CALIFORNIA
AIR RESOURCES BOARD

Performance Audit Procedures For Filter-Based Particulate Matter Monitors

Volume V
Audit Procedures Manual for Air Quality Monitoring

QMB SOP Appendix AS
Version 1.0

Quality Assurance Section

Quality Management Branch

Monitoring and Laboratory Division

Approval Signatures	Approval Date
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Disclaimer: Mention of any trade name or commercial product in this standard operating procedure does not constitute endorsement or recommendation of this product by the California Air Resources Board. Specific brand names and instrument descriptions listed in the standard operating procedure are for equipment used by the California Air Resources Board's Quality Assurance Section. Any functionally equivalent instrumentation is acceptable.

PERFORMANCE AUDIT PROCEDURES
FOR FILTER-BASED PARTICULATE MATTER MONITORS

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PERFORMANCE AUDIT PROCEDURES
FOR FILTER-BASED PARTICULATE MATTER MONITORS

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ACRONYMS AND DEFINITIONS

Acronym	Definition
AIS	Audit Information System
AQDA	Air Quality Data Action
AQS	Air Quality System (U.S. EPA database)
AT	Ambient Temperature
BP	Barometric Pressure
CAN	Corrective Action Notification
CARB	California Air Resources Board
°C	Degrees Celsius
CFM	Cubic Feet per Minute
CMH	Cubic Meters per Hour
Hi-Vol	High Volume (A particulate matter sampler with an operating flow rate typically between 36 and 60 CFM)
inHg	Inches of Mercury
LPM	Liters Per Minute
Lo-Vol	Low Volume (A particulate matter sampler with an operating flow rate typically around 16.7 LPM)
MFC	Mass Flow Controller
$\mu g/m^3$	Microgram per Cubic Meter
mm	Millimeter
mmHg	Millimeters of Mercury
MLD	Monitoring and Laboratory Division
NIST	National Institute of Standards and Technology
PM	Particulate Matter
PM_{10}	Particulate matter less than 10 microns in diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
PMc	PM coarse ($PM_{10} – PM_{2.5}$)
POC	Parameter Operating Code
PQAO	Primary Quality Assurance Organization
ppb	Parts Per Billion
ppm	Parts Per Million
Qa	Flow Rate at Actual Conditions
Qs	Flow Rate at Standard Conditions
QAS	Quality Assurance Section
QMB	Quality Management Branch
SI	International System of Units (metric system)
SSI	Size Selective Inlet
SOP	Standard Operating Procedure
STP	Standard Temperature and Pressure
TSP	Total Suspended Particulate Matter
U.S. EPA	United States Environmental Protection Agency
VFC	Volumetric Flow Controller

Acronym	Definition
VSCC	Very Sharp Cut Cyclone

AS.1.0 INTRODUCTION

The California Air Resources Board's (CARB) Quality Assurance Section (QAS) is responsible for conducting independent assessments or performance audits on particulate matter (PM) monitors generating data for regulatory purposes. These audits are required semi-annually and should be performed 5 to 7 months apart in a calendar year (refer to the Code of Federal Regulations Title 40 (40 CFR), Part 58, Appendix A, Sections 3.2.2 (PM2.5) and 3.3.3 (PM10) for more details).

The audit procedures presented pertain to filter-based, non-continuous PM monitors operating in the California ambient air monitoring network. They are generally categorized by high volume (Hi-Vol) air samplers which operate at flow rates greater than 200 liters per minute (LPM), and low volume (Lo-Vol) which run at less than 200 LPM. Hi-Vols typically operate (and are measured) between 36 – 60 cubic feet per minute (CFM) and use an 8 inch by 10 inch quartz-fiber filter. Alternatively, Lo-Vols operate and are typically measured around 16.7 LPM. Lo-Vols use a standard 47 millimeter (mm) filter with cassette and can be sequential and non-sequential, single or multi-channel (dichotomous) samplers. Continuous-based PM monitors are covered in another Standard Operating Procedure (SOP) (CARB Quality Assurance Manual, Volume V, Appendix AR).

These monitors are federally approved to measure total suspended particulate matter (TSP), PM less than 10 microns in diameter (PM_{10}) and/or PM less than 2.5 microns in diameter ($PM_{2.5}$) concentrations, depending on their configuration. Audit techniques may vary among approved samplers because of differences in required sample collection parameters, flow controlling devices, sampler software, options utilized (i.e., continuous flow recorder), and sampler configuration.

Filter-based monitors extract samples from the atmosphere at a set flow rate, through appropriately sized filters over 24 hours, usually from midnight to midnight. Based on federal requirements related to the air monitoring network, sample collection occurs at a designated daily frequency such as every day, once every three days, once every six days, or once every 12 days. The ambient PM concentrations are determined by gravimetric analysis of the filters under specific laboratory conditions. With proper selection and handling, filters can also be used for chemical analysis, or speciation. Mass concentrations are usually reported in

micrograms per cubic meter (µg/m^3) of air sampled at United States Environmental Protection Agency (U.S. EPA) Standard Temperature and Pressure (STP) conditions of 25 degrees Celsius (°C) and 760 millimeters of mercury (mmHg). It is important to note, however, that monitors are audited by comparing flow values recorded under actual temperature and pressure conditions (volumetric flow).

AS.2.0 SUMMARY OF METHOD

An accurate measurement of PM concentration is dependent on the flow rate through the sample inlet cut point, which dictates the size fraction of PM collected. Therefore, the accuracy of filter-based PM samplers is determined by comparing the sampler's volumetric flow rate through the cut point to a certified audit flow standard, which may be an orifice or a volumetric flow meter. Additionally, the flow rate can be compared to the ideal flow rate (design) based on the manufacturer's specifications. Other variables such as ambient temperature (AT), barometric pressure (BP), and filter temperature are also evaluated against an audit standard. In low volume samplers, a leak check of the sample train is also performed. The results of the audit help determine whether the sampler responses are maintained within acceptable criteria to produce reliable ambient PM concentration data.

NOTE: Agencies may wish to avoid scheduling audits on run days as it may result in loss of ambient data, or force them to schedule a make-up run. U.S. EPA provides a calendar identifying run days based on the sampling frequency (https://www.epa.gov/amtic/sampling-schedule-calendar).

An accuracy assessment of the filter-based PM samplers can be achieved by conducting an audit under the following guidelines:

1. Without special preparation or adjustment of the system to be audited.

2. By individuals with a thorough knowledge of the instrument or process being evaluated, but not by the routine operator.

3. With standards traceable to the National Institute of Standards and Technology (NIST) that are completely independent of those used in

routine calibration/verification. They can be traceable to the same primary standard.

4. With complete documentation of audit data for submission to the operating agency. Audit data includes, but is not limited to: types of instruments and audit transfer standards, model and serial numbers, transfer standard traceability, calibration information, and collected audit data.

AS.3.0 INTERFERENCES

The interferences associated with this method mainly include factors that can alter the flow through the inlet head or audit standard. Lower than expected flow rates can be the result of a leak, which may be caused by improper installation of the audit flow standard. Also, flow through the sampler inlet head or audit flow standard is dependent on accurate measurement of AT and BP.

- Audit standards should be warmed up and operating under ambient conditions. If temperature or pressure values are fluctuating, the audit should not be conducted until values are relatively stable.

- Take precautions against altering the normal operating conditions of the sample train, and prevent air flow leaks during the audit.

AS.4.0 PERSONNEL QUALIFICATIONS

All new CARB auditors undertake a one-year training program that is documented and monitored by the QAS manager. The training includes in-office reading and coursework, hands-on field experience conducting audits, and shadowing an experienced auditor for one year along with several in-field evaluations by the QAS manager.

U.S. EPA reviews CARB's training program regularly for approval as an equivalent to U.S. EPA's national certification and recertification courses. Auditors should be familiar with the regulations and guidance cited in the references section (AS.10.0) prior to conducting any audits without supervision. Each auditor is expected to have a minimum level of on the job training and familiarity with the audit equipment prior to conducting the audit(s).

The U.S. EPA's Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Quality Monitoring Program (January 2017) should be considered as required reading prior to conducting audits.

NOTE: A station operator familiar with the equipment should also be present during the entire audit to perform the necessary operation of station equipment, as needed. Auditors should check for proper operating conditions, verify values and readings, and record audit data without changing the normal configuration of station equipment.

AS.5.0 HEALTH, SAFETY AND CAUTIONS

All personnel must follow any general health and safety guidelines as described by the facility where the audit is conducted. All audit equipment, including audit vehicles, should be used only for the purpose and in the manner described in this SOP and in the appropriate operator's manual.

Falls from portable ladders are one of the leading causes of occupational fatalities and injuries. Appropriate safety precautions should be taken and auditors should be familiar with, and trained on, proper ladder usage.

Care should be taken when accessing instruments, especially on station rooftops. All equipment being audited should be easily and safely accessible.

AS.6.0 EQUIPMENT AND SUPPLIES

All audit standards must be certified against a primary standard traceable to NIST. Audit equipment for flow rate, temperature and BP must not be the same as that equipment used for routine site verifications and/or calibrations, but can be traceable to the same primary standard.

Prior to departing for an audit, it is necessary to confirm that the proper audit equipment is in working order and the most recent worksheets are available. Information recorded during an audit includes, but is not limited to, sampler and audit transfer standard type, model and serial numbers, transfer standard traceability and calibration information, AT

and BP conditions, maintenance schedules and dates, and collected audit values.

Performance audits for filter-based PM monitors require the following equipment:

1. Calibrated and certified audit flow standard capable of measuring flow rate or pressure differential. The flow device should be within ±2% of a NIST-traceable standard, and certified on an annual basis.

2. A thermometer or thermistor capable of accurately measuring temperature in the range of -20°C to +60°C with a resolution of ±0.1°C. It must be referenced to a NIST thermometer and be certified annually. The thermometer should be within ±0.5°C of the NIST-traceable thermometer on the annual check.

3. A barometer capable of accurately measuring ambient pressures to the nearest millimeter of mercury (mmHg) in the range of 500 to 800 mmHg. The barometer must be referenced within ±5 mmHg of a barometer traceable to NIST at least annually.

4. Audit worksheets for PM monitors (specific to the type of audit).

5. Computer or tablet with access to the Audit Information System (AIS) audit software.

6. Spare (Dickson) recorder charts, clean filters, and miscellaneous hand tools, based on the type of audit. Quartz fiber (8 inch x 10 inch) filters for Hi-Vol samplers can be obtained from CARB's PM_{10} lab. Green anodized aluminum filter cassettes or standard 47 mm cassettes with Teflon-membrane filters are used for Lo-Vol samplers.

NOTE: The site operator is responsible for providing the sampler's volumetric flow rate, or providing calibration factors for the subsequent determination of the Hi-Vol sampler's flow rate (Qa).

AS.7.0 AUDIT PROCEDURES

Begin the audit by observing the equipment to be audited and its current configuration. Consult with the operator prior to navigating through display screens or making changes to the station equipment. Should it be unavoidable to complete the audit on a sample or run day, the operator must prepare the sampler for the audit and return it to the desired sampling frequency after the audit.

Allow the audit standards to warm up and equilibrate in accordance with manufacturers' recommendations. This is normally achieved by placing the audit standards within reach of the sampling inlet and exposed to ambient conditions, but not in direct sun. During the course of an audit, conditions such as temperature and pressure can vary and potentially influence the assessment results. As such, it is advisable to collect these measurements from the audit devices and sampler sequentially within as short a time interval as practically possible.

AS.7.1 HIGH VOLUME PM_{10} AND TSP SAMPLERS

As mentioned earlier, high volume PM_{10} and TSP samplers operate at flow rates greater than 200 liters per minute, but typically run (and are measured) at flow rates between 36-60 cubic feet per minute. These samplers are configured with a tent-shaped roof for TSP collection or a dome-shaped size selective inlet (SSI) for PM_{10} collection. Figure AS.1 and Figure AS.2 show examples of these samplers.

On each sampler, a system timer is programmed to start and stop the pump for the sampling period. During the run, PM is collected on filters as air flows from the inlet and through the mass flow controller or a critical orifice (which functions as the flow controller of the sampler). A recorder (sometimes a circular Dickson™ chart) provides a trace to document whether the sample flow rate was consistent and uninterrupted for the sampling period.

Figure AS.1 Examples of TSP and SSI Samplers

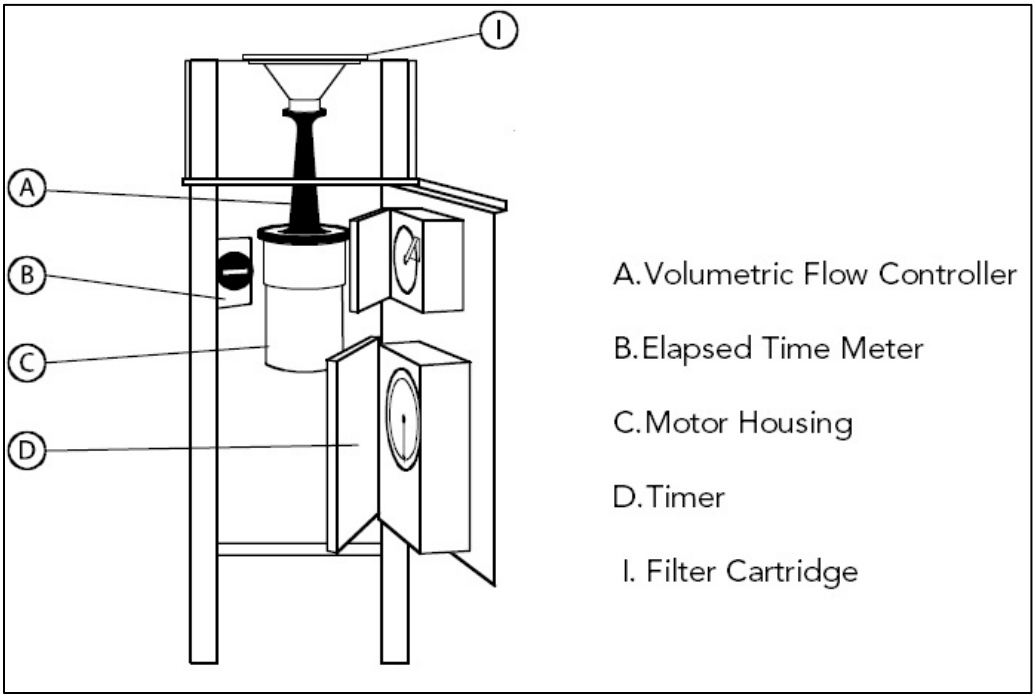


Figure AS.2 Diagram of a CARB Volumetric Flow Controller (VFC) base unit

Audit procedures will vary based on the type, model, and configuration of sampler being audited.

IMPORTANT: Consult the operator before touching or operating the equipment. Switches, timers, and power supplies can be changed or damaged if mishandled. If possible, the operator should perform the functions while the auditor observes and directs the audit procedures.

NOTE: Some Hi-Vol PM_{10} samplers in the CARB network are known as CARB Volumetric Flow Controller (VFC) samplers (see Figure AS.2). These samplers use an averaged slope and intercept, along with a pressure ratio, to calculate the sampler's volumetric flow. CARB VFCs can be identified by meeting both of the following requirements:

1. The sampler matches (or is similar to) Figure AS.2, especially the VFC (as labelled "A").

2. The operator (or PM laboratory) uses the following formula to calculate the sampler's volumetric flow rate:

   Volumetric CFM = [45.379 x (Po/Pa) - 2.243] + [(Ta - 25) x 0.059]

   where:

   Po/Pa = Pressure ratio (1 – Pf/Pa)
   Pf = differential pressure across filter (mmHg)
   Pa = the ambient pressure (mmHg)
   Ta = the temperature in degrees Celsius

Refer to AQSB SOP 408, section 3.3 as listed in the References Section (AS.10.0) for more information.

For samplers that utilize a Dickson chart recorder (see Figure AS.3), do the following:

- Record the following information on the back side of a new chart for the chart recorder: sampler ID number, site name, site number, date, auditor(s).

- Open the front door of the sampler and install the clean, annotated chart in the recorder. Remove the center cross tab on the chart so the chart can be rotated freely to mark the pen's position. NOTE: Use the

operator's chart style if possible to eliminate error due to different brand variation in the chart printing.

- Observe the recorder zero setting and mark it on the chart. Ask the operator if they normally adjust the zero as part of their weekly routine. If they do, instruct them to adjust the pen to indicate true zero. Prepare the pen to record the flow rate.

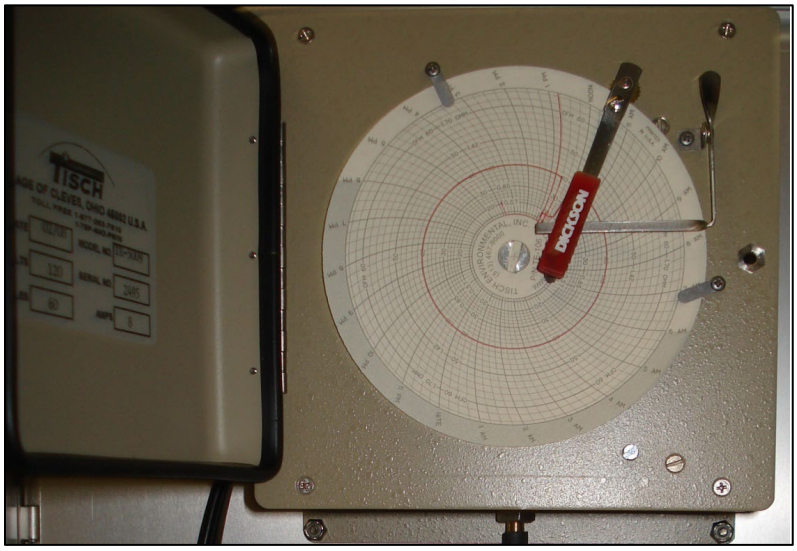


Figure AS.3 Dickson Chart Recorder

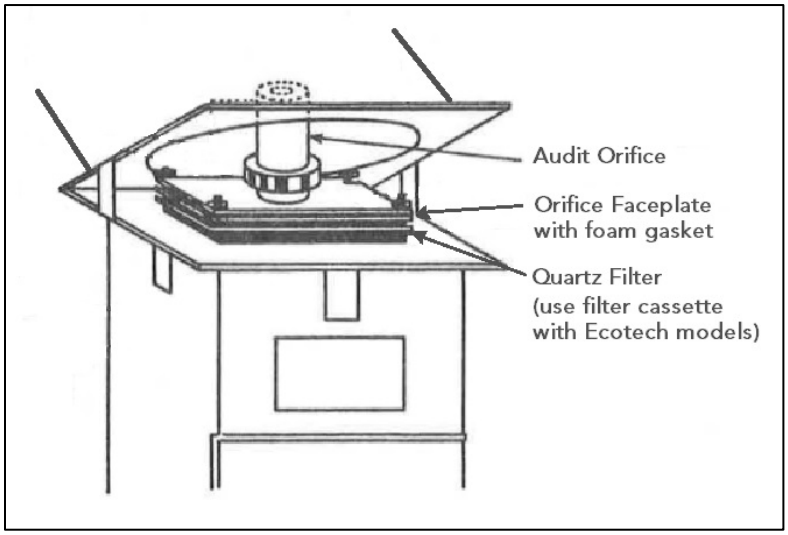


Figure AS.4 Audit Configuration for High Volume Samplers

For all high volume and TSP samplers, do the following:

1. Install a clean filter in the sampler. Do not use a filter cassette; place the filter directly on the sampler filter screen (except Ecotech models which are calibrated and audited with a filter cassette). See Figure AS.4.

2. Install the equilibrated audit orifice (and attached faceplate) on the sampler. Simultaneously tighten the faceplate nuts on alternate corners to prohibit leaks and to assure even tightening. The fittings should be hand-tightened; too much compression can damage the sealing gasket. NOTE: The sampler inlet may be partially lowered, within 2 inches, over the audit orifice to act as a draft shield.

3. Switch on the sampler and allow it to warm up to operating temperature (3 to 5 minutes).

4. Begin recording station and equipment information data on the Audit Worksheet (Figure AS.5).

5. When the sampler has warmed up to operating temperature, read the audit standard display (Qa) and record it as the "Audit Orifice (ΔP or CFM)" value on the audit worksheet.

   NOTE: If the magnehelic or chart reading is outside the range the operator normally sees, re-position the filter on the screen and/or refer to the troubleshooting section below.

   NOTE: If utilizing the chart recorder, make sure the recorder pen has clearly indicated a flow reading before turning off the sampler.

6. Ask the operator to calculate the instrument's actual flow (Qa) as he or she normally would. Record this reading on the QA Audit Worksheet as the station instrument flow rate. If the operator normally calculates the flow under standard conditions (Qstd), check the appropriate box in the Audit Information System and note this in the audit report. Record the calibration information (slope and intercept) used by the operator to calculate the flow rate, if applicable.

   NOTE: The third (blank) column on the Audit Worksheet can be used to record Qs values or alternative flow rates that must be converted

before they are compared to the audit value (i.e. Ecotech samplers display values in cubic meters per hour (CMH)).

7. Switch off the sampler until zero flow rate is attained and repeat steps 5, 6, and 7 two more times to obtain a total of three observations.

8. If the sampler is a CARB Volumetric Flow Controller (VFC) or uses a magnehelic, record the magnehelic reading while the sampler is running. Be sure to use the CARB VFC audit module in AIS to enter the audit data, as appropriate.

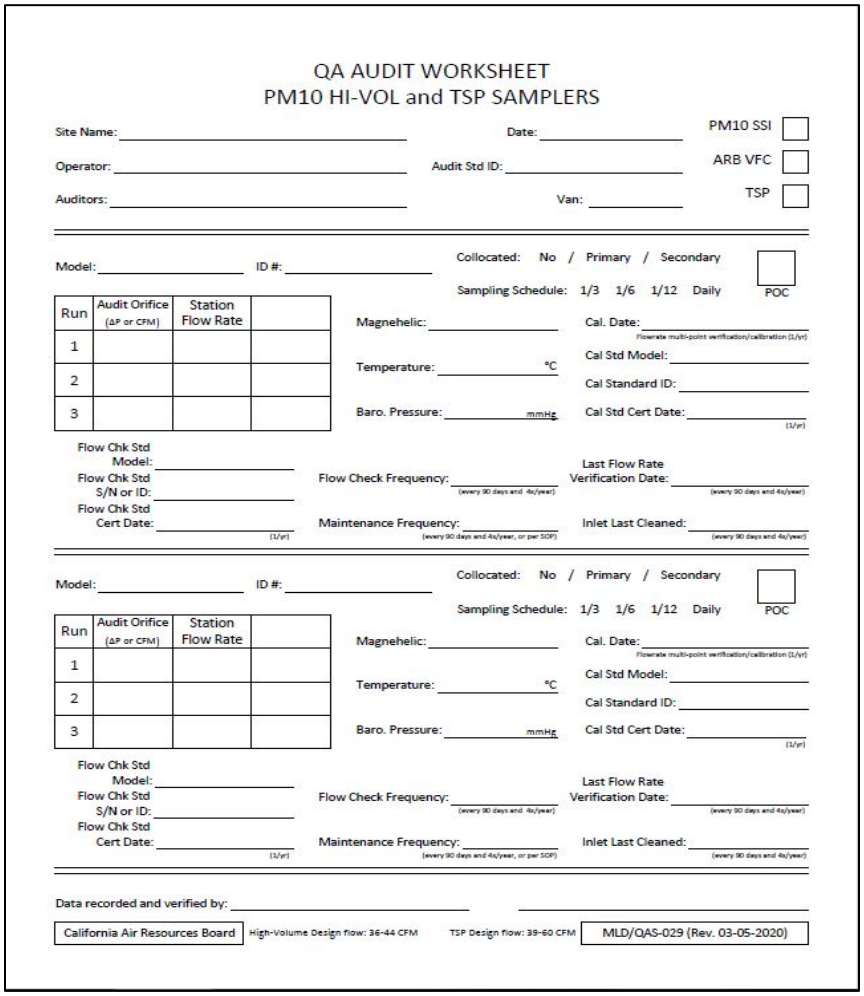
9. Obtain and record the ambient temperature and pressure from the appropriate audit standards. IMPORTANT: Be sure all audit standards have been properly equilibrated before recording data.

10. Verify that the true flow rate determined by the audit orifice is within the specified volumetric flow rate range (design) of 1.02 to 1.24 cubic meters per minute (35.9 to 43.9 CFM) for PM_{10} High Volume samplers and 1.1 to 1.7 cubic meters per minute (38.8 to 60.0 CFM) for TSP samplers. Convert Ecotech sampler flow rate units from CMH to CFM by dividing the value in CMH by 1.7.

11. Verify that the sampler's actual flow (as determined in Step 6) is within 7% of the true flow rate indicated by the audit orifice. If the flow rate exceeds audit criteria (Table AS.1), refer to the troubleshooting section below before recording the values.

12. Document all remaining audit data and return the sampler to the proper operational configuration.

13. Refer to Section AS.8.0 for post-audit procedures and data management.



QA AUDIT WORKSHEET
PM10 HI-VOL and TSP SAMPLERS

Site Name: _____ Date: _____ PM10 SSI ☐
Operator: _____ Audit Std ID: _____ ARB VFC ☐
Auditors: _____ Van: _____ TSP ☐

Model: _____ ID #: _____ Collocated: No / Primary / Secondary
Sampling Schedule: 1/3 1/6 1/12 Daily POC ☐

Run	Audit Orifice (ΔP or CFM)	Station Flow Rate	
1			
2			
3			

Magnehelic: _____ Cal. Date: _____ (Flowrate multi-point verification/calibration (1/yr))
Temperature: _____ °C Cal Std Model: _____
Cal Standard ID: _____
Baro. Pressure: _____ mmHg Cal Std Cert Date: _____ (1/yr)

Flow Chk Std Model: _____
Flow Chk Std S/N or ID: _____
Flow Chk Std Cert Date: _____ (1/yr)
Flow Check Frequency: _____ (every 90 days and 4x/year)
Last Flow Rate Verification Date: _____ (every 90 days and 4x/year)
Maintenance Frequency: _____ (every 90 days and 4x/year, or per SOP)
Inlet Last Cleaned: _____ (every 90 days and 4x/year)

Model: _____ ID #: _____ Collocated: No / Primary / Secondary
Sampling Schedule: 1/3 1/6 1/12 Daily POC ☐

Run	Audit Orifice (ΔP or CFM)	Station Flow Rate	
1			
2			
3			

Magnehelic: _____ Cal. Date: _____ (Flowrate multi-point verification/calibration (1/yr))
Temperature: _____ °C Cal Std Model: _____
Cal Standard ID: _____
Baro. Pressure: _____ mmHg Cal Std Cert Date: _____ (1/yr)

Flow Chk Std Model: _____
Flow Chk Std S/N or ID: _____
Flow Chk Std Cert Date: _____ (1/yr)
Flow Check Frequency: _____ (every 90 days and 4x/year)
Last Flow Rate Verification Date: _____ (every 90 days and 4x/year)
Maintenance Frequency: _____ (every 90 days and 4x/year, or per SOP)
Inlet Last Cleaned: _____ (every 90 days and 4x/year)

Data recorded and verified by: _____ _____

California Air Resources Board | High-Volume Design flow: 36-44 CFM | TSP Design flow: 39-60 CFM | MLD/QAS-029 (Rev. 03-05-2020)

Figure AS.5 QA Audit Worksheet for PM_{10} Hi-Vol and TSP Samplers

AS.7.1.1 TROUBLESHOOTING HI-VOL AND TSP SAMPLERS

If the audited flow rate exceeds the control or warning limits listed in Table AS.1, auditors should perform troubleshooting steps before recording data on the audit worksheet.

- Make sure the orifice gasket (between the orifice and faceplate) is present and the orifice is not cross-threaded on the faceplate.
- Ensure the foam gasket is not damaged or leaking.
- Ensure the filter is positioned properly, is clean and not torn.

- Check the orifice valve (if applicable) and set it to the correct flow range.
- Ensure tubing on pressure differential standards is not pinched or damaged.
- Be sure equipment is equilibrated to ambient temperature and pressure conditions. If conditions have changed since the equipment was turned on, it may be necessary to power-cycle the audit equipment.
- Ensure there is no flow through the audit equipment during its start-up. Keep audit equipment out of the wind during start-up.
- If using a digital manometer (only applicable models), ensure the zero was adjusted properly.

AS.7.2 LOW VOLUME SAMPLERS

Audit procedures presented here are applicable to various models of low volume, sequential and non-sequential, filter-based PM_{10} and $PM_{2.5}$ samplers. While dichotomous (or dual-channel) samplers are available for the simultaneous collection of fine and coarse PM, only the single-channel models are covered in this SOP. They including the following:

- Rupprecht & Patashnick (R&P) Partisol® Models 2000 or 2000i (non-sequential)
- Thermo Scientific (or R&P) Models 2025 or 2025i (sequential)

NOTE: As manufacturers change and merge, model names may vary. Audit procedures may vary with different models of samplers due to differences in sampler configuration, software versions, etc. Always consult with the operator before starting the audit.

All of the samplers use a standard 47mm Teflon™ membrane filter in a cassette, and operate at an actual flow rate of 16.67 LPM. These low volume monitors are sometimes referred to as Partisol® samplers. A calibrated flow audit standard (typically a BGI/MesaLabs DeltaCal®) is used to measure the sampler's operational flow rate. The sampler's indicated flow rate is then compared with the actual flow rate measured by the audit standard, which accounts for ambient temperature and pressure. The actual flow rate determined by the audit flow standard is

also compared with the design flow rate of 16.67 LPM. All samplers are checked for leaks using either manual or automatic (software-driven) leak checks.

Accurate measurement of PM mass concentration is dependent upon the ability of the sampler to maintain an inlet volumetric flow rate of 16.67 LPM in response to variations in ambient temperature and pressure. Performance audits of PM samplers must, therefore, also include verifications of the sampler's ambient temperature and barometric pressure sensors. Audit procedures are also included for a single-point temperature check of the sampler's ambient temperature sensor, a single-point check of the (inactive) filter temperature sensor, and a single point check of the barometric pressure sensor. All of the checks are conducted by collocating the appropriate audit standard with the sampler's sensor.

AS.7.2.1 GENERAL AUDIT PROCEDURES FOR LOW VOLUME SAMPLERS

Begin by reviewing Section AS.7.0

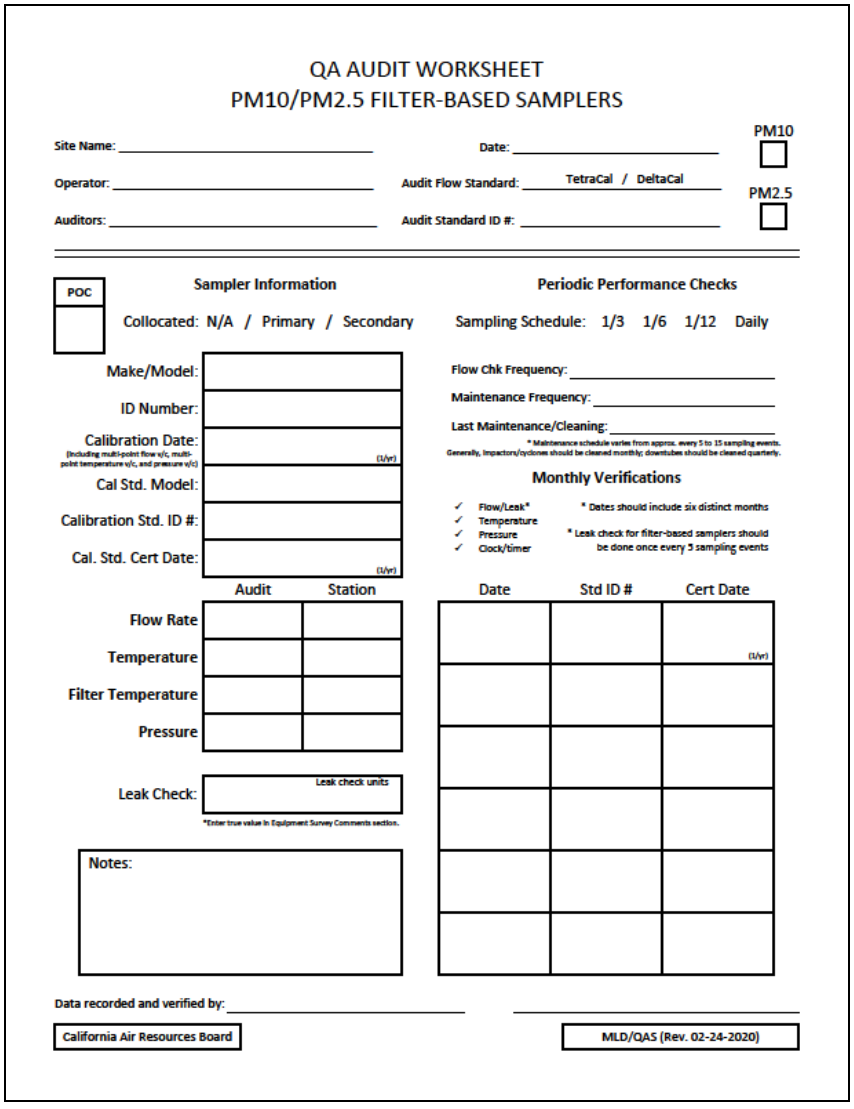
IMPORTANT: Consult the operator before touching or operating the equipment. Configurations, timing, and pre-programmed routines can be changed or deleted if the wrong button is pressed. Whenever possible, the operator should perform the functions while the auditor observes and directs the audit procedures.

Ask the operator to prepare the sampler by securing any filters and placing the sampler into "Audit" mode. In sequential samplers, this process may include advancing the audit filter cassette into place (see Section AS.7.2.3, step 2a).

While waiting for equilibration or stabilization of equipment, begin to record information onto the worksheet (Figure AS.6), which includes audit values and other data:

- Site name, audit date, site operator, auditor(s)
- Audit flow standard information
- Calibration information
- Monthly maintenance information, including flow and leak checks

- Information from the U.S. EPA Audit Quality System (AQS)



QA AUDIT WORKSHEET
PM10/PM2.5 FILTER-BASED SAMPLERS

Site Name: _____ Date: _____ PM10 ☐

Operator: _____ Audit Flow Standard: TetraCal / DeltaCal

Auditors: _____ Audit Standard ID #: _____ PM2.5 ☐

POC ☐

Sampler Information

Collocated: N/A / Primary / Secondary

Make/Model:
ID Number:
Calibration Date: (Including multi-point flow v/c, multi-point temperature v/c, and pressure v/c) (1/yr)
Cal Std. Model:
Calibration Std. ID #:
Cal. Std. Cert Date: (1/yr)

Periodic Performance Checks

Sampling Schedule: 1/3 1/6 1/12 Daily

Flow Chk Frequency: _____
Maintenance Frequency: _____
Last Maintenance/Cleaning: _____
* Maintenance schedule varies from approx. every 5 to 15 sampling events. Generally, impactors/cyclones should be cleaned monthly; downtubes should be cleaned quarterly.

Monthly Verifications

✓ Flow/Leak* ✓ Temperature ✓ Pressure ✓ Clock/timer

* Dates should include six distinct months
* Leak check for filter-based samplers should be done once every 5 sampling events

	Audit	Station
Flow Rate		
Temperature		
Filter Temperature		
Pressure		

Leak Check: (Leak check units) *Enter true value in Equipment Survey Comments section.

Notes:

Date	Std ID #	Cert Date (1/yr)

Data recorded and verified by: _____ _____

California Air Resources Board

MLD/QAS (Rev. 02-24-2020)

Figure AS.6 Audit Worksheet for PM_{10}/$PM_{2.5}$ Filter-Based Samplers

AS.7.2.2 NON-SEQUENTIAL PM SAMPLERS

Non-sequential samplers are (typically) single channel Lo-Vol samplers that utilize a filter housed in a cassette for ambient PM sample capture. The sampling line for each unit is configured with either a straight tube (without a Very Sharp Cut Cyclone (VSCC)) for PM_{10}, or with a VSCC in order to collect $PM_{2.5}$ samples (see Figure AS.7). The front panel of the sampler is navigated using pushbuttons or a touchscreen to obtain

information during the audit. Refer to the manufacturer's Instruction Manual(s) for more details on proper operation and audits of specific models.

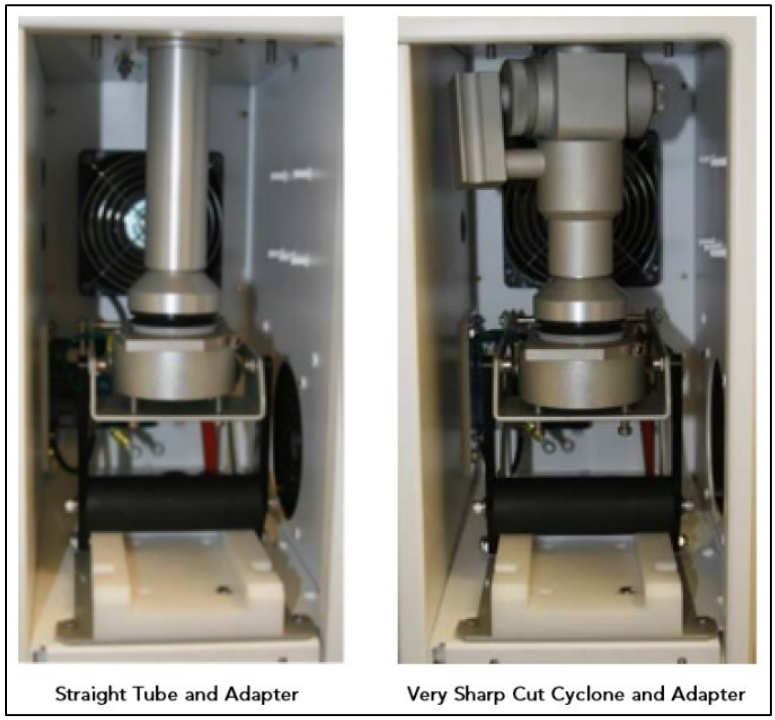


Figure AS.7 Non-Sequential PM Sampler Configurations

1. Audit Procedures (non-sequential samplers):

   Begin the audit by following the procedures outlined in Section AS.7.2.1. Be sure the sampler is in "Audit" mode, is not running, and there is no filter present. The sampler's display should be showing the Audit Menu where temperature, pressure, and flow values can be read. While checks can be performed in any order, they are most efficiently performed as listed below.

2. Ambient temperature check (non-sequential samplers):

   a. Locate the sampler's ambient temperature sensor for collocation with the equilibrated audit temperature standard. The solar radiation shield can be removed for easier collocation, if desired.

b. Position the audit sensor as close as possible to the sampler sensor without allowing the two sensors to touch. Protect the sensors from direct sunlight or excessive air movements as much as possible.

c. Allow both the audit sensor reading and the sampler's AT display values to stabilize. Record the both values on the Audit Worksheet.

3. Filter temperature check (non-sequential samplers):

a. Open the sampler door and carefully pull the handle of the filter platform forward to lower the platform, exposing the silver filter temperature sensor. The sampler should not be running. See Figure AS.8 below.

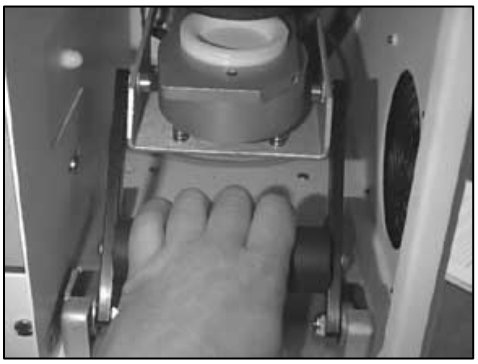


Figure AS.8 Lowering the Filter Platform of a Partisol 2000/2000i

b. Position the audit temperature sensor as close as possible to the sampler's filter temperature sensor without allowing the two sensors to touch. Protect the sensors from direct sunlight or excessive air movements as much as possible.

c. Allow both the audit sensor reading and the sampler's filter temperature display values to stabilize. Record both values on the Audit Worksheet.

4. Barometric Pressure check (non-sequential samplers):

a. The audit standard for barometric pressure should be oriented correctly and collocated within 10 meters horizontal distance and 0.5 meters vertical distance from the sampler's sensor.

b. Read and record the audit standard's display and the barometric pressure sensor reading from the sampler's display screen.

5. Flow verification (non-sequential samplers):

   a. Place a green aluminum leak check disk (or an audit filter with cassette) in the cassette carrier and insert the carrier into position in the sampler. Raise the filter platform by slowly pushing the filter platform handle back to its original position.

      NOTE: Be sure the filter platform is raised completely and a tight seal is formed between the upper and lower halves of the filter stage. If an audit filter cassette is being used, be sure it is the same type as normally used by the sampler's operator.

   b. Carefully remove the sampler PM_{10} inlet head and replace it with the audit flow standard's inlet. Any $PM_{2.5}$ VSCC should remain in place. Ensure that O-ring(s) within the audit head are present and form a tight seal around the downtube.

   c. With the "Audit" screen displayed on the sampler, turn on the pump (this procedure will vary and may require the [Valve] button to be toggled). Wait up to five minutes for flow stability.

   d. Record the flow values from the sampler and the audit flow standard's display (Qa). The measured flow should be within ±4% of the audit standard and ±5% of the displayed current flow (or design), which should be near 16.67 LPM (older samplers may round the display flow value to 16.7 LPM). If this is not the case, perform troubleshooting steps from the section below before proceeding.

   e. Remove the audit flow standard's head unit and stop the pump.

6. External Leak Check (non-sequential samplers):

a. Leak check procedures will vary based on software version and sampler configuration. Consult with the operator before conducting the leak check.

b. If the sampler has an automatic leak check function built in, follow the steps as displayed on the screen, which usually involve the following:

    i. Place the flow audit/leak check adapter (Figure AS.9) on the sampling downtube and close the valve.

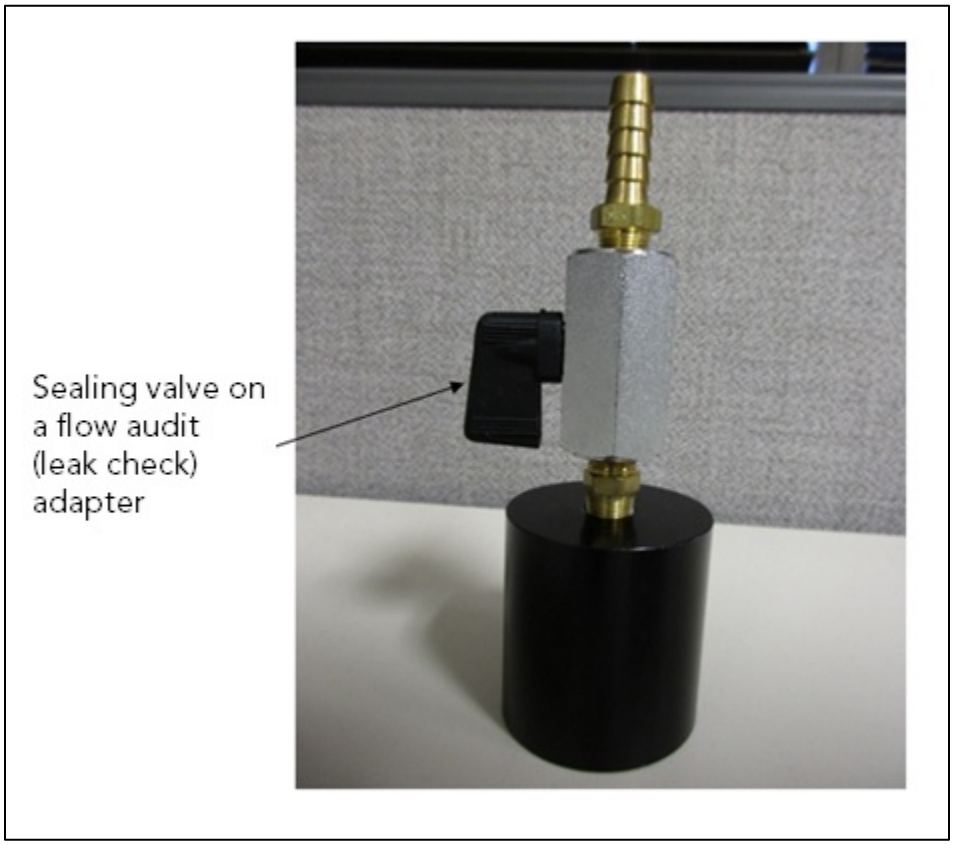


Figure AS.9 Flow Audit / Leak Check Adapter

    ii. Initiate an External Leak Check and wait for the timed procedure to finish.

    iii. A Pass or Fail message will display at the end of the leak check cycle. The leak check pass criterion is a pressure drop of 25 mmHg or less. The sampler will display a

message at the end of the cycle indicating the vacuum loss (mmHg) during the 60 second leak check, and a pass or fail message. Release the vacuum by (slowly) opening the flow audit/leak check adapter valve.

iv. If the leak check fails, ensure the valve is closed and the O-rings on the adapter are intact and fit snuggly against the downtube. Repeat the procedure and record the Leak Check value.

c. If a manual leak check is performed, follow the steps normally performed by the operator which usually involve the following:

i. Place the flow audit/leak check adapter (Figure AS.9) on the sampling downtube and open the valve.

ii. Turn on the flow valve, then the pump, and wait for the flow to stabilize.

iii. Close the valve on the flow audit adapter, which lowers the flow and starts to pull a vacuum.

iv. Locate two small valves on the tubing inside the pump housing and a small pressure gauge nearby. Close the valve to the left of the vacuum gauge. Note the value on the gauge (should be at least 15 inHg). Close the valve below the vacuum gauge, which shuts off flow to the pump. Turn the pump off. Watch the value of the vacuum gauge and time the leak check.

v. The small pressure gauge within the pump housing should not drop more than 8.5 inHg over one minute. If the leak check fails, ensure the valve is closed and the O-rings on the adapter are intact and fit snuggly against the downtube. Repeat the procedure and record the Leak Check value.

vi. Release the vacuum by (slowly) opening the flow audit/leak check adapter valve and the valves on the sampler.

7. Remove the flow audit adapter and the filter cassette. Return the sampler to its normal configuration and have the operator check its status.

8. Refer to Section AS.8.0 for post-audit procedures.

AS.7.2.3 SEQUENTIAL PM SAMPLERS

Low volume sequential PM samplers (typically the 2025 or 2025i models) operate with an automated filter exchange mechanism that allows for uninterrupted sampling on up to 16 filters at a desired frequency. This design includes a pair of filter cassette magazines or canisters that contain filters either prepared for sampling (supply) or loaded with a sample (storage). At the end of each run, the sampled filter is transferred into the storage canister while a fresh filter is advanced from the supply canister into the sampling position.

The 2025 series sampler is shown in Figure AS.10 along with the sampling train and PM configurations.

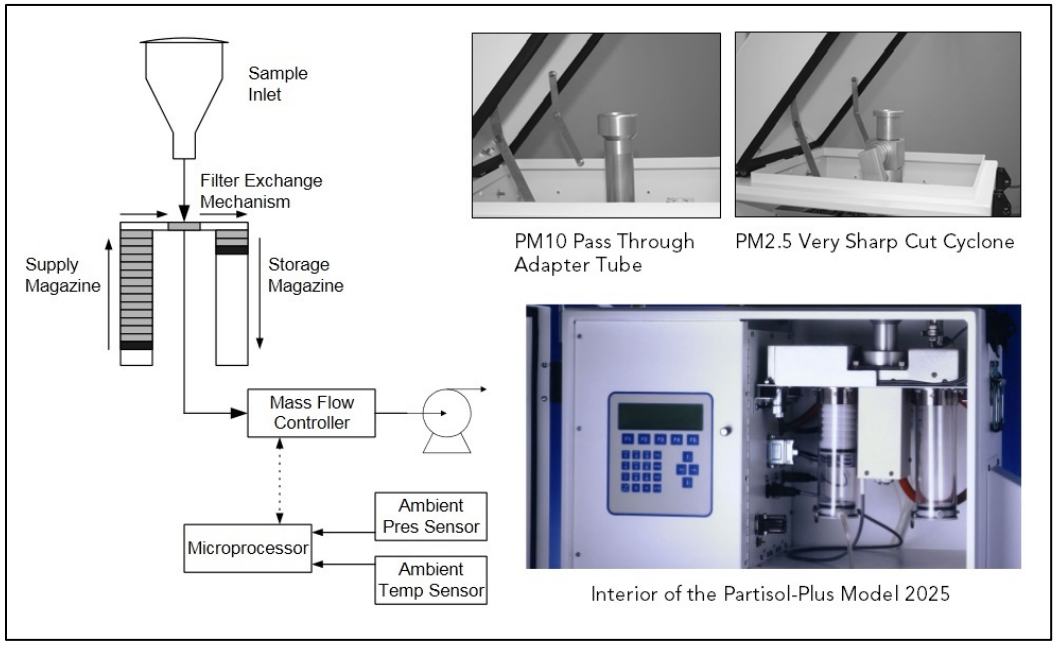


Figure AS.10 Model 2025 Sampling Train, Configurations, and Interior

The front panel of the sampler is navigated using pushbuttons or a touchscreen to obtain information during the audit. Refer to the

manufacturer's Instruction Manual(s) for more details on proper operation and audits of specific models.

1. Audit Procedures (sequential samplers):

   Begin the audit by following the procedures outlined in Section AS.7.2.1.

   The sampler's display should be showing the Audit Menu where temperature, pressure, and flow values can be read.

   NOTE: The following procedures can be performed while the sampler is operating so long as it is in "Audit" mode and the procedure is done in less than 20 minutes. While the checks can be performed in any order, the filter temperature check should be done after the flow and leak checks because removal of the $PM_{2.5}$ VSCC is necessary.

   IMPORTANT: Because sampled and/or unsampled filters may be waiting to be processed, it is critical that proper care is taken to ensure their integrity, including the timing, numbering, and status of the filter(s). It is highly recommended that the operator perform the functions while the auditor observes and directs the audit procedures.

2. Flow check (sequential samplers):

   a. Have the operator place a green aluminum leak check disk (or an audit filter with cassette) into position for sampling using the "Advance Filter" function. If an audit filter cassette is being used, be sure it is the same type as normally used by the sampler's operator.

   b. Carefully remove the sampler PM_{10} inlet head and replace it with the audit flow standard's head unit. Any $PM_{2.5}$ VSCC should remain in place. Ensure that O-ring(s) within the audit head are present and form a tight seal around the downtube.

   c. With the "Audit" screen displayed on the sampler, turn on the pump (this procedure will vary and may require the [Valve] button to be toggled). Wait up to five minutes for flow stability.

   d. Record the flow values from the sampler and the audit flow standard's display (Qa). The measured flow should be within

±4% of the audit standard and ±5% of the displayed current flow (or design), which should be near 16.67 LPM. If this is not the case, perform troubleshooting steps from the section below before proceeding.

e. Stop the pump and remove the audit standard's head unit.

3. External Leak Check (sequential samplers):

    a. Leak check procedures will vary based on software version and sampler configuration. Consult with the operator before conducting the leak check.

    b. Sequential PM samplers usually have an automatic leak check function built in. Follow the steps as displayed on the screen, which usually involve the following:

        i. Place the flow audit/leak check adapter (Figure AS.9) on the sampling downtube and close the valve.

        ii. Initiate an External Leak Check and wait for the timed procedure to finish.

        iii. A Pass or Fail message will display at the end of the leak check cycle. The leak check pass criterion is a pressure drop of 25 mmHg or less. The sampler will display a message at the end of the cycle indicating the vacuum loss (mmHg) during the 60 second leak check, and a pass or fail message. Release the vacuum by (slowly) opening the flow audit/leak check adapter valve.

        iv. If the leak check fails, ensure the valve is closed and the O-rings on the adapter are intact and fit snuggly against the downtube. Repeat the procedure and record the Leak Check value. Remove the flow audit adapter.

4. Ambient temperature check (sequential samplers):

    a. Locate the sampler's ambient temperature sensor for collocation with the equilibrated audit temperature standard. The solar radiation shield can be removed for easier collocation, if desired.

b. Position the audit sensor as close as possible to the sampler sensor without allowing the two sensors to touch. Protect the sensors from direct sunlight or excessive air movements as much as possible.

c. Allow both the audit sensor reading and the sampler's AT display values to stabilize. Record the both values on the Audit Worksheet.

5. Filter temperature check (sequential samplers):

a. Unlatch and open the sampler's top cover. Pull straight upward to remove the $PM_{2.5}$ VSCC or PM_{10} Pass Through Adapter Tube.

b. Insert the audit temperature sensor into the sampling chamber as shown in Figure AS.11 (below). Position the audit temperature sensor as close as possible to the sampler's filter temperature sensor without making contact. Protect the sensors from direct sunlight or excessive air movements as much as possible.

c. Allow both the audit sensor reading and the sampler's filter temperature display values to stabilize. Record both values on the Audit Worksheet.

d. Replace the VSCC or Pass Though Adapter Tube. Close and latch the cover. Replace the PM_{10} Inlet head.

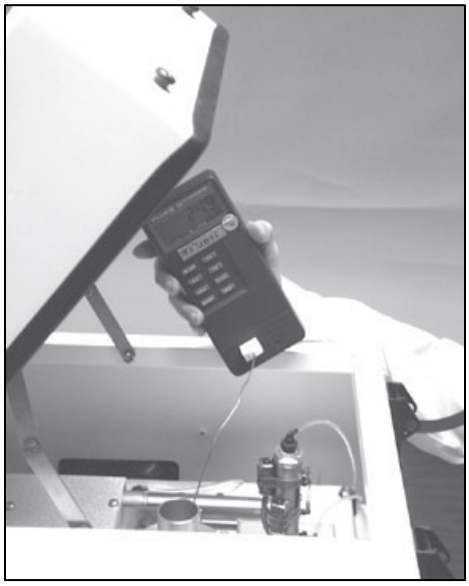


Figure AS.11 Filter Temperature Check in a Model 2025 or 2025i

6. Barometric Pressure check (sequential samplers):

    a. The audit standard for barometric pressure should be oriented correctly and collocated within 10 meters horizontal distance and 0.5 meters vertical distance from the sampler's sensor.

    b. Read and record the audit standard's display and the BP sensor reading from the sampler's display screen.

7. Consult with the operator to retrieve the audit filter cassette using the "Advance Filter" function. Return the sampler to its normal operating configuration, and have the operator check its status.

8. Refer to Section AS.8.0 for post-audit procedures.

AS.7.3 TROUBLESHOOTING LOW VOLUME SAMPLERS

If the audited flow rate exceeds the control or warning limits listed in Table AS.1, auditors should perform troubleshooting steps before recording data on the audit worksheet.

- Be sure equipment is equilibrated to ambient temperature and pressure conditions. If conditions have changed since the equipment

was turned on, it may be necessary to power-cycle the audit equipment.

- Ensure there is no flow through the audit equipment during its start-up. Keep audit equipment out of the wind during start-up.

- Ensure O-rings on the flow audit standard head and the leak check adapter are in good condition and fit snuggly on the downtube.

- If a filter with cassette is used, be sure it matches the type used by the sampler being audited and that the halves are pressed tightly together. Use the green machined aluminum leak check disk when possible.

AS.8.0 DATA MANAGEMENT AND RECORDS

Always use the most recent audit worksheets, which are available on QA audit laptops and in the Cabinet (S:\Cabinet\Forms & Worksheets).

Worksheets should be filled out carefully, using ink (no pencil) with legible characters and numbers. There should be no erasures, alterations, or correction fluid. Errors should be crossed-out with a single line, dated and initialed. Notes should be made on any exceptional events or conditions that may have an effect on the data, the equipment, or routine operation of the sampler during the audit. Audit Worksheets and Preliminary Audit Reports will be reviewed by a minimum of two people, including management, before finalization of the audit.

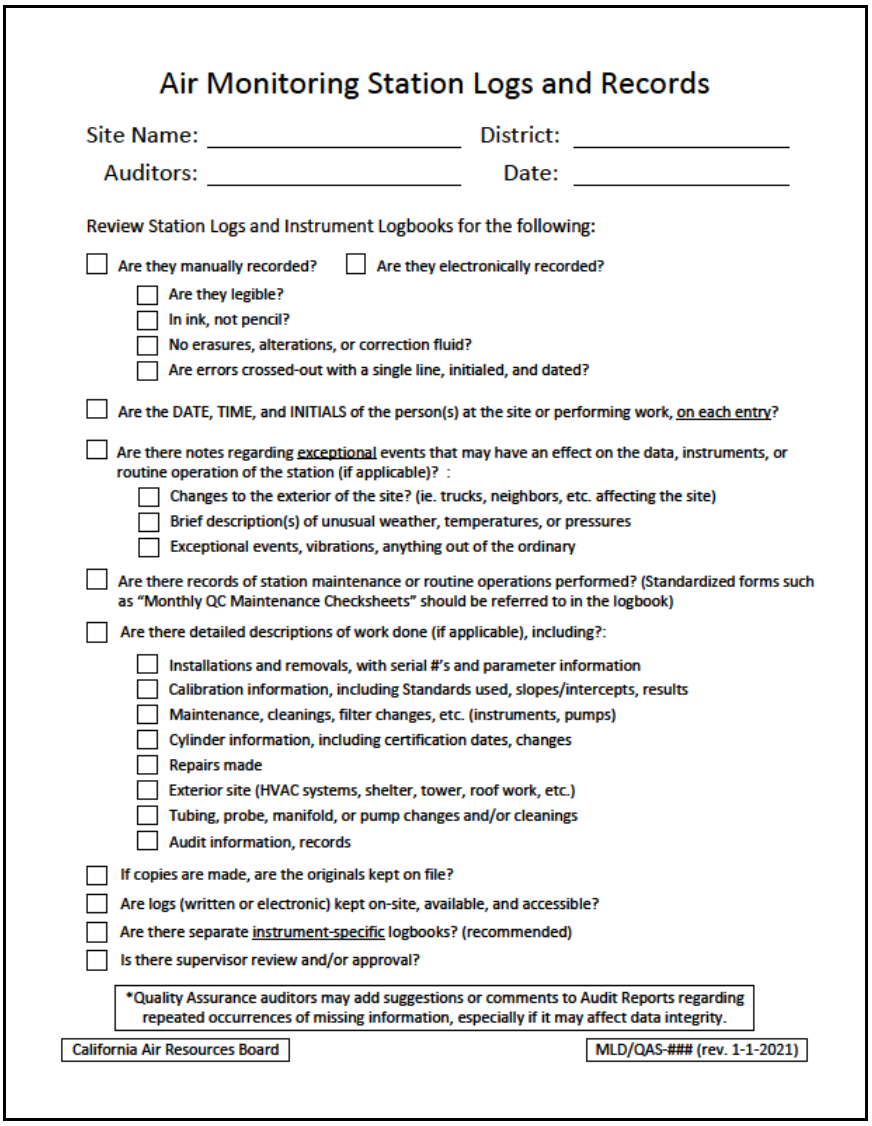
AS.8.1 GENERAL AUDIT PROCEDURES

1. Review the Audit Worksheet for completeness and accuracy, then sign it. Verify that all audit steps are complete.

2. Input data from the Audit Worksheet into AIS to generate results and a preliminary report. Review AIS for any questions or data that is not on the worksheets (such as verification of the most recent AQS information). The second auditor (if present) should review and verify that the Audit Worksheet and AIS entries match.

3. Station maintenance records and logbooks should be reviewed for missing audit data and completeness. A checklist has been developed to assist in the review of station logs and records (see Figure AS.12).

While not required, it should be used to identify any deficiency, especially in the past six months, which should be documented as a "Comment" or "Action Item" in the Audit Report.



Air Monitoring Station Logs and Records

Site Name: _____ District: _____

Auditors: _____ Date: _____

Review Station Logs and Instrument Logbooks for the following:

- ☐ Are they manually recorded? ☐ Are they electronically recorded?
  - ☐ Are they legible?
  - ☐ In ink, not pencil?
  - ☐ No erasures, alterations, or correction fluid?
  - ☐ Are errors crossed-out with a single line, initialed, and dated?
- ☐ Are the DATE, TIME, and INITIALS of the person(s) at the site or performing work, on each entry?
- ☐ Are there notes regarding exceptional events that may have an effect on the data, instruments, or routine operation of the station (if applicable)? :
  - ☐ Changes to the exterior of the site? (ie. trucks, neighbors, etc. affecting the site)
  - ☐ Brief description(s) of unusual weather, temperatures, or pressures
  - ☐ Exceptional events, vibrations, anything out of the ordinary
- ☐ Are there records of station maintenance or routine operations performed? (Standardized forms such as "Monthly QC Maintenance Checksheets" should be referred to in the logbook)
- ☐ Are there detailed descriptions of work done (if applicable), including?:
  - ☐ Installations and removals, with serial #'s and parameter information
  - ☐ Calibration information, including Standards used, slopes/intercepts, results
  - ☐ Maintenance, cleanings, filter changes, etc. (instruments, pumps)
  - ☐ Cylinder information, including certification dates, changes
  - ☐ Repairs made
  - ☐ Exterior site (HVAC systems, shelter, tower, roof work, etc.)
  - ☐ Tubing, probe, manifold, or pump changes and/or cleanings
  - ☐ Audit information, records
- ☐ If copies are made, are the originals kept on file?
- ☐ Are logs (written or electronic) kept on-site, available, and accessible?
- ☐ Are there separate instrument-specific logbooks? (recommended)
- ☐ Is there supervisor review and/or approval?

*Quality Assurance auditors may add suggestions or comments to Audit Reports regarding repeated occurrences of missing information, especially if it may affect data integrity.

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Figure AS.12 Air Monitoring Station Logs and Records Checklist

4. See Section AS.9.2 for audit criteria.

   NOTE: It is highly recommended to repeat or troubleshoot a procedure to confirm results that exceed audit criteria.

5. Notify the operator of preliminary audit results and any necessary follow up actions. Forward a copy of the preliminary report to the operator and/or their supervisor upon return from the field.

AS.8.2 AUDIT INFORMATION SYSTEM

The Audit Information System is used by QAS to manage data and site information collected during performance evaluations of air monitoring stations throughout the state. More information can be found in the Quality Assurance Manual, Volume V, Appendix AK: Using the Audit Information System (Refer to References; Section AS.10.0). Data should be entered into AIS using the following guidelines.

- Audits of high-volume samplers where the station operator calculates the flow should be entered into AIS using the PM_{10} Hi-Vol module.
- If the high-volume sampler is a CARB VFC and has a magnehelic which is used to calculate the sampler's flow rate, the data should be entered into AIS using the ARB PM_{10} Hi-Vol module.
- Audits of TSP samplers should be entered into AIS using the TSP module.
- Audits of low-volume PM_{10} samplers (typically non-sequential) should be entered into AIS using the Partisol/PM_{10} Lo-Vol module.
- Audits of low-volume $PM_{2.5}$ samplers (sequential and non-sequential) should be entered into AIS using the $PM_{2.5}$ module.

AS.8.3 U.S. EPA AIR QUALITY SYSTEM

The U.S. EPA maintains a database for air monitoring data commonly called AQS (previously known as AIRS). The AQS parameters and associated methods relevant to audits of filter-based PM monitoring can be found here: https://www.epa.gov/aqs/aqs-code-list

Federal Reference Method (FRM) and Federal Equivalent Method (FEM) designations and more information about air monitoring methods for criteria pollutants can be found here: https://www.epa.gov/amtic/air-monitoring-methods-criteria-pollutants.

The reporting of audit data to AQS is described in Section AS.9.1.

AS.9.0 QUALITY ASSURANCE AND QUALITY CONTROL

Quality control (QC) includes establishing specifications or acceptance criteria for each quality characteristic of the monitoring/analytical process, assessing procedures used in the monitoring/analytical process to determine conformance to these specifications, and taking any necessary corrective actions to bring them into conformance.

This section describes conditions that are required to determine the outcome of the audit. It includes the frequency of QC checks, limits/criteria for QC results, actions required if QC results are not within limits/criteria [issuance of Air Quality Data Action (AQDA) request or a Corrective Action Notification (CAN)], and procedures for reporting QC data and results.

AS.9.1 FREQUENCY AND REPORTING OF AUDITS

Particulate monitors (specifically, flow rates) are required to be audited twice per year, per 40 CFR Part 58, Appendix A, Sections 3.2.2 ($PM_{2.5}$) and 3.3.3 (PM_{10}). The two audits should ideally be spaced between 5 and 7 months apart. The audit should be conducted by a trained, experienced technician other than the routine site operator. The flow rate of the audit transfer standard and the corresponding flow rate measured by the monitor is reported to AQS. The percent differences between these flow rates are used to evaluate monitor performance. Mass concentrations are usually reported in micrograms per cubic meter of air sampled at U.S. EPA Standard Temperature and Pressure (STP) conditions of 25°C and 760 mmHg. It is important to note, however, that monitors are audited by comparing flow values recorded under actual (or local) temperature and pressure conditions.

AS.9.2 LIMITS AND CRITERIA

The following table (Table AS.1) provides the acceptable criteria for each audited parameter of filter-based PM samplers. Any identified exceedance of established audit criteria or deviation from operational standards may result in corrective action.

Table AS.1 Audit Criteria (Control and Warning Limits)

Parameter	**Filter-Based Range**	**Control Limit**	**Warning**
PM_{10}	High Volume	± 7% of Transfer Standard ± 10% from Design flow rate	± 5% of Transfer Standard
TSP	High Volume	± 7% of Transfer Standard	± 5% of Transfer Standard
PM_{10}-$PM_{2.5}$ (PMcoarse)	Low Volume	± 4% of Transfer Standard ± 5% from Design flow rate	none
PM_{10}* (*criteria based on data usage)	Low Volume	± 10% of Transfer Standard	± 7% of Transfer Standard
PM_{10}* (*criteria based on data usage)	Low Volume	± 4% of Transfer Standard ± 5% from Design flow rate	none
$PM_{2.5}$	Low Volume	± 4% of Transfer Standard ± 5% from Design flow rate	none

AS.9.2.1 SITING CRITERIA

While 40 CFR Part 58, Appendix E contains specific location criteria applicable to SLAMS, NCore, and PAMS ambient air quality monitoring probes and inlets, the appendix describes siting criteria applicable to all PM monitors in the CARB Primary Quality Assurance Organization (PQAO). Adherence to these siting criteria is necessary to ensure the uniform collection of compatible and comparable air quality data. The PM-specific inlet siting criteria (in meters) are related to the spatial scale of the monitor as shown below in Table AS.2.

In addition, all monitors must have unrestricted airflow 270 degrees around the inlet.

Collocated monitors must be within 4 meters of each other and at least 2 meters apart for flow rates greater than 200 liters/min (high-volume), or at least 1 meter apart for samplers having flow rates less than 200 liters/minute (low volume) to preclude airflow interference, unless an approved waiver is in place.

Table AS.2 Siting Criteria for PM Monitors (distances in meters)

Monitoring Scale	**Inlet Height from Ground**	**Horizontal distance to walls or parapets**	**Distance from inlet to trees**	**Distance from inlet to roadway**
Micro	2-7	>2	>10	2-10
Middle	2-15 2-7 (PMc or near-road)	>2	>10	*refer to chart in CFR
Neighborhood	2-15 2-7 (near-road)	>2	>10	*refer to chart in CFR
Regional	2-15 2-7 (near-road)	>2	>10	*refer to chart in CFR
Urban	2-15 2-7 (near-road)	>2	>10	*refer to chart in CFR

AS.9.3 CORRECTIVE ACTIONS

CANs are issued to document deficiencies that may potentially impact data quality, completeness, storage, or reporting. Refer to the SOP for Corrective Action Notifications (Volume V, Appendix AN) for guidance.

AQDA Requests are issued when the audit reveals that the station's monitor(s) are not operating within federal critical criteria or CARB control limits. Refer to the SOP for Air Quality Data Action Requests (Volume V, Appendix AO) for guidance.

AS.10.0 REFERENCES

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AS.11.0 REVISION HISTORY

Section	Version 1 (February 2021)
All	New Standard Operating Procedure incorporating: • Performance Audit Procedures for High-Volume Samplers (CARB QA Manual, Volume V, Appendix D) • Performance Audit Procedures for $PM_{2.5}$ Samplers (CARB QA Manual, Volume V, Appendix Z) Differentiates PM samplers by Filter-Based versus Continuous PM samplers to align with U.S. EPA criteria.