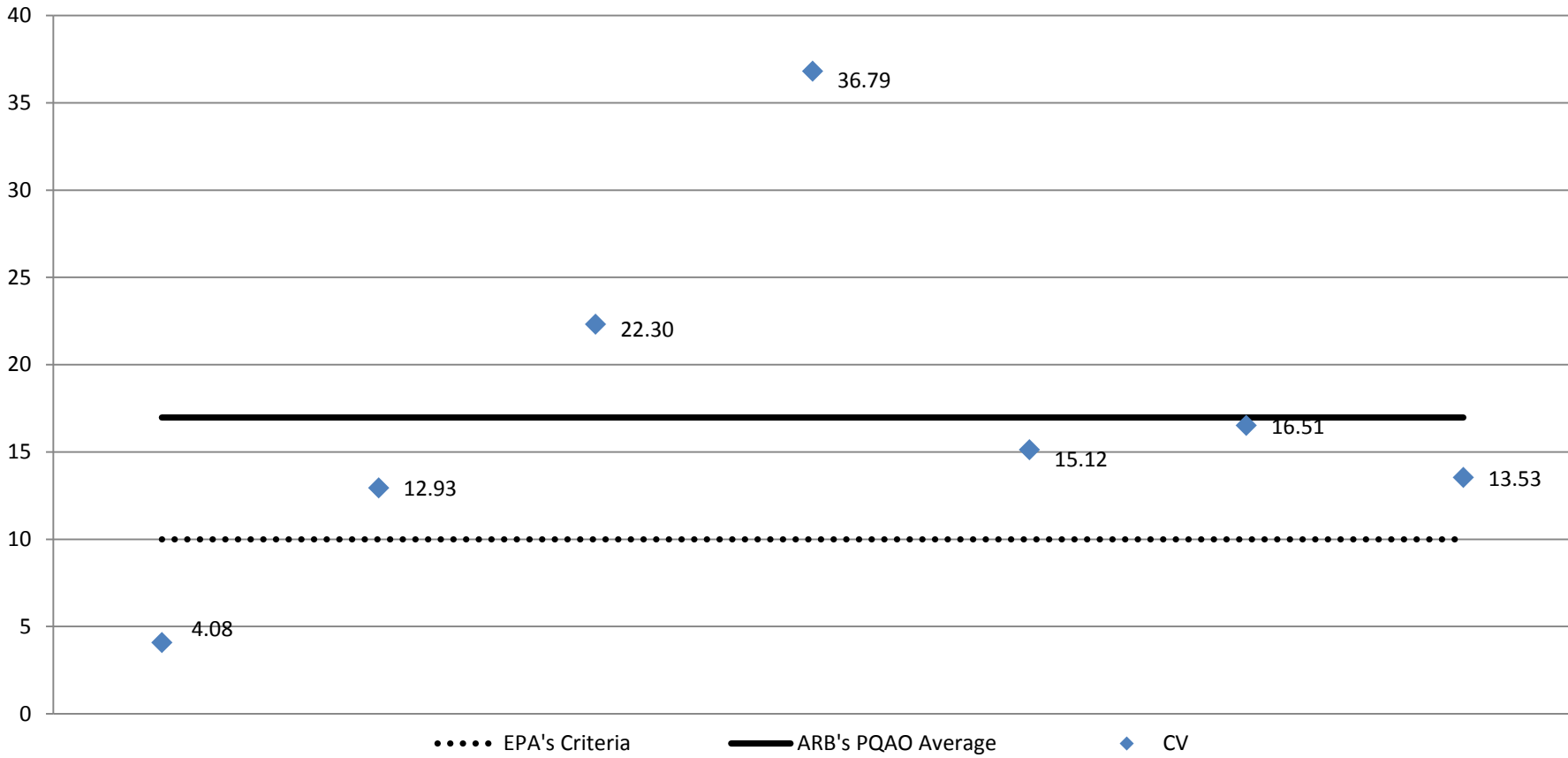
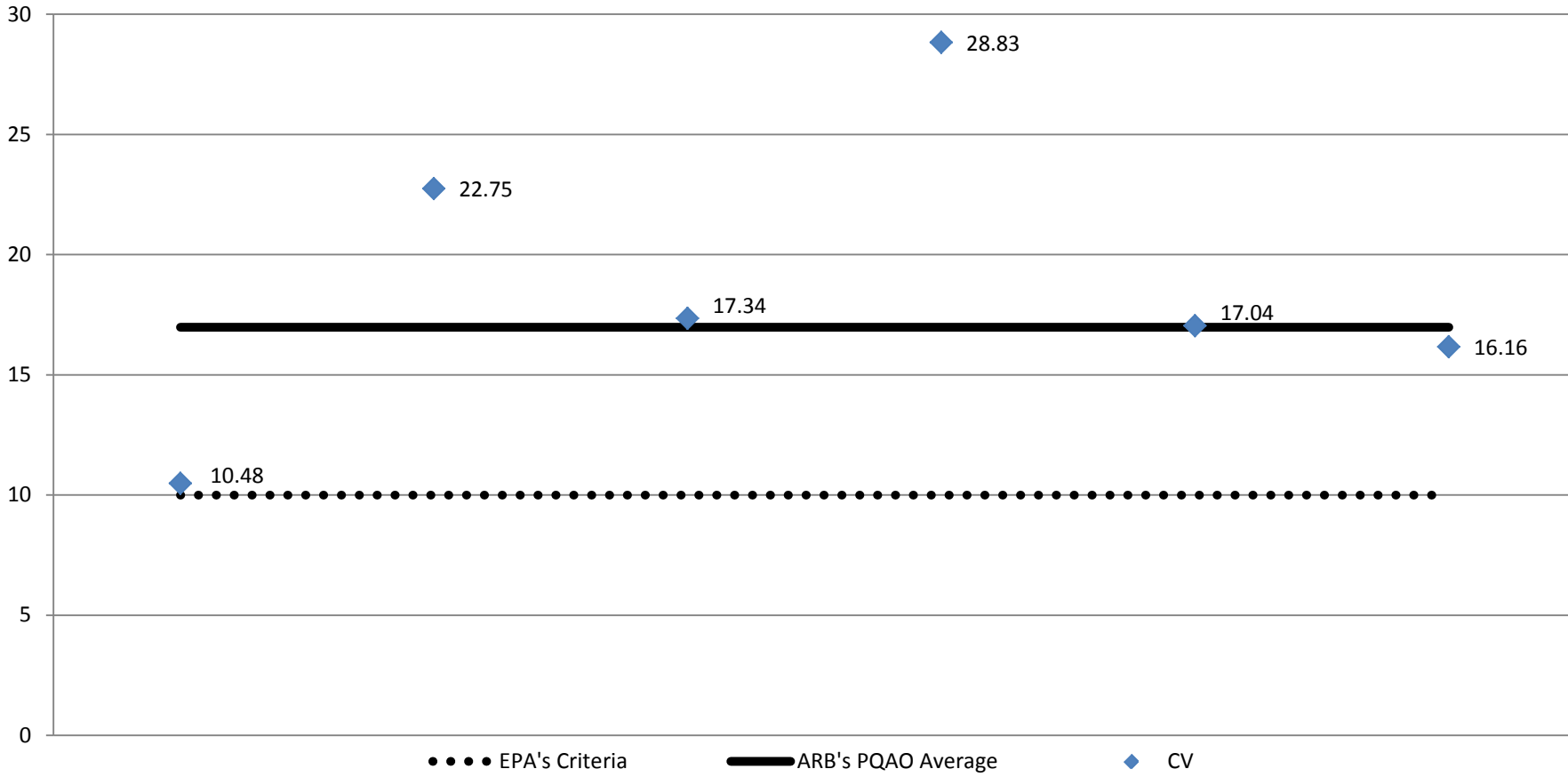


Figure B5-2 (cont'd). 2015 Precision Based on Collocated Samplers (PM2.5)

Site Name:	Fresno Garland	Calexico-Ethel	Keeler	Bakersfield	Madera	Salinas
Poc:	1	1	3	1	3	3
CV Value:	10.48	22.75	17.34	28.23	17.04	16.16
Bias*:	+/- 12.46	+/- 34.75	+ 32.16	+/- 20.46	+ 30.60	+/- 18.85
Method*:	145/145	145/145	181/145	145/145	170/145	170/117
Obs:	30	26	80	26	86	42



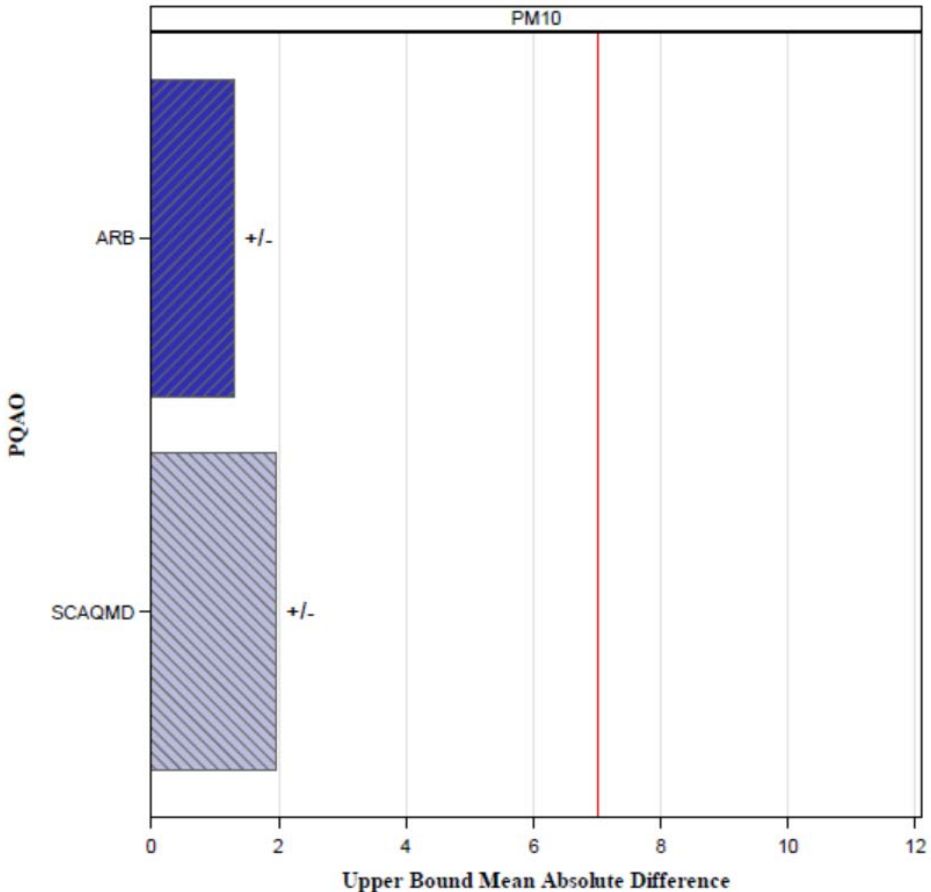
Bias Results Via Monthly Flow Rate Verifications: As noted earlier, only continuous PM10 samplers are required to report monthly flow rate verifications to AQS (starting April 2016, this rule would apply to all PM samplers). Although not required, ARB's PQAO also reported some flow rate verifications to AQS in 2015 for PM2.5. Bias results via the monthly flow rate verifications for 2015 and the preceding two years, as well as the 3-year average, are shown in Table B5-1 and B5-2. In summary, the bias criteria of ± 10 percent for PM10 and ± 4 percent for PM2.5 were met in each PQAO for which data are available. However, all PQAOs are encouraged to upload all flow rate verification data for a more comprehensive assessment of PM bias. Figures B6 and B7 display the summary statistics.

Table B5-1. 2015 Continuous PM10 Bias Results Based on Flow Rate Verifications

Pollutant	PQAO	Year	# of Samplers in Network	# of Samplers Reporting Flow Rates	Average % Difference	Bias (%)	CFR Criteria for Bias Met?
PM10	ARB	2015	67	67	- 0.26	± 1.29	Yes
		2014	56	31	0.18	± 1.35	Yes
		2013	46	34	0.24	± 0.92	Yes
		Avg	-	-	0.05	± 1.19	Yes
	SDCAPCD	2015	NDA	NDA	NDA	NDA	NDA
		2014	NDA	NDA	NDA	NDA	NDA
		2013	NDA	NDA	NDA	NDA	NDA
		Avg	NDA	NDA	NDA	NDA	NDA
	SCAQMD	2015	8	8	0.30	± 1.95	Yes
		2014	10	10	- 0.03	± 1.79	Yes
		2013	11	11	- 0.66	± 1.01	Yes
		Avg	-	-	- 0.26	± 1.58	Yes

- Flow rate verifications available for continuous PM methods only, with just PM10 required to be in AQS.
- CFR criteria for bias: $\pm 7\%$ (of standard) except for dichotomous samplers, which are subjected to $\pm 4\%$.
- Further details on samplers not uploading the required flow rate data can be viewed in Appendix B.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016.
- Results reflect current information in AQS, including changes to past data since the 2014 Annual Data Quality Report. Therefore, results for 2014 and 2013 might differ from those in the 2014 DQ report.

Figure B6. 2015 Bias via Flow Checks – PM10



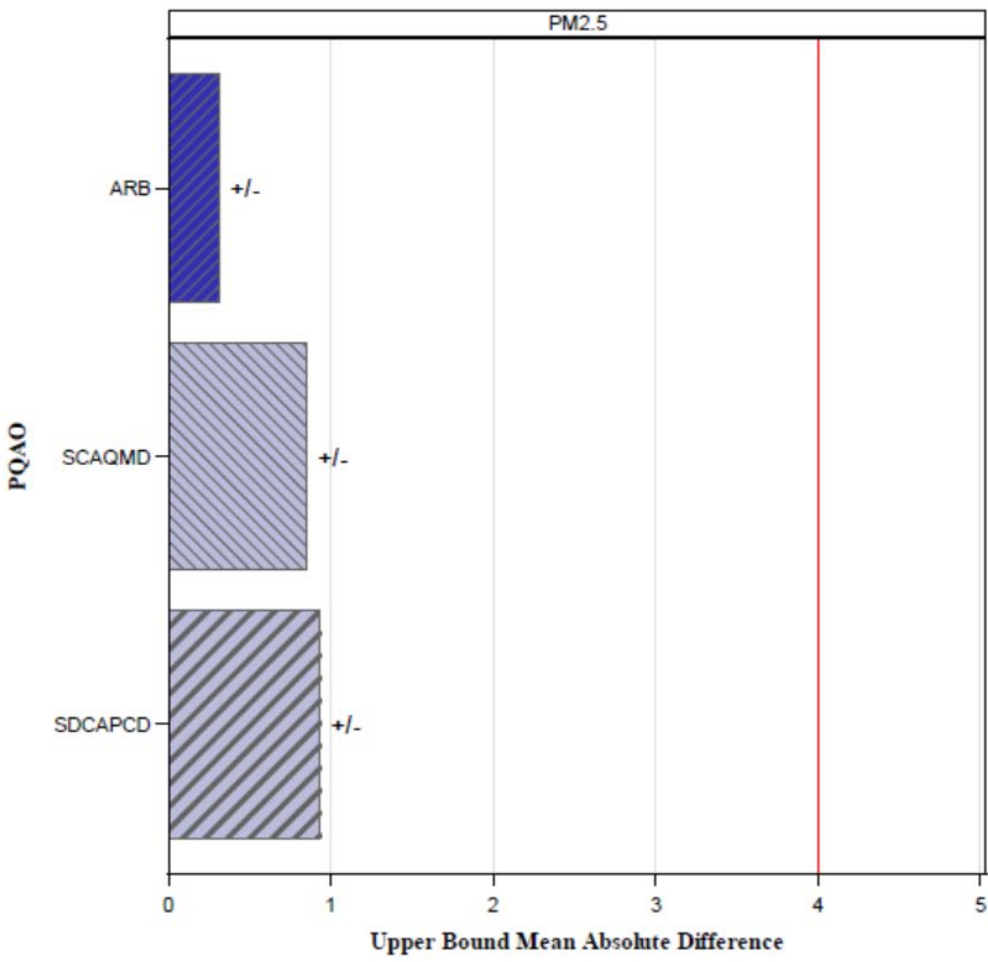
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.
- PM10 bias criteria for both manual and continuous samplers are based on mandatory flow checks. However, only continuous PM10 flow checks are required to be reported to AQS and are included in the Figure.
- Specific criteria can be found in Section III and Appendix A.
- Further details on samplers not meeting criteria can be viewed in Appendix B.

Table B5-2. 2015 All (Continuous and Manual) PM2.5 Bias Results Based on Flow Rate Verifications

Pollutant	PQAO	Year	# of all Samplers in Network	# of Samplers Reporting Flow Rates	Average % Difference	Bias (%)	CFR Criteria for Bias Met?
PM2.5	ARB	2015	89	33	- 0.02	± 0.31	Yes
		2014	80	22	0.03	± 0.66	Yes
		2013	74	15	- 0.14	± 0.48	Yes
		Avg	-	-	- 0.04	± 0.48	Yes
	SDCAPCD	2015	6	6	- 0.01	± 0.93	Yes
		2014	NDA	NDA	NDA	NDA	NDA
		2013	NDA	NDA	NDA	NDA	NDA
		Avg	NDA	NDA	NDA	NDA	NDA
	SCAQMD	2015	22	22	1.05	± 0.85	Yes
		2014	NDA	NDA	NDA	NDA	NDA
		2013	NDA	NDA	NDA	NDA	NDA
		Avg	NDA	NDA	NDA	NDA	NDA

- Although not federally required to be reported to AQS, the following districts within ARB's PQAO uploaded data: Antelope Valley AQMD, Great Basin Unified APCD, Monterey Bay Unified APCD, North Coast Unified AQMD, Placer County APCD, Sacramento Metropolitan AQMD, San Luis Obispo County APCD, Santa Barbara County APCD, and Ventura County APCD.
- CFR criteria for bias: ±4% (of standard).
- NDA= No Data Available from AQS.
- For SCAQMD, a change in coding PM2.5 samplers from 88101 to 88502 resulted in no data for PM2.5 reported in AMP 256 for 2013-2015.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016.
- Results reflect current information in AQS, including changes to past data since the 2014 Annual Data Quality Report. Therefore, results for 2014 and 2013 might differ from those in the 2014 DQ report.

Figure B7. 2015 Bias via Flow Checks – PM2.5



- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.
- PM2.5 bias criteria are based on flow checks (only flow rate checks from continuous PM10 are required to be reported to AQS).
- Specific criteria can be found in Section III and Appendix A.
- Further details on samplers not meeting criteria can be viewed in Appendix B.

Accuracy Validation Via Performance Audits: Since an accurate measurement of PM is dependent upon the flow rate, ARB and other PQAOs are required to conduct semi-annual flow rate audits on all PM samplers at each site. Such audits are to be conducted five to seven months apart on each sampler in a given calendar year. In addition, as explained earlier, PQAOs are also required to submit the continuous PM10 monthly flow rate verifications to AQS; in this case, bias estimates based on flow rate verifications are further verified using the semi-annual flow rate audit data.

Table B6 and Figures B8-B9 summarize the 2015 performance audit results for PM samplers. The numbers of samplers as well as those that met the required number of audits in 2015 are displayed. (Two audits are required if a sampler operates more than seven months; one audit if less than seven months but more than three months, zero if less than three months.) The average percent difference between the sampler flow rates and the audit flow rates represents the arithmetic mean of the combined differences from the certified value of all the individual audit points for each sampler. Table B7 presents similar data for local air districts within ARB's PQAQ. Note that in Figure B8, the percent of PM samplers is defined as the number of samplers meeting the required number of audits divided by the total number of samplers in each PQAQ.

ARB conducts the semi-annual flow rate audits for most samplers operating within ARB's PQAQ. In addition, certain local districts within ARB's PQAQ were to conduct their own audits in 2015. For example, Great Basin Unified APCD conducts one of the semi-annual flow rate audits for the sites operating under it. ARB's policy is to audit non-ARB PQAQ monitoring sites at least once every five years. Non-ARB PQAQs are responsible for performing audits on their own as part of the annual performance evaluation program.

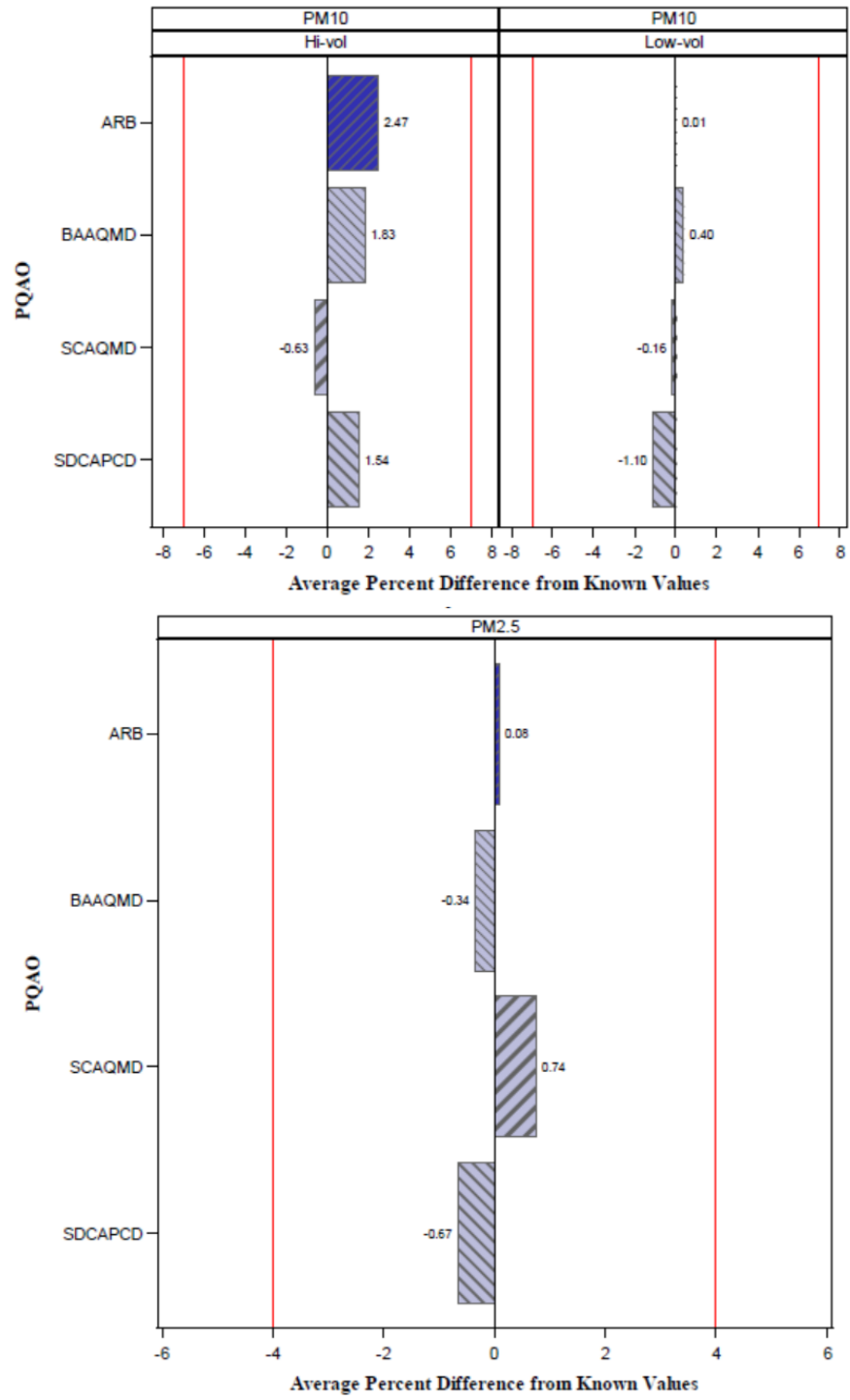
Overall, the results of the audited samplers indicate that the PM samplers in the network were operating within ARB's flow rate audit criteria. For continuous PM10, flow rate audit results agree with bias estimates based on the flow rate verifications under ARB's PQAQ, further validating that the continuous PM10 samplers were operating accurately. Similar results also apply to PM2.5 samplers which reported flow rate verifications (as shown in Table B5-2). Thus, the PM network operating under ARB's PQAQ is generally accurate.

Table B6. 2015 Results for Particulate Sampler Performance Audits

Pollutant	Collection Method	PQAO	# of Samplers	# of Audits Required	# of Audits Conducted	# of Samplers Meeting Required Number of Audits	# of Flow Rate Audits Not Meeting ARB Criteria	Average Percent Difference
PM10	Hi-Vol	ARB	38	69	69 ^{ab}	36	0	2.47
		BAAQMD	7	14	15 ^c	7	0	1.83
		SCAQMD	24	46	53 ^c	23	1	-0.63
		SDCAPCD	6	12	13 ^c	5	0	1.54
	Low-Vol	ARB	70	130	157 ^c	67	0	0.01
		BAAQMD	1	2	2	1	0	0.40
		SCAQMD	9	16	18	8	0	-0.16
		SDCAPCD	1	2	2	1	0	-1.10
PM2.5	All	ARB	89	173	170 ^{bc}	85	0	0.08
		BAAQMD	17	34	37 ^c	17	0	-0.34
		SCAQMD	22	44	53 ^c	20	0	0.74
		SDCAPCD	6	12	12 ^c	4	0	-0.67

- ^a A few PM10 samplers not listed as “audited” were found to be non-operational at the time of the scheduled audits;
- ^b A few PM10 samplers not listed as “audited” had audits performed on dates that were not 5 to 7 months apart, not meeting CFR requirements on timing.
- ^c AQDAs were issued for audits not meeting criteria.
- ^c Sites were audited multiple times in a quarter (by different entities or due to re-audits.)
- ARB’s flow rate audit criteria for 2015 were $\pm 7\%$ for PM10 Hi-Vol and $\pm 4\%$ for PM10 Low-Vol and PM2.5. Only audits conducted by ARB were subjected to the AQDA process. Further details on samplers not meeting these criteria can be found in Appendix B.
- The number of audits required per year: two if sampler is operating for more than seven months, one if less than seven months but more than three months, zero if less than three months.
- Further details on samplers not meeting these criteria can be viewed in Appendix B.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.

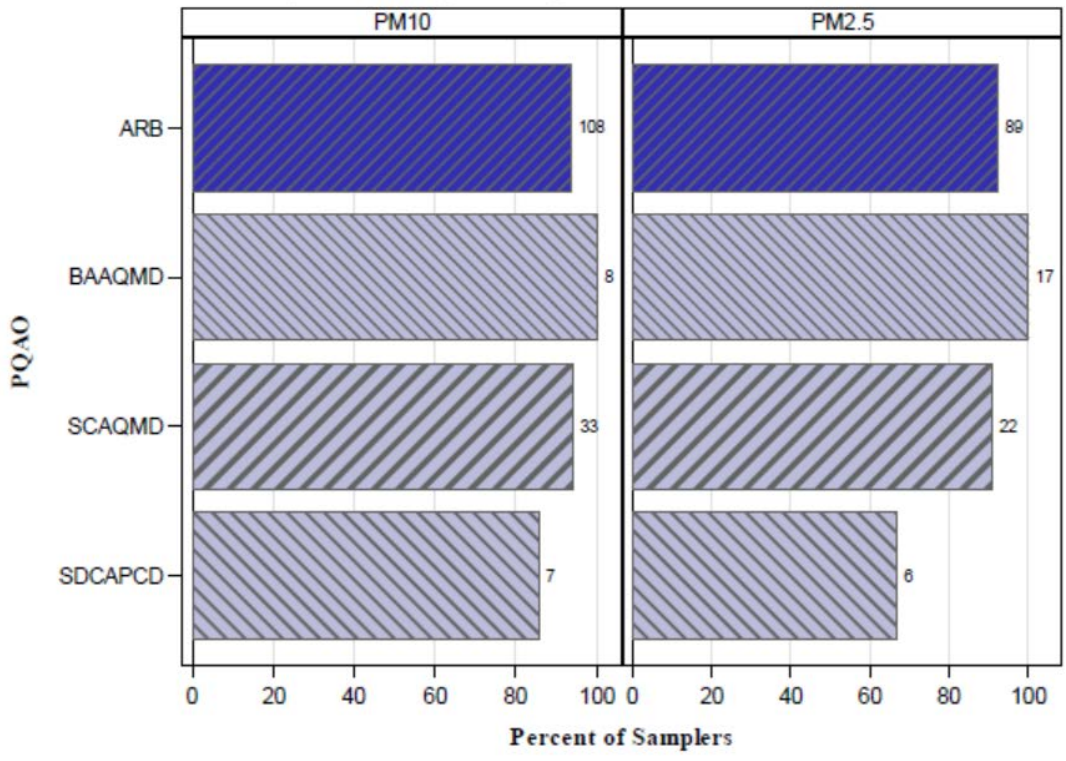
Figure B8. 2015 Accuracy via Audits – PM



- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016.
- ARB's performance audit criteria for 2015: ±7% for PM10 Hi-Vol and ±4% for PM10 Low-Vol and PM2.5. Only audits conducted by ARB were subjected to the AQDA process.

Figure B9. Percent of PM Samplers Meeting the Required Number of Performance Audits

(Total Samplers in Network Indicated on Bars)



- The number of audits required per year: two if sampler is operating for more than seven months, one if less than seven months but more than three months, zero if less than three months. Further details on samplers not meeting criteria can be viewed in Appendix B.
- National average includes state, county, district, National Park Service, and tribal sites, including those in California;
- Source: AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.

**Table B7. 2015 Results for Particulate Sampler Flow Rate Audits for Local Air Districts
Within ARB's PQAQ**

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	# of Samplers	# of Samplers not Audited	# of Flow Rate Audits Not Meeting ARB Criteria	Average Percent Difference
PM10	Antelope Valley AQMD	D	1	1	0	0.10
	Butte County AQMD	A	1	0	0	-0.42
	Calaveras County APCD	A	1	0	0	0.85
	Colusa County APCD	A	1	0	0	3.26
	Eastern Kern APCD	D	3	0	0	3.32
	El Dorado County AQMD	A	1	0	0	0.94
	Feather River AQMD	A	1	0	0	-0.06
	Glenn County APCD	A	1	0	0	0.10
	Great Basin Unified APCD	D	17	0	0	-0.28
	Imperial County APCD	D	9	0	0	2.73
	Mariposa County APCD	A	1	0	0	-0.39
	Mendocino County AQMD	D	1	0	0	-1.48
	Mojave Desert AQMD	D	5	0	0	1.96
	Monterey Bay Unified APCD	D	2	0	0	1.08
	North Coast Unified AQMD	D	1	0	0	-0.97
	Northern Sonoma County APCD	D	3	0	0	-0.28
	Placer County APCD	B	2	1	0	5.29
	Sacramento Metropolitan AQMD	B	8	1	0	2.43
	San Joaquin Valley Unified APCD	B	23	2	0	1.05
	San Luis Obispo County APCD	D	8	0	0	-0.29
	Santa Barbara County APCD	D	7	0	0	-0.63
	Shasta County AQMD	D	3	0	0	0.91
	Siskiyou County APCD	D	1	0	0	3.28
	Tehama County APCD	D	2	0	0	1.52
Ventura County APCD	D	2	0	0	-0.01	
Yolo-Solano AQMD	B	3	0	0	0.64	
PM2.5	Antelope Valley AQMD	D	1	0	0	0.12
	Butte County AQMD	A	1	0	0	0.62
	Calaveras County APCD	A	1	0	0	1.37
	Colusa County APCD	A	1	0	0	0.39
	Eastern Kern APCD	D	2	1	0	0.60
	Feather River AQMD	A	1	0	0	0.03
	Great Basin Unified APCD	D	3	0	0	-0.76

Table B7 (cont'd). 2015 Results for Particulate Sampler Flow Rate Audits for Local Air Districts Within ARB's PQAO

Pollutant	Geographic Area	Monitoring by (District=D, ARB=A, or Both=B)	# of Samplers	# of Samplers not Audited	# of Flow Rate Audits Not Meeting ARB Criteria	Average Percent Difference
PM2.5	Imperial County APCD	D	6	0	0	0.48
	Lake County APCD	D	1	0	0	-1.42
	Mendocino County AQMD	D	2	0	0	-0.31
	Mojave Desert AQMD	D	2	0	0	0.96
	Monterey Bay Unified APCD	D	7	0	0	0.89
	North Coast Unified AQMD	D	2	1	0	-0.23
	Northern Sierra AQMD	D	6	1	0	0.46
	Placer County APCD	B	3	1	0	1.24
	Sacramento Metropolitan AQMD	B	7	0	0	0.35
	San Joaquin Valley Unified APCD	B	25	0	0	-0.26
	San Luis Obispo County APCD	D	5	0	0	0.12
	Santa Barbara County APCD	D	4	0	0	-0.67
	Shasta County AQMD	D	1	0	0	0.91
	Siskiyou County APCD	D	1	0	0	-2.85
	Ventura County APCD	D	6	0	0	0.20
Yolo-Solano AQMD	B	1	0	0	-0.73	

- ARB's flow rate audit criteria for 2015 were $\pm 7\%$ for PM10 Hi-Vol and $\pm 4\%$ for PM10 Low-Vol and PM2.5. Only audits conducted by ARB were subjected to the AQDA process. Further details on samplers not meeting these criteria can be found in Appendix B.
- Further details on samplers not meeting these criteria can be viewed in Appendix B.
- Source: Air Quality System, AMP 256 Data Quality Indicator Report, run September 2016, except as noted in Appendix B.

IV. CONCLUSIONS AND RECOMMENDATIONS

This report provides ambient air quality data producers and users with a centralized review of the data quality within ARB's PQAO with respect to MQOs. In addition, comparisons to other PQAOs in California and the national average are shown where appropriate.

Below are some highlights for 2015.

Gaseous Pollutants (CO, O₃, NO₂, and SO₂)

- Ninety-eight percent of the instruments operating under ARB's PQAO achieved the ambient data capture rate of at least 75 percent in 2015.
- Ninety-seven percent of the instruments operating within ARB's PQAO reported at least 75 percent of the required one-point QC checks for the gaseous pollutants.
- All of the California PQAOs met the CFR criteria for precision and bias based on one-point QC checks.
- The performance audit acceptance criteria were met, on average, at the PQAO level for ARB's PQAO (as well as other PQAOs) with only a small number of analyzers not passing performance audit criteria. This validates the bias estimates based on one-point QC checks.

Particulate Matter (PM₁₀ and PM_{2.5})

- Ninety-seven percent of the particulate samplers operating under ARB's PQAO achieved the ambient data capture rate of at least 75 percent in 2015.
- ARB's PQAO is short of meeting the required number of collocated sampling sites for PM₁₀ and for one method of collecting PM_{2.5}, an improvement compared to previous years, when more than one method did not meet the requirement.
- For the four PM₁₀ and thirteen PM_{2.5} pairs of collocated samplers that were present within ARB's PQAO, all reported at least 75 percent of the required precision data.
- Based on collocated PM data, CFR requirements for precision were met by ARB's PQAO (as well as other California PQAOs) for PM₁₀ except at one location. However, ARB's PQAO did not meet the precision requirements at the PQAO level for any method of collecting PM_{2.5}, as shown in Table IV-1. Although precision values are comparable to previous years, an investigation into further improving PM_{2.5} precision is encouraged.

Table IV-1. 2015 Precision Assessment for PM2.5

PQAO	Method 117	Method 118	Method 120	Method 143	Method 145	Method 170	Method 181
ARB	X	X	-----	✓	X	X	X
BAAQMD	-----	-----	-----	-----	-----	X	-----
SCAQMD	-----	-----	X	-----	X	-----	-----
SDCAPCD	-----	-----	-----	-----	✓	-----	-----

Dashed marks (-----) = method not applicable to PQAO; X = No; and ✓ = Yes. NDA=No data available in AQS.

- Although there is no specific MQO for bias between collocated PM samplers, an assessment of bias between collocated PM samplers in ARB’s PQAO was performed and showed some unusually high values. An investigation into the cause(s) behind the large bias between some of the collocated PM2.5 samplers is encouraged.
- Flow rate verifications are required to be performed on all PM samplers, but only those from continuous PM10 are required to be uploaded. Data from several continuous PM10 samplers from Antelope Valley APCD and Mojave Desert AQMD were missing in AQS for 2015. To enhance consistency in regulation and avoid any confusion, U.S. EPA requires that, starting in April 2016, data on flow rate checks be uploaded to AQS for all PM sampler methods. Thus, it is encouraged that all monitoring agencies within ARB’s PQAO upload flow rate verification data (one-point flow checks) to U.S. EPA’s AQS for all PM sampling methods, as such information would allow for a more comprehensive assessment of PM accuracy.
- Flow rate audit data indicate that ARB’s PQAO met ARB criteria. This finding is consistent with the limited bias information that can be ascertained from the routine flow rate verification data available in AQS.

In an effort to compare 2015 data quality results across geographic areas within California, results for both gases and PM are summarized in one composite table in the Executive Summary. To make a fair comparison, we divided the geographic areas into three categories according to monitoring activities: 1) gas only; 2) gas and PM without collocation; and 3) gas and PM with collocation. Below are some key observations for 2015 (they are similar to results from 2014):

- There are two areas that monitored gases only, and both achieved all MQOs.
- Among nineteen areas that monitored gases and PM without collocation, thirteen met all MQOs, three did not meet the MQOs for ozone only, one did not meet the MQOs for PM only, and two did not meet for both ozone and PM.
- Among nine areas that monitored gases and PM with collocation, none achieved all MQOs, mainly due to high CVs associated with PM2.5.

High CV values between collocated samplers have been observed within the ARB PQAO and at a national level. Although ARB has conducted an assessment of the potential causes behind low PM2.5 precision and the large bias between some of the collocated PM2.5 samplers within the ARB PQAO, no definitive source of the issue has

been identified. Some of the observations from our assessment include: 1) ambient PM_{2.5} values in California are somewhat higher than the rest of the nation; 2) CV values tend to be higher among collocations of non-identical methods (i.e. FEM collocated with FRM) than those of identical methods; 3) empirically, due to the inherent nature of percent differences being magnified in the low concentration range, CV values would decrease if the cut-off limits were raised from 3 ug/m³; 4) sites that meet the CV criteria are not consistent from year to year.

Although CFR criteria for precision and accuracy are generally applied and evaluated at the PQAO level, assessments at the district or site level may differ and can be important as well. Therefore, data producers are strongly encouraged to review the site-level information and assess whether their data quality objectives are met. It is important to note that when certain CFR criteria are not met, it does not necessarily mean that the corresponding air quality data should not be used, but rather, the data should be used with the knowledge of the quality behind it. The 2015 ambient data in AQS for the ARB's PQAO have been certified and are considered suitable for comparison to federal ambient air quality standards.

The statistics presented in this report are intended as assessment tools for the data producers to identify areas where program improvements can be made to achieve all MQOs set by U.S. EPA or the data producers themselves. ARB has recently implemented a comprehensive corrective action system throughout ARB's PQAO which is expected to serve as an essential component for improving data quality and facilitating continuous process improvement. Specifically, ARB developed the Corrective Action Notification (CAN) process that can be used to document issues that impact or potentially impact data quality, completeness, storage, or reporting. The goal of the CAN process is to investigate, correct, and reduce the recurrence of these issues. As such, the information obtained from this report can be coupled with the CAN process to identify issues (not already identified by AQDAs), improve data quality, and ensure compliance with State, federal, and local requirements.

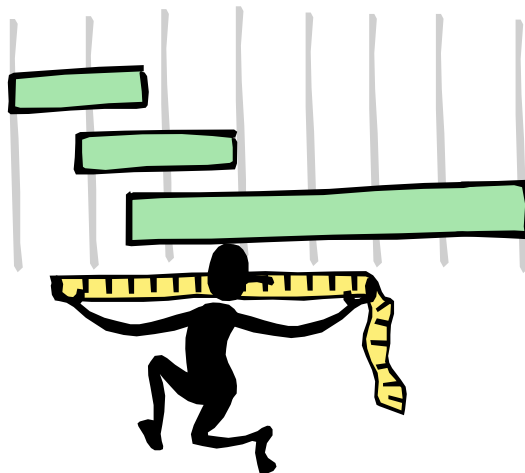
A complete listing of all references used in this report can be found in Appendix E.

APPENDIX A

U.S. EPA's MEASUREMENT QUALITY OBJECTIVES

TOOLS FOR ASSESSING PRECISION AND BIAS/ACCURACY

ARB PERFORMANCE AUDIT CRITERIA



U.S. EPA's Measurement Quality Objectives

Table 1. Ambient Air Monitoring Measurement Quality Samples

(Table A-2 in 40 CFR Part 58 Appendix A; QA Handbook Volume II Appendix D, May 2013)

Method	CFR Reference	Coverage (annual)	Minimum frequency	MQOs
Automated Methods				
One-Point QC: for SO ₂ , NO ₂ , O ₃ , CO	Section 3.2.1	Each analyzer	Once per 2 weeks	O ₃ Precision 7%, Bias ± 7%. NO ₂ Precision 15%, Bias ± 15%. SO₂ and CO Precision 10% , Bias ± 10%
Annual performance evaluation for SO ₂ , NO ₂ , O ₃ , CO	Section 3.2.2	Each analyzer	Once per year	≤ 15 % for each audit concentration
National performance audit program for SO ₂ , NO ₂ , O ₃ , CO	Section 2.4	20% of sites per year	Once per year	O ₃ ≤ 10 % for each audit concentration NO ₂ , SO ₂ , CO ≤ 15 % for each audit concentration
Flow rate verification PM10, PM2.5	Section 3.2.3	Each sampler	Once every month	PM10 ≤ 7% of standard and design value PM2.5 ≤ 4% of standard and 5% of design value
Semi-annual flow rate audit PM10 Continuous, PM2.5	Section 3.2.4	Each sampler	Once every 6 months	PM10 ≤ 10% of standard and design value PM2.5 ≤ 4% of standard and 5% of design value
Collocated sampling PM2.5	Section 3.2.5	15%	Every twelve days	10% precision
PM Performance evaluation program PM2.5	Section 3.2.7	1. 5 valid audits for primary QA orgs, with ≤ 5 sites 2. 8 valid audits for primary QA orgs, with > 5 sites 3. All samplers in 6 years	Over all 4 quarters	± 10% bias
Manual Methods				
Collocated sampling PM10, TSP, PM2.5	3.3.1 and 3.3.5	15%	Every 12 days	PM10, PM2.5, - 10% precision TSP - 20% precision
Flow rate verification PM10 (low Vol), PM2.5	3.3.2	Each sampler	Once every month	≤ 4% of standard and 5% of design value
Flow rate verification PM10 (High-Vol), TSP	3.3.2	Each sampler	Once every quarter	≤ 7% of standard and design value
Semi-annual flow rate audit PM10 (low Vol), PM2.5	3.3.3	Each sampler, all locations	Once every 6 months	≤ 4% of standard and 5% of design value
Semi-annual flow rate audit PM10 (High-Vol), TSP	3.3.3	Each sampler, all locations	Once every 6 months	≤ 7% of standard and 10% of design value
Performance evaluation program PM2.5	3.3.7 and 3.3.8	1. 5 valid audits for primary QA orgs, with ≤ 5 sites 2. 8 valid audits for primary QA orgs, with ≥ 5 sites 3. All samplers in 6 years	Over all 4 quarters	± 10% bias

Tools for Assessing Precision and Bias/Accuracy

Pollutant	Precision		Bias/Accuracy			
	1-Pt QC Checks (in AQS)	Collocated Measurements (in AQS)	1-Pt QC Checks (in AQS)	Flow Rate Verification (in AQS)	Flow checks performed (not required in AQS)	Performance Audits (in AQS)
Gaseous O3, CO, NO2, SO2	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>			annual
Continuous						
PM2.5		<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/> monthly	semi-annual
PM10				<input checked="" type="checkbox"/> monthly		semi-annual
Manual						
PM2.5		<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/> monthly	semi-annual
PM10 (high vol)		<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/> quarterly	semi-annual
PM10 (low vol)		<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/> monthly	semi-annual

ARB's Performance Audit Criteria (2015)

ARB's Control and Warning Limits

<u>Limits</u>		<u>Instrument</u>
<u>Control</u>	<u>Warning</u>	
±10 %	±7 %	Ozone
±15 %	±10 %	Carbon Monoxide, Nitrogen Dioxide, Sulfur Dioxide
±15 %	±10 %	Total Suspended Particulate (TSP) Samplers, including Lead.
±10 %	±7 %	Dichotomous (Dichot), Tapered Element Oscillating Microbalance (TEOM), Beta Attenuated Monitors (BAM)
±7 % (Flow) ±10 % (Design)	None None	PM10 Hi-Vol
±4 % (Flow) ±5 % (Design)	None None	PM10 Low-Vol, PM2.5

Acceptance Criteria For Meteorological (MET) Sensors

<u>Limits</u>	<u>Sensor</u>
±1.0° Celsius (±0.5°C PAMS only)	Ambient Temperature
±2.25mm of Mercury (Hg)	Barometric Pressure
less than or equal to 5° combined accuracy and orientation error	Wind Direction
less than or equal to 0.5m/s	Wind Direction Starting Threshold
±0.25m/s between 0.5 and 5m/s and less than 5 % difference above 5m/s	Horizontal Wind Speed
less than or equal to 0.5m/s	Horizontal Wind Speed Starting Threshold

Note: ARB does not audit relative humidity, solar radiation, and vertical wind speed.

APPENDIX B

ARB's PQAO DATA QUALITY ISSUES

Background

This appendix contains a listing of samplers that did not meet a particular measurement quality objective (MQO). These data are provided for informational purposes only, as most MQOs are assessed at the PQAO level.

Gases - Ambient Data Completeness <75% Reported						
Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-071-0001	1	Barstow	Mojave Desert AQMD	Mojave Desert AQMD	CO	71%
06-067-0014	1	Sacramento-Goldenland Court	Sac Metro AQMD	Sac Metro AQMD	CO	74%
06-037-9033	1	Lancaster-43301 Division Street	Antelope Valley AQMD	Antelope Valley AQMD	NO ₂	66%
06-023-1005	1	Eureka-Humboldt Hill	North Coast Unified AQMD	North Coast Unified AQMD	NO ₂	74% (Data not certified)
06-103-0005	1	Red Bluff-Oak Street	Tehama County APCD	Tehama County APCD	O ₃	48% (site relocated 1/21/15)
Gases - Precision/Bias 1-Point Checks <75% Reported						
Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-067-0014	1	Sacramento-Goldenland Court	Sac Metro AQMD	Sac Metro AQMD	CO	73% reported (issue with gas calibrator).
06-067-0015	1	Sacramento-Bercut	Sac Metro AQMD	Sac Metro AQMD	CO	60% reported (data logger malfunctioned)
06-067-0006	1	Sacramento-Del Paso Manor	Sac Metro AQMD	Sac Metro AQMD	NO ₂	69% (issue with calibrator)
06-067-0015	1	Sacramento-Bercut	Sac Metro AQMD	Sac Metro AQMD	NO ₂	60% reported (data logger malfunctioned)
06-027-0002	1	White Mountain Research Station	Great Basin APCD	Great Basin APCD	O ₃	65%
06-027-0002	1	White Mountain Research Station	Great Basin APCD	Great Basin APCD	SO ₂	62%
Gases – Precision/Accuracy/Bias Criteria Exceeded						
Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-025-4003	1	Westmoreland	Imperial County APCD	Imperial County APCD	O ₃	7.38 exceeds 7% of CV criteria
06-113-0004	1	UC Davis Campus	Yolo-Solano AQMD	ARB	O ₃	7.26 exceeds 7% of CV criteria

Gases – Precision/Accuracy/Bias Criteria Exceeded

Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-023-1004	1	Eureka Jacobs Ave	North Coast Unified AQMD	North Coast Unified AQMD	SO ₂	10.83 exceeds 10% of Bias criteria
06-023-1005	1	Eureka-Humboldt Hill	North Coast Unified AQMD	North Coast Unified AQMD	NO ₂	18.99 exceeds (15% of Audit criteria)
06-057-0007	1	White Cloud	Northern Sierra AQMD	ARB	O ₃	-11.66 exceeds (10% Audit criteria)
06-019-0011	3	Fresno-Garland	San Joaquin Valley APCD	ARB	SO ₂	15.39, exceeds (15% Audit criteria)
06-023-1005	1	Eureka-Humboldt Hill	North Coast Unified AQMD	North Coast Unified AQMD	SO ₂	- 17.95, -18.69, - 19.02 exceeds (15% Audit criteria)

Gas Audits Not Performed

Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-067-0015	1	Sacramento-Bercut	Sac Metro AQMD	Sac Metro AQMD	CO	Site began 12/3/2015
06-067-0015	1	Sacramento-Bercut	Sac Metro AQMD	Sac Metro AQMD	NO ₂	Site began 12/3/2015
06-079-8001	1	Atascadero-Lewis Avenue	San Luis Obispo County APCD	San Luis Obispo County APCD	NO ₂	Site closed 2/23/15
06-079-8001	1	Atascadero-Lewis Avenue	San Luis Obispo County APCD	San Luis Obispo County APCD	O ₃	Site closed 2/23/15
06-103-0005	1	Red Bluff-Oak Street	Tehama County APCD	Tehama County APCD	O ₃	Site relocated 1/21/15

PM - Ambient Data Completeness <75% reported

Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-031-0004	7	Corcoran-Patterson	San Joaquin Valley APCD	San Joaquin Valley APCD	PM10	68% reported.
06-061-0006	1	Roseville-N Sunrise Blvd	Placer County APCD	ARB	PM10	67% reported.

PM - Ambient Data Completeness <75% reported

Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-067-0002	1	North Highlands-Blackfoot Way	Sac Metro AQMD	Sac Metro AQMD	PM10	30%
06-057-1001	1	Truckee-Fire Station	Northern Sierra AQMD	Northern Sierra AQMD	PM2.5	15%
06-057-1001	2	Truckee-Fire Station	Northern Sierra AQMD	Northern Sierra AQMD	PM2.5	70%
06-067-0012	4	Folsom-Natoma Street	Sac Metro AQMD	Sac Metro AQMD	PM2.5	49%

PM Precision Criteria Not Met

Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-061-0006	1	Roseville-N Sunrise Blvd	Placer County APCD	ARB	PM2.5	Although AMP256 report indicates 48%, 100% collocated data were reported for operating period of July-Dec 2015
06-027-1003	6	Keeler-Cerro Gordo Road	Great Basin Unified APCD	Great Basin Unified APCD	PM10	Exceeds 10% CV criteria (24.91)
06-019-0011	1	Fresno-Garland	San Joaquin Valley APCD	ARB	PM2.5	Exceeds 10% CV criteria (10.48)
06-025-0005	1	Calexico-Ethel Street	Imperial County APCD	ARB	PM2.5	Exceeds 10% CV criteria (22.75)
06-027-1003	3	Keeler-Cerro Gordo Road	Great Basin Unified APCD	Great Basin Unified APCD	PM2.5	Exceeds 10% CV criteria (17.34)
06-029-0014	1	Bakersfield-5558 California Avenue	San Joaquin Valley APCD	ARB	PM2.5	Exceeds 10% CV criteria (28.83)
06-039-2010	3	Madera-28261 Avenue 14	San Joaquin Valley APCD	San Joaquin Valley APCD	PM2.5	Exceeds 10% CV criteria (17.04)
06-053-1003	3	Salinas-#3	Monterey Bay Unified APCD	Monterey Bay Unified APCD	PM2.5	Exceeds 10% CV criteria (16.16)

PM Precision Criteria Not Met

Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-067-0006	1	Sacramento-Del Paso Manor	Sac Metro AQMD	Sac Metro AQMD	PM2.5	Exceeds 10% CV criteria (12.93)
06-067-0012	3	Folsom-Natoma Street	Sac Metro AQMD	Sac Metro AQMD	PM2.5	Exceeds 10% CV criteria (22.30)
06-071-0306	1	Victorville-14306 Park Avenue	Mojave Desert AQMD	Mojave Desert AQMD	PM2.5	Exceeds 10% CV criteria (36.79)
06-077-1002	3	Stockton-Hazelton Street	San Joaquin Valley APCD	ARB	PM2.5	Exceeds 10% CV criteria (15.12)
06-099-0005	3	Modesto-14th Street	San Joaquin Valley APCD	ARB	PM2.5	Exceeds 10% CV criteria (16.51)
06-111-2002	3	Simi Valley-Cochran Street	Ventura County APCD	Ventura County APCD	PM2.5	Exceeds 10% CV criteria (13.53)

PM Audits Not Performed

Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-029-0010	1	Bakersfield-Golden	San Joaquin Valley APCD	San Joaquin Valley APCD	PM10	Only one audit conducted
06-037-9033	1	Lancaster-43301 Division Street	Antelope Valley AQMD	Antelope Valley AQMD	PM10	Audits were conducted but not performed within six month period
06-061-0006	3	Roseville-N Sunrise Blvd	Placer County APCD	ARB	PM10	Audits were conducted but not performed within six month period
06-067-0002	1	North Highlands-Blackfoot Way	Sac Metro AQMD	Sac Metro AQMD	PM10	Site not in operation due to damage
06-107-2002	5	Visalia-N Church Street	San Joaquin Valley APCD	ARB	PM10	Only one audit conducted
06-023-1005	1	Eureka-Humboldt Hill	North Coast Unified AQMD	North Coast Unified AQMD	PM2.5	Only one audit conducted

PM Audits Not Performed

Site ID	POC	Site Name	District	Monitoring Agency	Pollutant	Issue/Comment
06-029-0015	1	Ridgecrest	Eastern Kern APCD	Eastern Kern APCD	PM2.5	Audit failed 2/13/15; re-audit on 4/9/15 and next audit on 8/15/15 did not fall within 5-to-7-month window
06-057-1001	2	Truckee-Fire Station	Northern Sierra AQMD	Northern Sierra AQMD	PM2.5	Monitoring discontinued; one audit conducted
06-061-0006	2	Roseville-N Sunrise Blvd	Placer County APCD	ARB	PM2.5	Site added in April not able to perform audit

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APPENDIX C

METEOROLOGICAL SENSOR PERFORMANCE AUDITS CONDUCTED BY ARB

Meteorology



Meteorological Tower

ARB and local air districts monitor meteorological parameters such as wind speed, wind direction, ambient temperature, relative humidity, barometric pressure, and total solar radiation. Real-time meteorological data are generated to characterize meteorological processes such as transport and diffusion, and to make air quality forecasts and burn-day decisions. The data are also used for control strategy modeling and urban airshed modeling. A State/local meteorology subcommittee of the Air Monitoring Technical Advisory Committee agreed to define the level of acceptability for meteorological data as those used by U.S. EPA for both the Prevention of Significant Deterioration and Photochemical Assessment Monitoring Stations programs. QMB evaluates meteorological parameters according to those levels.

The wind speed, wind direction, barometric pressure, and outside temperature data sets are subject to meeting ARB's performance criteria, which can be found in Appendix A of this report. Relative humidity sensors are not audited by ARB. Since the inception of the meteorological audit program, the data quality has improved significantly.

Accuracy: The accuracy of meteorological sensors is checked by annual performance audits. The table below summarizes the 2015 audit results. They represent the data collected by ARB. As meteorological sensors are not required in CFR to be audited by other PQAOs, and ARB only audits non-PQAO sites at least once every five years, the number of audits under ARB PQAO appears large compared to a few audits under other PQAOs. The average percent or degree difference represents the arithmetic mean of the combined differences from the certified value of all the individual audit points for each sensor. The minimum and maximum are included to convey the range in the percent differences. Information about the meteorological monitoring program is available at <http://www.arb.ca.gov/aqgm/met.htm>.

2014 Results for Meteorological Sensor Performance Audits Conducted by ARB[update]

Sensor	PQAO	# of Audits	# of Audits That Failed	Avg % or Degree Difference	Minimum % Difference	Maximum % Difference
Ambient Temperature (degrees C)	ARB	82	1	0.22	-0.21	0.65
	Other PQAOs	0	0	0.00	0.00	0.00
Wind Direction (degrees)	ARB	59	1	-0.46	-3.81	2.88
	Other PQAOs	5	0	1.16	-1.05	3.37
Horizontal Wind Speed (%)	ARB	80	1	0.23	-1.42	1.89
	Other PQAOs	5	0	0.36	-0.79	1.51
Barometric Pressure (mmHg)	ARB	27	0	-0.12	-1.81	1.56
	Other PQAOs	0	0	0.00	0.00	0.00

Note: ARB's acceptance criteria for meteorological sensors are: ± 1 degree Celsius for ambient temperature, 5% combined accuracy and orientation error for wind direction, 0.25% m/s between 0.5 and 5 m/s and 5% difference above 5 m/s for horizontal wind speed, and ± 2.25 mm Hg for barometric pressure.

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APPENDIX D

DETAILED CALCULATIONS OF STATISTICS USED TO ASSESS PRECISION AND ACCURACY

The materials in this Appendix were adapted from U.S. EPA’s “Guideline on the Meaning and the Use of Precision and Bias Data Required by 40 CFR Part 58 to Appendix A”.

Data Quality Indicators Calculated for Each Measured Pollutant

Pollutant	Gaseous Assessments (Precision or Bias)	One-Point Flow Rate Bias Estimate	PM2.5 Bias	PM2.5 Absolute Bias	Semi-Annual Flow Rate Audits	Precision Estimate from Collocated Samples	Lead Bias
O ₃	Precision Estimate/ Bias Estimate						
SO ₂	Precision Estimate/ Bias Estimate						
NO ₂	Precision Estimate/ Bias Estimate						
CO	Precision Estimate/ Bias Estimate						
PM2.5		One-Point Flow Rate	Bias Estimate	Absolute Bias Estimate	Semi-Annual Flow Rate	Precision Estimate	
PM10		One-Point Flow Rate			Semi-Annual Flow Rate	Precision Estimate	
Lead							Precision Estimate/ Bias Estimate

D.1 Gaseous Precision and Bias Assessments

Applies to: CO, O₃, NO₂, SO₂

40 CFR Part 58 Appendix A References:

- **4.1.1 Percent Difference**
- **4.1.2 Precision Estimate**
- **4.1.3 Bias Estimate**
- **4.1.3.1 Assigning a sign (positive / negative) to the bias estimate.**
- **4.1.3.2 Calculate the 25th and 75th percentiles of the percent differences for each site.**
- **4.1.4 Validation of Bias Using the one-point QC Checks**

Precision and bias estimates are based on 1-point Q/C checks. Then, bias estimates are validated using the annual performance evaluations (audits).

Percent Difference

Equations from this section come from *CFR Pt. 58, App. A, Section 4, “Calculations for Data Quality Assessment”*. For each single point check, calculate the percent difference, d_i , as follows:

Equation 1

$$d_i = \frac{meas - audit}{audit} \cdot 100$$

where *meas* is the concentration indicated by the monitoring organization's instrument and *audit* is the audit concentration of the standard used in the QC check being measured.

Precision Estimate

The precision estimate is used to assess the one-point QC checks for gaseous pollutants described in section 3.2.1 of CFR Part 58, Appendix A. The precision estimator is the coefficient of variation upper bound and is calculated using Equation 2 as follows:

Equation 2

$$CV = \sqrt{\frac{n \cdot \sum_{i=1}^n d_i^2 - \left(\sum_{i=1}^n d_i\right)^2}{n(n-1)}} \cdot \sqrt{\frac{n-1}{\chi_{0.1, n-1}^2}}$$

where $\chi_{0.1, n-1}^2$ is the 10th percentile of a chi-squared distribution with $n-1$ degrees of freedom.

Bias Estimate

The bias estimate is calculated using the one point QC checks for SO₂, NO₂, O₃, or CO described in CFR, section 3.2.1. The bias estimator is an upper bound on the mean absolute value of the percent differences as described in Equation 3 as follows:

Equation 3

$$|bias| = AB + t_{0.95, n-1} \cdot \frac{AS}{\sqrt{n}}$$

where n is the number of single point checks being aggregated; $t_{0.95, n-1}$ is the 95th quantile of a t-distribution with $n-1$ degrees of freedom; the quantity AB is the mean of the absolute values of the d_i 's (calculated by Equation 1) and is expressed as Equation 4 as follows:

Equation 4

$$AB = \frac{1}{n} \cdot \sum_{i=1}^n |d_i|$$

and the quantity AS is the standard deviation of the absolute value of the d_i 's and is calculated using Equation 5 as follows:

Equation 5

$$AS = \sqrt{\frac{n \cdot \sum_{i=1}^n |d_i|^2 - \left(\sum_{i=1}^n |d_i| \right)^2}{n(n-1)}}$$

Since the bias statistic as calculated in Equation 3 of this Appendix uses absolute values, it does not have a tendency (negative or positive bias) associated with it. A sign will be designated by rank ordering the percent differences (d_i 's) of the QC check samples from a given site for a particular assessment interval. Calculate the 25th and 75th percentiles of the percent differences for each site. The absolute bias upper bound should be flagged as positive if both percentiles are positive and negative if both percentiles are negative. The absolute bias upper bound would not be flagged if the 25th and 75th percentiles are of different signs (i.e., straddling zero).

Validation of Bias

The annual performance evaluations (audits) for SO₂, NO₂, O₃, or CO are used to verify the results obtained from the one-point QC checks and to validate those results across a range of concentration levels. To quantify this annually at the site level and at the 3-year primary quality assurance organization level, probability limits will be calculated from the one-point QC checks using equations 6 and 7:

Equation 6

$$\text{Upper Probability Limit} = m + 1.96 \cdot S$$

Equation 7

$$\text{Lower Probability Limit} = \bar{m} - 1.96 \cdot S$$

where, \bar{m} is the mean (equation 8):

Equation 8

$$\bar{m} = \frac{1}{k} \cdot \sum_{i=1}^k d_i$$

where, k is the total number of one point QC checks for the interval being evaluated and S is the standard deviation of the percent differences (equation 9) as follows:

Equation 9

$$S = \sqrt{\frac{k \cdot \sum_{i=1}^k d_i^2 - \left(\sum_{i=1}^k d_i \right)^2}{k(k-1)}}$$

D.2 Precision Estimates from Collocated Samples

Applies to: PM2.5, PM10, Lead

40 CFR Part 58 Appendix A References:

- *4.2.1 Precision Estimate from Collocated Samplers*
- *4.3.1 Precision Estimate (PM2.5)*
- *4.4.1 Precision Estimate (Lead)*

Precision is estimated for manual instrumentation via duplicate measurements from collocated samplers at a minimum concentration (see table below for minimum concentration levels).

Minimum Concentration Levels for Particulate Matter Precision Assessments

Pollutant	Minimum Concentration Level (in $\mu\text{g}/\text{m}^3$)
PM2.5	3
Lo-Vol PM10	3
Hi-Vol PM10	15
Lead	0.15

Precision is aggregated at the primary quality assurance organization (PQAO) level quarterly, annually, and at the 3-year level. For each collocated data pair, the relative percent difference, d_i , is calculated by Equation 4.

Equation 10

$$d_i = \frac{X_i - Y_i}{(X_i + Y_i)/2} \cdot 100$$

where X_i is the concentration of the primary sampler and Y_i is the concentration value from the audit sampler.

The precision upper bound statistic, CV_{ub} , is a standard deviation on d_i with a 90 percent upper confidence limit (Equation 11).

Equation 11

$$CV_{ub} = \sqrt{\frac{n \cdot \sum_{i=1}^n d_i^2 - \left(\sum_{i=1}^n d_i\right)^2}{2n(n-1)}} \cdot \sqrt{\frac{n-1}{\chi_{0.1, n-1}^2}}$$

where, n is the number of valid data pairs being aggregated, and $\chi_{0.1, n-1}^2$ is the 10th percentile of a chi-squared distribution with $n-1$ degrees of freedom. The factor of 2 in the denominator adjusts for the fact that each d_i is calculated from two values with error.

D.3 PM2.5 Bias Assessment

Applies to: PM2.5

40 CFR Part 58 Appendix A Reference:

- 4.3.2 Bias Estimate (PM_{2.5})

The bias estimate is calculated using the Performance Evaluation Program (PEP) audits described in CFR, section 4.1.3 of Part 58, Appendix A. The bias estimator is based on upper and lower probability limits on the mean percent differences (Equation 1). The mean percent difference, D , is calculated by Equation 12 below.

Equation 12

$$D = \frac{1}{n_j} \cdot \sum_{i=1}^{n_j} d_i$$

Confidence intervals can be constructed for these average bias estimates in Equation 12 of this document using equations 13 and 14 below:

Equation 13

$$\text{Upper 90\% Confidence Interval} = D + t_{0.95,df} \cdot \frac{s_d}{\sqrt{n_j}}$$

Equation 14

$$\text{Lower 90\% Confidence Interval} = D - t_{0.95,df} \cdot \frac{s_d}{\sqrt{n_j}}$$

Where, $t_{0.95,df}$ is the 95th quantile of a t-distribution with degrees of freedom $df=n_j-1$ and s_d is an estimate of the variability of the average bias and is calculated using Equation 15 below:

Equation 15

$$s_d = \sqrt{\frac{\sum_{i=1}^{n_j} (d_i - D)^2}{n_j - 1}}$$

D.4 PM2.5 Absolute Bias Assessment

Applies to: PM2.5

40 CFR Part 58 Appendix A Reference:

- **4.1.3 Bias Estimate**

The bias estimate is calculated using the Performance Evaluation Program (PEP) audits described in CFR, section 4.1.3 of Part 58, Appendix A. The bias estimator is an upper bound on the mean absolute value of the percent differences (Equation 1), as described in Equation 3 as follows:

Equation 3

$$|bias| = AB + t_{0.95, n-1} \cdot \frac{AS}{\sqrt{n}}$$

where n is the number of PEP audits being aggregated; $t_{0.95, n-1}$ is the 95th quantile of a t-distribution with $n-1$ degrees of freedom; the quantity AB is the mean of the absolute values of the d_i 's (calculated by Equation 1) and is expressed as Equation 4 as follows:

Equation 4

$$AB = \frac{1}{n} \cdot \sum_{i=1}^n |d_i|$$

and the quantity AS is the standard deviation of the absolute value of the d_i 's (Equation 1) and is calculated using Equation 5 as follows:

Equation 5

$$AS = \sqrt{\frac{n \cdot \sum_{i=1}^n |d_i|^2 - \left(\sum_{i=1}^n |d_i| \right)^2}{n(n-1)}}$$

Since the bias statistic as calculated in Equations 3 and 6 of this Appendix uses absolute values, it does not have a sign direction (negative or positive bias) associated with it. A sign will be designated by rank ordering the percent differences of the QC check samples from a given site for a particular assessment interval. Calculate the 25th and 75th percentiles of the percent differences for each site. The absolute bias upper bound should be flagged as positive if both percentiles are positive and negative if both percentiles are negative. The absolute bias upper bound would not be flagged if the 25th and 75th percentiles are of different signs (i.e., straddling zero).

D.5 One-Point Flow Rate Bias Estimate

Applies to: PM10, PM2.5

40 CFR Part 58 Appendix A References:

- **4.2.2 Bias Estimate Using One-Point Flow Rate Verifications (PM10)**
- **4.3.2 Bias Estimate (PM10-2.5)**
- **Assigning a sign (positive / negative) to the bias estimate.**

The bias estimate is calculated using the collocated audits previously described. The bias estimator is an upper bound on the mean absolute value of the percent differences (Equation 1), as described in Equation 3 as follows:

Equation 3

$$|bias| = AB + t_{0.95, n-1} \cdot \frac{AS}{\sqrt{n}}$$

where n is the number of flow audits being aggregated; $t_{0.95, n-1}$ is the 95th quantile of a t-distribution with $n-1$ degrees of freedom; the quantity AB is the mean of the absolute values of the d_i 's (calculated by Equation 4) and is expressed as Equation 4 as follows:

Equation 4

$$AB = \frac{1}{n} \cdot \sum_{i=1}^n |d_i|$$

and the quantity AS is the standard deviation of the absolute value of the d_i 's (Equation 4) and is calculated using Equation 5 as follows:

Equation 5

$$AS = \sqrt{\frac{n \cdot \sum_{i=1}^n |d_i|^2 - \left(\sum_{i=1}^n |d_i| \right)^2}{n(n-1)}}$$

Since the bias statistic as calculated in Equation 3 of this Appendix uses absolute values, it does not have a sign direction (negative or positive bias) associated with it. A sign will be designated by rank ordering the percent differences of the QC check samples from a given site for a particular assessment interval. Calculate the 25th and 75th percentiles of the percent differences for each site. The absolute bias upper bound should be flagged as positive if both percentiles are positive and negative if both percentiles are negative. The absolute bias upper bound would not be flagged if the 25th and 75th percentiles are of different signs (i.e., straddling zero).

D.6 Semi-Annual Flow Rate Audits

Applies to: PM10, TSP, PM2.5, PM10-2.5

40 CFR Part 58 Appendix A References:

- **4.2.3 Assessment Semi-Annual Flow Rate Audits**
- **4.2.4 Percent Differences**

The flow rate audits are used to assess the results obtained from the one-point flow rate verifications and to provide an estimate of flow rate acceptability. For each flow rate audit, calculate the percent difference in volume using equation 1 of this Appendix where meas is the value indicated by the sampler's volume measurement and audit is the actual volume indicated by the auditing flow meter.

Equation 1

$$d_i = \frac{meas - audit}{audit} \cdot 100$$

To quantify this annually at the site level and at the 3-year primary quality assurance

organization level, probability limits are calculated from the percent differences using equations 6 and 7 of this document where \underline{m} is the mean described in equation 8 of this document and \underline{k} is the total number of one-point flow rate verifications for the year

Equation 6

$$\text{Upper Probability Limit} = m + 1.96 \cdot S$$

Equation 7

$$\text{Lower Probability Limit} = m - 1.96 \cdot S$$

where, \underline{m} is the mean (equation 8):

Equation 8

$$m = \frac{1}{k} \cdot \sum_{i=1}^k d_i$$

where, \underline{k} is the total number of one point QC checks for the interval being evaluated and \underline{S} is the standard deviation of the percent differences (equation 9) as follows:

Equation 9

$$S = \sqrt{\frac{k \cdot \sum_{i=1}^k d_i^2 - \left(\sum_{i=1}^k d_i \right)^2}{k(k-1)}}$$

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APPENDIX E

REFERENCES

References

1. Quality Assurance Handbook for Air Pollution Measurement Systems. Volume I: A Field Guide to Environmental Quality Assurance, EPA-600/R-34/038a, April 1994.
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4. State and Local Air Monitoring Network Plan, California Air Resources Board, June 2009.
5. Code of Federal Regulations, Title 40, Protection of the Environment, Part 58, Ambient Air Quality Surveillance (Nov 2012).
6. Air Monitoring Quality Assurance Manual. Volume I. Quality Assurance Plan, Monitoring and Laboratory Division, California Air Resources Board, June 2005.