



COLORADO

**Department of Public
Health & Environment**

Air Pollution Control Division

Technical Services Program

APPENDIX PM1

**Standard Operation Procedure for Monitoring PM₁₀ in Ambient Air
Using a High Volume (Hi-Vol)
Volumetric – Mass-Flow Controlled (MFC) Sampler**

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1.0 SCOPE AND APPLICATION

1.1 Introduction

On October 17, 2006, the U.S. EPA revised the National Ambient Air Quality Standard (NAAQS) for particulate matter with an aerodynamic diameter smaller than 10 microns, or PM₁₀. The previous annual standard for PM₁₀ was abolished and the previous 24-hour standard of 150 µg/m³ was retained. This final rule became effective on December 18, 2006.

PM₁₀ is the designation of particulate matter in the atmosphere that has an aerodynamic diameter of 10 µm or less. PM₁₀ sampling is designated as a method in the *Code of Federal Regulations* (CFR) (40 CFR Part 50, Appendix J) (EPA). PM₁₀ includes two general size categories of particles, fine and coarse. Fine particles, known as PM_{2.5} (particles smaller than 2.5 microns in aerodynamic diameter) penetrate more deeply into the lungs and are more difficult for the body to remove than coarse particles (10 – 2.5 microns). Several recent health studies indicate a link between fine particle concentrations in the outdoor air and certain health effects (40 CFR Part 58, EPA 2004a and EPA 2004b). Fine particles are generally emitted from combustion activities (such as industrial and residential fuel burning and motor vehicles) while coarse particles mainly come from dust emitted during activities such as re-entrained road dust from vehicular travel, construction and agricultural activities. Some of the health effects that have been linked to fine particulate matter pollution include: Premature death, increased hospital admissions and emergency room visits (primarily by the elderly and individuals with cardiopulmonary disease), increased respiratory symptoms and disease in children and individuals with cardiopulmonary disease, and decreased lung function and alterations in lung tissue and structure, particularly in children and people with asthma. Fine particulate or PM_{2.5} is more fully described in the, “Standard Operating Procedures for Monitoring PM_{2.5} in Ambient Air” Appendix PM2, and elsewhere in the Quality Assurance Project Plan.

The health effects that have been linked to coarse particulate matter pollution are not well understood at this time due to the lack of monitoring and health studies associated with coarse particulate (PM_{10-2.5}). Also, the health effects of coarse particles may be confounded by PM_{2.5} particles in the PM₁₀ health studies. Thus, PM₁₀ monitoring will most likely be conducted until it can be replaced by PM_{10-2.5} monitoring.

This document is intended to instruct Colorado field personnel, local operators, and auditors that use the Sierra Anderson 1200 Federal Reference Method (FRM) sampler on proper methodologies to monitor ambient air for PM₁₀ particles. The formal specifications for the Sierra Anderson 1200 sampler and for obtaining valid reference method measurements are set forth in the U.S. Environmental Protection Agency’s (EPA) monitoring regulations in 40 CFR Part 50, Appendix K (EPA 2006). This document reviews those formal requirements, manufacturer guidelines, good QA/QC protocol, and provides clarifications and supplemental information in greater detail than can be provided in the formal regulatory requirements. Because this supplemental information is intended for method users, it emphasizes the operational aspects of the method, rather than the design and performance specifications for the sampler. The document also provides recommended quality assurance (QA) procedures and guidance to help monitoring agencies reliably achieve high quality data established for PM₁₀ monitoring by the Colorado Air Pollution Control Division (APCD). The information provided here, have been used by the APCD to develop its own agency-specific standard operating procedure (SOP) for the Sierra Anderson 1200 sampler.

1.2 Method Overview

A high-volume PM₁₀ (HI-Vol PM₁₀) sampler draws a known volume of ambient air at a constant flow rate through a size-selective input and through a glass fiber or quartz filter. Glass fiber filters are routinely used for PM₁₀ sampling and quartz filters are used for special purpose sampling. Particles in the PM₁₀ size range are then collected on the filter during a specified 24-hour (midnight to midnight) sampling period. Each sample filter is weighed before and after sampling to determine the net weight (mass) gain of the collected PM₁₀ sample (see the Lab SOP of this QAPP for a complete description of lab activities). The total sample volume is determined from the calculated flow rate using a monthly average ambient temperature and an

annual average pressure and the sample duration. The mass concentration of PM₁₀ in the ambient air is computed as the total mass of collected particles in the PM₁₀ size range divided by the actual volume of air sampled, and is expressed in micrograms per cubic meter of air ($\mu\text{g}/\text{m}^3$). A complete description of the method can be found in 40 CFR Part 58, Appendix J and in Quality Assurance Guidance Document 2.11 “Monitoring PM₁₀ in Ambient Air Using a High-Volume Sampler Method” (EPA 1990).

2.0 SUMMARY OF METHOD

2.1 The Inlet

The Mass-Flow-Controlled (MFC) PM₁₀ samplers use an impaction inlet (See [Figure EOD-2](#)). The symmetrical design of the inlet ensures wind-direction insensitivity. APCD currently uses Sierra Anderson 1200 model samplers for PM₁₀ High-Volume (Hi-Vol) sampling. Ambient air that is drawn into the inlet is evacuated from the buffer chamber through nine acceleration nozzles into the first impaction chamber and accelerated further through an additional 16 jets into a second chamber. These jets have critical diameters to provide necessary changes in velocity to effect particle size fractionation. The airflow exits the inlet through nine vent tubes onto the sample filter. Air velocities are critical to maintain the correct particle size cut point within the inlet. Therefore, a flow rate as close as possible to the prescribed 1.13m³/min. must be maintained during the 24-hour sampling period. The flow rate in an MFC system is actively sensed and controlled at a calibrated set point by an electronic mass-flow controller during sampling.

2.2 Measurement

The total volume of air sampled is determined from the measured mass flow rate and the sampling time. The concentration of PM₁₀ in the ambient air is calculated as the total mass of collected particles in the PM₁₀ size range divided by the volume of air sampled. The PM₁₀ measurement is expressed as micrograms per actual cubic meter ($\mu\text{g}/\text{m}^3$). The performance parameters of samplers are tested in accordance with explicit test procedures that are prescribed in 40 CFR Part 53 (EPA 1997).

3.0 DEFINITIONS AND ACRONYMS

<u>Acronyms</u>	<u>Definitions</u>
APCD	Air Pollution Control Division
AC	Alternating current
ASTM	American Society for Testing and Materials
C	Celsius – temperature measured in degrees centigrade
CHEM	Chemistry
CFR	Code of Federal Regulations
CDPHE	Colorado Department of Public Health and Environment
DOP	Diocetyl phthalate
EPA	Environment Protection Agency
g	gram
Hi-Vol	High Volume air sampler (refers to the relatively high volume of air flow through the inlet of greater than 200 liters/minute)
K	Kelvin- temperature in degrees kelvin
LAN	Local Access Network
MFC	Mass Flow Controller
m	Meters
Hg	Mercury
mmHg	Millimeters of Mercury
NAAQS	National Ambient Air Quality Standard
NIST	National Institute of Standards and Technology
PMT	Particulate Data Handling System
PM ₁₀	Particulate Matter 10 microns or less in aerodynamic diameter
PSD	Prevention of Significant Deterioration
QAPP	Quality Assurance Project Plan

QA/QC	Quality Assurance/Quality Control
RH	Relative Humidity
S/N	Serial Number
SLAMS	State and Local Air Monitoring Site
SOP	Standard Operating Procedure
TSP	Technical Services Program
TSP	Total Suspended Particulates
µg	microgram

4.0 HEALTH AND SAFETY WARNINGS

1. Use caution on ladders and rooftops, especially in inclement weather or under snow pack conditions. Stay at least 6 feet away from the edge of a roof when there is no parapet.
2. Wear sturdy work shoes with a good traction soles.
3. Only one person at a time on a ladder. Strap the ladder in place where possible.
4. Use a rope to pull equipment up to the roof.
5. Always unplug the sampler when servicing or replacing parts.
6. Use extreme caution if any electrical outlets or connects have come into contact with water.
7. Strap inlets, front panels, and timer box doors into open position while working on the sampler to avoid unexpected movement due to winds or uneven weight distribution.
8. Sunscreen and eye protection are recommended.

5.0 CAUTIONS

1. Keep sampler inlet and other parts clean to maintain optimal operations.
2. Inspect the system regularly (e.g., each time a sample is installed) for leaks, structural integrity, gasket integrity, and functionality.
3. Verify that timers and mass flow controllers are working properly every six months.
4. Replace motors periodically, usually once every six months or sooner as needed.
5. Inspect the filter cassettes whenever possible to make sure they are in good working condition and properly installed.
6. Take care to fill out “Sample Record Sheets” and all other documentation related to the sample or sampler as completely and accurately as possible. Write clearly. If a mistake is made, draw a single line through it, write the correction, and then initial the change and add the date the change was made near the corrected data.

6.0 INTERFERENCES

1. Do not excessively handle the filters. Only handle filters on the edges. Do not handle a filter with dirty hands or work-type gloves. Mishandling of filters can cause inaccurate mass measurements.

2. Bad weather can cause problems with sample recovery. Avoid changing filters when it is precipitating heavily, especially combined with high winds. Cover the sampled filters quickly and do the packing for shipping inside in a clean area of your office.
3. Bent or damaged filters (pinholes, tears, corners missing, etc.) will compromise sample collection and may give erroneous manometer readings. Do not use bent or damaged filters for sample collection.

7.0 PERSONNEL QUALIFICATIONS

Refer to section 2.4 of the CDPHE/APCD/TSP Quality Assurance Project Plan (QAPP).

8.0 APPARATUS AND MATERIALS

1. A flow rate transfer standard capable of measuring flow at $\pm 2\%$ of a NIST traceable standard orifice, adapter face plate, and associated manometer. Associated manometer should have at least a 12-inch range and scale divisions of 0.1 inches. An oil manometer, with an 8-inch range and scale divisions to the nearest 0.1-inch, to measure the sampler exit orifice plenum pressure. This manometer is mounted inside the sampler housing.

NOTE: Manometers used in the field may be subject to damage or malfunction and should be checked frequently for leaks, clogs, color changes from red to clear may indicate a density change, etc.

2. A thermometer capable of accurately measuring temperature over the range of -10 to 50°C readable to the nearest $\pm 0.1^{\circ}\text{C}$ and NIST traceable within accuracy of 0.5°C verified at least annually.
3. A barometer capable of accurately measuring ambient barometric pressure over a range of 18 to 28 inches mercury (Hg) to the nearest 0.04 inch Hg and traceable to a barometer of known accuracy (referenced to a NIST barometer) within ± 0.2 inches Hg at least annually.
4. A laptop computer loaded with current MS Access database programs, which will perform calculations, plus data sheets, field data sheets, and a writing utensil.
5. A new or reconditioned motor.
6. A cassette cover-plate.
7. Miscellaneous hand tools, spare parts and tubing, replacement cassettes or replacement gaskets, glue, Molykote 316, and cleaning supplies.
8. Spare quartz filters.
9. Spare timers and mass flow controllers.

9.0 SAMPLER QC AS FOUND FLOW VERIFICATION CHECK

Prior to performing a calibration a one point QC flow check should be performed to verify the sampler is operating within the acceptable flow range prior to calibration. The PM₁₀ MFC QC check procedure presented in this section relates known flow rates to the pressure in the exit orifice plenum. The known flow rates are determined by an orifice transfer standard that has previously been certified or calibrated against a *National Institute of Standards and Technology* (NIST) traceable standard. The orifice transfer standard can be the same as the standard used for calibration. No adjustments may be made to the sampler system before the QC check is performed. The PM₁₀ sampler inlet is designed to operate at an actual volumetric flow rate of 1.132 m³/min, and the acceptable flow rate range is $\pm 10\%$ of this value.

9.1 COLLECT ANALYZER INFORMATION AND PERFORM ONE-POINT FLOW RATE CHECK

1. Collect required information from the PM₁₀ high volume sampler which is being verified and collect current ambient conditions. Information collected includes:
 - Current date and time (Mountain Standard Time)
 - Sampler location
 - Sampler number
 - Motor number
 - Current sampler set point
 - Current ambient temperature
 - Current ambient pressure
2. Turn on sampler to let the instrument to run for 5 – 10 minutes to warm up motor.
3. After the sampler warm up period is complete, record the initial ΔP_{ex} (sampler) monometer reading with the sampler in normal sample condition (i.e. with sample head down and secure over sample media). Remember to leave the operator a note with this reading for the sample record they may be collecting. If the installed filter has not yet sampled a new initial reading should be recorded after the new motor installation and calibration so that the operator can update the sample record when they collect the sample.
4. Turn sampler off. Open sampler head and place metal cover over sample media cassette to protect from particulates settling on the media and damaging the filter while the QC check is being performed. Loosen and remove thumb screws. Remove the sample filter cassette and set it aside in a clean location.
5. Set up audit system as follows:
 - i. Place the audit quartz filter on sampler inlet screen and cover with flow transfer standard plate. Ensure the filter does not shift and covers the entire sample surface.
 - ii. Secure flow transfer standard plate with the supplied wing nuts, making sure to secure all four corners evenly to prevent leaks.
 - iii. Ensure the flow transfer standard monometer is level and the monometer is zeroed.
 - iv. Ensure audit monometer is not connected to the orifice pressure port at this time.
6. Perform sampler leak check as follows:
 - i. Block the flow orifice openings with rubber stoppers, or other means, to block the air flow from entering the orifice ports. Additionally, remove the manometer tube from the front of the transfer standard and seal the pressure port with cap or some other device to prevent air flow.
 - ii. Turn on the sampler for a short period of time.

Note: avoid running the sampler for longer than 30 seconds at a time with the orifice blocked. This precaution will reduce the chance that the motor will overheat due to lack of cooling air and in turn reduce the lifespan of the motor.
 - iii. Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. Observe sampler manometer, a leak-free system will not produce an upscale response in the sampler's exit orifice manometer. All leaks must be eliminated before proceeding with the audit.
 - iv. When the sampler is determined to be leak-free, turn off the sampler and unblock the orifice.
 - v. Connect the manometer tube to the front of the transfer standard orifice.

7. Perform one-point flow rate verification:
 - i. Turn on the sampler and allow sampler flow controller to stabilize for 2 to 5 minutes.
 - ii. Ensure audit orifice is in the wide-open position. Briefly inspect QC and field equipment for leaks or damage. Take ΔH_2O (orifice) monometer reading from the orifice transfer standard and take ΔP_{ex} (sampler) monometer reading.
 - iii. Turn off sampler. Remove the orifice transfer standard, audit faceplate and audit filter.
 - iv. Reinstall sample filter cassette and secure snugly/evenly with the provided thumb screws. Remove cover plate from cassette. Lower inlet (sampler) head back on top of sampler and secure in place.
 - v. Turn sampler on and allow unit flow to stabilize. Take final ΔP_{ex} (sampler) monometer reading. Compare this reading to initial ΔP_{ex} (sampler) monometer reading from Step 3. This will assure equipment is being left in as good or better operating condition than when auditor arrived. Note any discrepancies. If the initial and final ΔP_{ex} (sampler) values are not similar, then a possible cassette leak or cassette installation problem might exist.

It is important to note that the High Volume Transfer Standard Orifice plate and manometer must be maintained. On a yearly basis, at least the rubber seal on the bottom of the orifice plate should be replaced and the manometer oil inside the manometer should also be replaced. The audit manometer must also be checked for leaks by carefully drawing oil up the manometer and blocking the air. A leak free manometer will hold this oil in place after the air flow is blocked on one end of the manometer.

8. Using the auditor's field laptop, open the P&A Database at C:\Program Files\P&A Database\P&ADatabase.mdb. Select the "Enter / Edit New PM₁₀/TSP Audits" button from the Main Menu form. This initiates the Access Form in which audit data can be entered ([Figure 7.1](#)).
9. On the electronic audit form, enter all the requested Site Information, Orifice Information, Temperature/Pressure Information and Calibration Information. In the "Action Description" field enter "QC as Found". Enter ΔP_{ex} (sampler) manometer value from Step 3. Enter the ΔH_2O (orifice) monometer reading measured in Step 7. Enter ΔP_{ex} (sampler) manometer value from Step 7. Enter the final ΔP_{ex} (sampler) monometer value from step 7. The program will calculate if the one-point audit calibration passes or fails, if actual/design flow-rate passes or fails.
10. Save the QC as Found record by clicking the *Capture Data* button on the audit form.
11. The Audit database software program performs the following calculations:

Equation: 7.A

$$\text{Audit } Q_a (\text{orifice}) = A(\Delta H_2O)^B \times \sqrt{\left(\frac{760}{Pa}\right) \times \left(\frac{Ta}{298.15}\right)}$$

Audit Q_a (orifice) = Actual flow rate as indicated by the monometer reading affiliated with the audit orifice flow transfer standard

A = Orifice transfer standard calibration factor

B = Orifice transfer standard calibration exponent

ΔH_2O = Pressure drop (in inches H₂O) across the orifice transfer standard

Pa = Ambient pressure (in mm Hg)

Ta = Ambient temperature (in K)

760 represents standard pressure (in mm Hg)

298.15 represents standard temperature (in K)

Equation: 7.B

$$Qa(sampler) = \frac{\left(\sqrt{\Delta P_{ex}(sampler)} \times (T_a + 30) \times P_a\right) - b}{m}$$

$\Delta P_{ex}(sampler)$ = Reading taken from the sampler monometer which measures the pressure drop across the motor plenum exit

P_a and T_a are defined above

30 represent the estimated temperature increase as air flows through the sampler motor

b = y- intercept from most recent sampler calibration

m = Slope from most recent sampler calibration

Equation: 7.C

$$Audit Flow \% Difference = \left(\frac{Qa(sampler) - Audit Qa(orifice)}{Audit Qa(orifice)} \right) \times 100$$

Equation: 7.D

$$Qa(corrected) = Qa(sampler) \left(\frac{100 - Audit Flow \% Diff.}{100} \right)$$

Equation: 7.E

$$Design Flow \% Difference = \left(\frac{Qa(corrected) - 1.132}{1.132} \right) \times 100$$

Press the <Capture Data> key to store the audit record to the archive data table. Note: verify that the flow is within the correct design flow range.

10.0 SAMPLER CALIBRATION AND STANDARDIZATION

The PM₁₀ MFC sampler calibration procedure presented in this section relates known flow rates to the pressure in the exit orifice plenum. The known flow rates are determined by an orifice transfer standard that has previously been certified or calibrated against a NIST traceable standard.

For this calibration procedure, the following conditions are assumed:

- The sampler flow rate is determined by measuring the exit orifice plenum pressure, using an 8-inch oil manometer, which is inside the sampler.
- The orifice transfer standard for the flow-rate calibration is an orifice device equipped with an integral variable-resistance valve that has been certified according to the procedure presented in the “Quality Assurance Handbook for Air Pollution Measurement Systems” Volume II, and APCD “Standards Verification and Calibration SOP” Appendix QA2 of this QAPP. The pressure drop across the orifice is measured by a manometer.
- The sampler is calibrated using six flow rates over a range from 1.02 m³/min to 1.24 m³/min. The sampler inlet is designed to operate at an actual volumetric flow rate of 1.132 m³/min, and the acceptable flow-rate range is ±10 percent of this value. Values deviating by more than ±7% should however be reported to the Particulate Monitoring group as in the “warning range”, which may require sampler recalibration.

- The current ambient temperature and ambient pressure are used in the calculations.
- The high volume PM₁₀ MFC sampler is equipped with a mass flow controller to control its airflow rate through the orifice. This must be removed from the system to perform the calibration.

Caution: Tighten the four faceplate or cassette thumbnuts evenly on alternate corners to properly align and uniformly seat the gaskets. The nuts should be hand-tightened only - too much compression can damage the sealing gaskets or warp the top of the cone holding the sampler screen.

10.1 Motor Replacement

Motor replacement is normally performed on a non-sampling day. The exposed sample will most likely be in place on the sampler.

1. Check the general appearance and condition of the sampler and make note of any problems found at the time. Make the necessary repairs, if practicable. Turn the sampler on and allow the flow to stabilize. Take the final manometer reading for the sample. On a sheet of paper, record the final manometer reading for the sample, the elapsed time, sampler ID, the date, and your name. Leave this information for the operator, along with the information on the new motor number and the proper set point with the person or local agency that is running the sampler. This information should also be documented on the index card on the inside of the sampler door.
2. Release the sampler inlet (head) and tilt backwards or remove, if appropriate. Remove the sample cassette containing the last sample by unscrewing the four retaining thumbnuts. Check the cassette and its gaskets for leaks or wear that would indicate a need for replacement. Replace the gasket if necessary. Put the cassette cover plate over the sample. Put the sample in a safe place.
3. Unplug the motor from the mass flow controller. Unplug the mass flow controller from the timer. Disconnect the manometer tubing from the motor.
4. Remove the sampling cone and motor from the shelter and place it on top of the sampler. Take care not to pull on the mass flow sensor cord. Remove the old motor and replace it with the new one, making sure the gasket is properly positioned and the connecting ring is not cross-threaded. Replace the motor and cone in the sampler.
5. Connect the manometer tubing to the motor exit orifice plenum.
6. Plug the sampler directly into the power source of the instrument's timer.

10.2 Leak Check

1. Check gaskets on the calibration orifice and replace if they are questionable. Place a quartz filter and the orifice onto the sampler and secure it with the four thumbnuts.
2. Plug the motor directly into a stable line voltage source i.e., to the sampler's on-off timer and perform an orifice leak test.
3. Leak test the sampler by blocking the orifice intake holes with rubber stoppers. Disconnect the orifice manometer tubing and block the manometer port with a plenum plug (if necessary heavy tape may be used, but a thumb works pretty well). Listen for a whistling sound that would indicate a leak in the system. The motor manometer should not show a change in pressure. Leaks are caused by a damaged or missing gasket or improper threading. Eliminate leaks before proceeding. When the system is determined to be leak-free, turn off the sampler and unblock the orifice.

Caution: The motor will overheat due to the lack of cooling air. Avoid running the sampler for longer than 30 seconds when performing the leak test.

10.3 Multi-Point Calibration (and Calculations)

Caution: Do not attempt to calibrate or verify sampler under extremely windy conditions. Short-term wind fluctuations will produce erroneous pressure readings by the calibration orifice. At times, an open box may be used to shield the orifice inlet when winds are causing fluctuations in the manometer response, or readings can be taken when there is a break in wind gusts. The sampler inlet may also be partially lowered over the calibration orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2 inches of clearance at the bottom for airflow and for the manometer tubing.

Note: If there is a sampled filter in the instrument, note the final manometer reading and Elapsed Time Meter reading for the operator. If there is a new filter setup for the next sampling event, place a filter cassette cover over the filter and set aside for the calibration. Note the new sampler ID and initial manometer and Elapsed Time Meter reading for the operator.

1. See [Figure EOD-1](#) for diagram of sampler calibration/audit setup.
2. Check gaskets on orifice transfer standard faceplate. Make any necessary repairs. Place protective cover on filter cassette and remove cassette from sampler. Place quartz filter over sampler screen. Place orifice faceplate on top of sampler screen (on top of filter). Attach orifice transfer standard to faceplate (if not already attached). Zero manometers. Check manometers for leaks, plugs, or other problems. Turn on instrument. Secure faceplate with thumbnuts. Let instrument warm up for about 5 minutes.
3. Log on to a laptop computer that is preloaded with APCD PM₁₀/TSP calibration software. Pull up the calibration software on the laptop computer. (See [Figure EOD-3](#).)
4. Follow macro and select data inputs from the drop down list in the macro (follow the example for WELBY as follows): Site name (WELBY), enter; Instrument No. (PM₁₀-1), enter; Motor No. (e.g. 4020), enter; Date (05/11/14), enter; Action Description (Calibration or Re-calibration), enter; Calibrators Initials (JO), enter; Conditions (Acceptable), enter; Filter type (Glass or Quartz), enter; Orifice Calibration Date (Most current date [11/8/05]), enter; Ta (deg. in °F) [current temperature (50 °F)], enter; Opt Plenum Temp (deg. °F) [NO ENTRY], enter; PA (inHg), [current barometric pressure (24.9inHg)], enter.

Note: For a more complete set of calculations, see Section 14.0 of this SOP

Caution: Due to the possibility of computer failure, be sure to write all of this information on a data sheet or pad of paper. This will allow regeneration of the calibration at a later date.

5. The PM₁₀ sampler should be equilibrated after about 5 minutes of running. The computer program will generate six orifice transfer manometer readings to be targeted where the flow rate will be measured between 0.9 and 1.3 m³/min with at least three of these points falling between 1.02 and 1.24 m³/min. Dial in each of these pressure readings, recording the ΔH_2O (orifice) and ΔP_{ex} (SAMPLER) values at each point. Turn off sampler after these 12 measurements are recorded.
6. The calibration software program will perform the following calculations:

Equation 9.A

$$Q_a (\text{orifice}) = A(\Delta H_2O)^B \times \sqrt{\left(\frac{760}{P_a}\right) \times \left(\frac{T_a}{298.15}\right)} \quad (= X \text{ Value})$$

Where: Q_a (orifice) = actual volumetric flow rate as indicated by the orifice transfer standard.
 A = Orifice transfer standard calibration factor
 B = Orifice transfer standard calibration exponent
 ΔH_2O = Pressure drop (inH₂O) across the orifice transfer standard.
 P_a = Ambient pressure (mmHg)
 T_a = Ambient temperature (°K)
 760 represents standard pressure (mmHg)
 298.15 represents standard temperature (°K)

Equation 9.B

$$P_{ex(TRANS)} = \sqrt{\left(\Delta P_{ex} (\text{sampler}) \times \left(\frac{T_a + 30}{P_a}\right)\right)} \quad (= Y \text{ Value})$$

Where: $P_{ex(TRANS)}$ = TRANSFORMED sampler manometer reading to account for estimated motor plenum exit temperature

$\Delta P_{ex} (\text{sampler})$ = pressure drop at sampler motor plenum exit (inH₂O)

P_a and T_a are defined above

30 represents the estimated temperature increase as air flows through the motor.

A linear regression is calculated where Q_a (orifice) values are plotted on the x -axis and $P_{ex(TRANS)}$ values are plotted on the y -axis to determine a slope (m) and a y -intercept (b) for the calibration of the motor.

- The values obtained during the calibration are used in the linear regression equation to verify that all readings used in the calibration fall within the design flow range of 0.9 to 1.3 m³/min with at least 3 points falling in the 1.02 to 1.24 m³/min range. Also to verify that each individual value being used is within ± 0.04 m³/min of the corresponding orifice transfer standard value generated.

Equation 9.C

$$Q_a (\text{sampler}) = \frac{(\Delta P_{ex(TRANS)} - b)}{m}$$

Equation 9.D

$$\% \text{ Difference (Design Flow)} = \left(\frac{Q_a (\text{sampler}) - 1.132}{1.132}\right) \times 100$$

8. Remove the orifice and quartz filter from the top of the sampler. Install a cassette with a clean quartz filter. Reconnect timer and mass flow controller. Tighten cassette down with the four thumbscrews. Turn the sampler on. Turn set screw on front of MFC until desired set-point for $\Delta P_{\text{ex (SAMPLER)}}$ is achieved. (The calibration software program calculates the set-point value) This set point is equivalent to a flow rate of 1.132 m³/min. Record $\Delta P_{\text{ex (SAMPLER)}}$ value after the flow rate has been constant for at least 5 minutes. The calibration software program will calculate the flow rate using Equation 9.C. This value must fall within $\pm 10\%$ of the true design flow rate using Equation 9.B. If it is greater than $\pm 7\%$, a warning will be generated. Turn the sampler off. Remove cassette. Place clear quartz filter on sampler screen. Put faceplate adapter and orifice transfer standard on top of filter. Tighten thumbscrews. Turn sampler on. Give the system a few minutes to achieve equilibrium. Record ΔH_2O (orifice) and $\Delta P_{\text{ex (SAMPLER)}}$ values. The calibration software program will calculate Q_a (sampler) using Equation 9.C and Q_a (orifice) using Equation 9.A. Calculations will be performed by the computer to determine the difference between these two values using Equation 9.E:

Equation 9.E

$$\% \text{ Difference} = \left(\frac{Q_a(\text{sampler}) - Q_a(\text{orifice})}{Q_a(\text{orifice})} \right) \times 100$$

This value should fall within $\pm 7\%$ and must fall within $\pm 10\%$. If either of these conditions fail personnel should investigate possible sources of error (especially data entry errors). Should repair(s) be necessary they should be undertaken if practicable and the calibration performed again.

9. Turn the sampler off. Remove the orifice and filter from top of sampler. Remove protective cover from sample filter cassette. Return this sampler filter cassette to top of instrument. Tighten thumbscrews. Turn sampler on and check that the manometer reading is within the operational range of the calibration. Turn sampler off. Close sampler head and secure in place with head clamps.
10. If the spreadsheet calculations at any point generate a warning or failure, the problem must be investigated, corrected, and the instrument must be recalibrated.
11. Written or verbal contact must be made with the site operator to relay information that a motor change was performed.
12. Upon returning to the office, the calibration sheet stored on the computer must be downloaded to the printer to be kept in a permanent file. The calibration data and one point flow verification must also be entered into the PMT data system. A hand written or printed hard copy must be kept in case the digital copy is lost or stolen. See CDPHE/APCD/TSP QAPP Appendix D3 for data handling.

10.4 Orifice Calibration

Orifice flow rate transfer standards are used for calibrations and performance audits of high flow filter based particulate samplers, commonly referred to in the industry as TSP (Total Suspended Particulate) monitors and PM₁₀ monitors, either volumetric or mass flow controlled. The pressure differential measured across the orifice can be related to airflow. Because these devices do not provide a direct measure of airflow, they are regularly certified against an NIST traceable airflow standard. Certification of the APCD orifice transfer standards are consistent with the procedures detailed in the EPA's Quality Assurance Handbook for Air Pollution Measurement Systems

Volume II.¹ A complete description of the current orifice calibration procedure can be found in appendix “QA2 Standards Verification and Calibration SOP”.

11.0 SAMPLER OPERATION AND MAINTENANCE

Note: Before performing any maintenance on the PM₁₀ Hi-Vol MFC sampler, check the “Hi-Vol Sampling Scheduling” for the current year, month, and day the sample is to be taken. Remember, the sample period begins at midnight (00:00 hours) of that day.

11.1 Sample Collection Procedure for Field Operators

11.1.1 Hi-Vol Supplies Needed

1. One clean (white), undamaged, pre-weighed (tared) quartz filter protected by glassine envelope. Make sure it is unblemished and unfolded. A pre-folded filter hinders accurate sample collection by weakening the web fiber structure at the crease and allowing the smallest particles to pass through. Additionally, a folded filter causes the manometer readings (air flow through the filter paper) to be inaccurate.
2. One cassette assembly.
3. One 9X12 Particulate Sampler Field Envelope (PSFE) (See [Figure EOD-4](#)).
4. A ballpoint pen, to record data taken. **A pencil should never be used**, as the lead can smear or rub off during mailing. If a mistake is made, draw a single line through it, write the correction, and then initial the change and add the date the change was made near the corrected data.
5. A bag with a shoulder strap to carry above items up to the roof while you are climbing the ladder.

11.1.2 Mounting the quartz filter on the cassette

1. In a clean indoor location, prepare the cassette for sampling. Remove the protective metal plate from atop the cassette.
2. Loosen the two thumbnuts then lift the filter gasket off the screen.
3. Verify that the filter number stamped onto the filter is the same as the filter number that is listed above the bar code on the PSFE.
4. Remove filter from glassine sleeve and place the quartz filter squarely on the screen. The quartz filter should be centered so that when the sample is taken, the sampled material will be deposited equally on the quartz filter, with an even border all around. The side of the quartz filter with the Filter Number is placed down against the supporting screen. Record the filter number on the PSFE.
5. Replace the filter gasket and fasten snugly with the thumbnuts. Do not under tighten the thumbnuts, as this allows air leakage, while over tightening will damage and shorten the life of the sponge rubber gasket.
6. Replace the protective plate onto the cassette.
7. Replace empty glassine sleeve into corresponding PSFE (verify the filter ID's).

11.1.3 Mounting the cassette on the screen

Note: If a previously sampled filter is in the sampler, follow procedures in part 10.1.6 before proceeding

1. Loosen the head bolts, be sure the bolts are completely opened and dropped before lifting the head of the sampler.
2. Remove the protective cover from the filter holder containing the clean filter about to be installed.

Note: **Never operate sampler motor with the protective cover in place** on the filter holder (cassette cover), as this will cause severe damage to the sampler motor.

3. Place the filter holder on the screen, tighten nuts then turn on the motor, then tighten all four thumbnuts securely (diagonally in a crisscross manner) so no leaks are present. Do not over-tighten. Replace head of sampler.

11.1.4 Taking the Manometer Reading “Before” (Sampling)

1. After the new filter is installed in the sampler, switch sampler “on”. There will be a short delay before the motor climbs to its operating speed.
2. Run the motor a minimum of (5) five minutes before obtaining the beginning flow rate.
3. While the motor is warming up, record the following information on the PSFE (if it is not already pre-filled).
 - Site: – Name of the sampling site (usually the city, town name or location name e.g., Telluride or Pagosa Springs Middle School).
 - Filter Number - as indicated on the quartz filter pad located in the glassine sleeve. The number printed on the filter must match the number on the PSFE located on the barcode stamp.
 - Sampler Number: – Describes the sampler type and unit number (1, 2, 3, or 4 or the letter (A or B)) and the 5 digit motor number. Example in EOD-4: PM10-4-19142. Extreme care must be taken to record the proper information corresponding to each sampler. (Note: The MOTOR NUMBER is extremely important to record on each sample with the correct associated date, as that motor number ties back to the initial calibration. This number can be found imprinted on the motor casing, and may also be found on the index card taped to the inside of the sampler door.)
 - Sample Date: – The exact date the sample is to be taken, written as month, day, and year, e.g., 8-21-06.
 - Time On: Record the number on the elapsed time meter before the sampler has started sampling. This will be recorded when the sampler is set up for the next run.
 - Technician: print your full name legibly (not like the example shown in Figure EOD-4: Particulate Sampler Field Envelope (PSFE), that PSFE only shows the operator’s initials).
 - Comments: record any unusual conditions during the sampling day, which might affect the sample, (i.e., missed sample, defective filter on retrieval, equipment or sample problem, unusual weather or pollution conditions, e.g., high winds with blowing dust, wildfire smoke, heavy snow or rain, construction and/or street sweeping that is causing dust near the monitor, etc.)
4. Enter the U-tube manometer reading on the PSFE in the box labeled “Before” under the heading “Manometer Readings”. This manometer reading is found by looking at the red manometer fluid in the u-tube at eye level with the meniscus (bottom of the curved red gauge oil fluid). Find the

number of inches away from zero on each side and add the two numbers together to determine the pressure differential (see [figure 10-1](#))

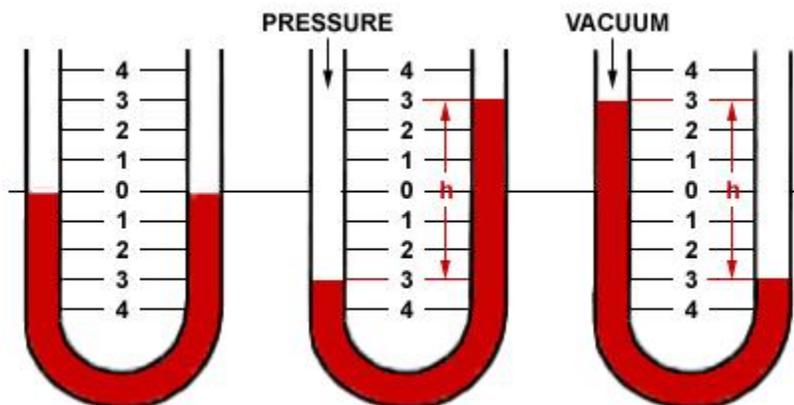


Figure 10-1

5. Note: Pressure differential (measured in inches of H₂O or red gauge oil is an indicator of airflow in PM₁₀ sampling systems. The pressure differential value is determined using a U-tube manometer filled with appropriate red gauge oil. Both sides of the U-tube are graduated with hatch marks. A measurement is taken by reading the deflection of the column of gauge oil on the right-hand side of the U-tube and reading the deflection of the column of oil on the left-hand side of the U-tube, and adding the absolute value of the two readings. For further instructions see Section 11.2.
6. Shut off the sampler motor.
7. Enter the pre-sampling elapsed time meter reading on the PSFE on the “Time On” line.

11.1.5 Setting the “Timer” (approximately 8” x 12” gray box on the outside of the sampler house with 3 attached electrical cords)

1. Set daily on/off timer to start at 00:00 hours (midnight) on the day of the sample run. Note: All PM₁₀ Hi-Vol samples in the United States start (LST – local standard time) at the same time so they can be compared.
2. The sampling period is indicated between the lugs on the timer plate. The period between the lugs is pre-set within 15 minutes of a 24-hour period, so no attempt should be made to move those lugs.
3. Set the timer plate for the period remaining before the scheduled sampling date. NOTE: Always advance timer plate as indicated by the arrows; never attempt to turn the timer plate counterclockwise.
4. Set sampler to run for 24 hours, and end at 24:00 hours (also midnight) the same day.

11.1.6 Removal of an exposed sample

1. Open the sampler door and enter the post sampling elapsed time meter reading on the blank line labeled “Time Off” on the PSFE. Subtract the “Time On” from the “Time Off” to obtain the run time and enter this total on the blank line labeled “Run Time”. Normally this will be around 1440 ± 15 minutes unless there was a power outage or sampler problem.

2. Switch motor on. Allow motor to warm up for five (5) minutes.
3. Determine the post sampling manometer value as done in section 10.4.1 step 3 (adding the right and left legs of the manometer). Enter this value on the PSFE, in the box labeled “Manometer Readings” in the “After” box.
4. Make sure all the following fields on the PSFE are completely filled out.
 - Site: – Name of the sampling site (usually the city or town name and location e.g., Telluride or Pagosa Springs Middle School).
 - Sampler Number: – Describes the sampler type and unit number (1, 2, 3, or 4 or the letter (A or B)) and the 5 digit motor number. Example in Figure EOD-4: PM10-2-7777. Extreme care must be taken to record the proper information corresponding to each sampler. (Note: The MOTOR NUMBER is extremely important to record, as that motor number ties back to the initial calibration. This number can be found imprinted on the motor casing, and may also be found on the index card taped to the inside of the sampler door, if it is still legible.)
 - Sample Date: – The exact date the sample was taken, written as month, day, and year, e.g., 8-21-06.
 - Time Off: Five digit number (in minutes) from the elapsed time meter after the sampler has finished sampling.
 - Run Time: Subtract (Time off – Time on) to get the number of minutes the sample ran, e.g., 48701 – 47261 = 1440 minutes. Enter “1440”
 - Technician: print your full name legibly (not like the example shown in Figure EOD-4, that only shows the operator’s initials).
 - Comments: record any unusual conditions during the sampling day, which might affect the sample, (i.e., missed sample, defective filter, equipment or sample problem, unusual weather or pollution conditions, e.g., high winds with blowing dust, wildfire smoke snow, rain, construction, street sweeping, etc.)
5. Turn the motor off. Loosen the retaining bolts around the head, carefully lowering them completely so they no longer obstruct the head.
6. Lift head until the weight is held by the chain assembly or remove the head if needed.
5. Remove the thumbnuts and the filter cassette.
6. Replace the protective cover onto the filter holder during transit.
7. Prepare the sampler for the next sample. (Section 10.1.3 and 10.1.4)

11.1.7 Removal of an exposed sample from the cassette

1. In a clean indoor location, remove the exposed filter from the cassette. Remove the protective cover from the filter holder.
2. Remove the thumbnuts holding the filter gasket.
3. Remove filter gasket from supporting screen.

4. Carefully fold the sample filter lengthwise by bringing opposite edges together and creasing the fold ([Figure EOD-5](#)).
5. Place the filter with the creased edge down, totally within a glassine sleeve so that no edges are exposed to damage.
6. Place the glassine sleeve with the sample filter in the Particulate Sample Field Envelope (PSFE).
7. Send the completed sample to the Air Pollution gravimetric laboratory within two weeks. The sampled filters must be stored in their glassine sleeves inside their PSFE and in a clean indoor environment for up to two weeks. Sampled filters and their PSFE's may be sent to the gravimetric laboratory in batches (up to 5 filters with PSFE's) that can easily fit inside the APCD provided Business Reply Envelopes.

Sampler, air flow, or motor problems should be reported to Colorado Department of Public Health and environment, Air Pollution Control Division immediately after detected:

Field Technician jack.mcdonnel@state.co.us

Field Technician john.olasin@state.co.us

Criteria Monitoring Sector Supervisor erick.mattson@state.co.us

11.2 Preventive Maintenance

11.2.1 Motor Maintenance

Internal maintenance measures provide for a complete motor exchange program for all particulate monitoring sites, statewide. Motor replacement is handled on a scheduled basis or as needed. The “Motor Replacement Listing” is maintained and updated as motor changes are performed throughout the network. The listing master copy is kept in the office. The listing shows the site name, sampler identification number (#1, #2, etc.), motor number, current set point, date of original calibration, and the projected date of the motor replacement.

Sampler motor replacement is performed according to the following schedule:

MOTOR CHANGE FREQUENCY			
Sampling Frequency	Sampling Days	Samplers per Site	Months
1/6	30	1	6
1/3	30	2	6
1/1	30	4	4

Motors returned from the field are reconditioned by putting them through a preventative maintenance program to insure availability and reliability for future uses in the exchange program which includes a general inspection of the wiring and motor cushion and then completed with a motor replacement.

11.2.2 PM₁₀ Motor Change Procedure

Replace the motor blower assembly with a new one as described below. Use an Ametek vacuum motor (Model No. 116311-01) or equivalent.

1. Remove the four screws from the mounting plate and remove cover.
2. Loosen cord retention screws from base of short case motor, or loosen the cord retention ring on long case motor ([Figure EOD-6](#)).

3. Slide motor blower assembly out of the motor casing.
4. Remove the two wire nuts and disconnect both wires.
5. Loosen and detach ground wire connection from the motor.
6. Discard defective motor blower and obtain a new motor.
7. Examine cushion for cracks or deterioration and replace if necessary.
8. Remount the motor cushion and motor mounting ring onto the new motor.
9. Cut motor wire leads in half to remove excess wire length.
10. Secure the ground wire from the power source to the new motor.
11. Strip off ½” of wire insulation on the two motor wires and connect to the power source leads with wire nuts.
12. Insert the motor onto the motor housing, being careful not to crimp any wires.
13. Replace the mounting cover plate and tighten with four screws.
14. Tighten power cord retention screws or retention ring to hold cord firmly in place.
15. Run motor in the motor run-in box at full line voltage for a period for 10 minutes to properly seat the brushes.
16. The motor is now ready to be part of the network motor exchange program.

11.2.3 Gasket Replacement

On an as needed basis, all airtight gaskets on Sierra PM₁₀ units are replaced. These gaskets include filter cassette gaskets, top pan gaskets and head gaskets. These gaskets are usually replaced as a matter of routine maintenance, to avoid air leaks and loss of reliable data.

11.2.4 Sierra PM₁₀ Head Cleaning Procedure

Head cleaning is conducted on a quarterly basis as per the Head Cleaning Schedule.

1. The heads of all Sierra PM₁₀ sampling units ([Figure EOD-2](#)) are cleaned to remove collected particulate matter from the sampler head.
2. The equipment required to perform head cleaning, includes:
 - Pressure water tank (optional –use paper towels and water/isopropyl alcohol and wipe surfaces clean)
 - Silicone spray oil (Molykote 316), for coating the impaction plate
 - Disposable paper towels (blue shop towels or equivalent)
 - isopropyl alcohol and water in a spray bottle
 - Replacement head gaskets as needed
 - Misc. hand tools

Head cleaning for the Sierra PM₁₀ samplers used in the network are detailed in the following procedure.

11.2.4.1 Sierra 1200 PM₁₀ Sampler

Disassembly

1. Remove the eight (8) thumb bolts located on top of the head and lift the top pan off the unit.
2. Loosen the four (4) hook-catch bolts that hold the head top and bottom parts together and lift the top of the head to allow clearance for removal of the first stage inlet jets.
3. Remove the first stage inlet from the head and clean with paper towel.

4. Remove shim plate and clean with paper towel.
5. Remove the bug screen and clean with a brush.
6. Unfasten chain clip and tilt second stage of head completely behind sampler body.

Cleaning:

1. Wash all parts and inlets with water or a mixture of water and isopropyl alcohol (add isopropyl alcohol to the water 50/50 in cold weather to prevent freezing. 100% alcohol can also be used in winter) and paper shop towels to remove collected particulate matter.
2. Clean all nozzles with a bottlebrush.
3. Check the bug screen and remove any debris or particulate matter that has collected there. Use a soft brush to clean the screen.
4. Clean the oiled material from impaction plate using paper towels or a soap and water solution.
5. Dry all parts.

Reassembly

1. Coat the shim with silicone spray (Molykote 316) and allow to completely dry.
2. Inspect the gasket that seals the head to the body top pan and replace it if worn, damaged, or significantly compressed.
3. Reposition second stage inlet of the head upright on the sampler body and attach the hook-catch bolts.
4. Attach the chain clip to the eyebolt on the sampler head.
5. Replace the bug screen.
6. Install the shim on the second stage inlet and secure with the spring bolts.
7. Replace the second stage inlet into the sampling head...
8. Inspect the gasket between the first and second stages and replace it if worn, damaged, or significantly compressed.
9. Replace the first stage inlet and secure in place with hinge bolts and the support arm.
Note: Make sure the alignment hole of the first stage is in position with the post on the second stage.
10. Lift the first stage inlet to release support arm and close the head, making sure the alignment hold on the first stage is in position with the post on the second stage.
11. If needed, adjust the tension of the hook-catch bolts so that the head is held firmly together and fasten in place.
12. Replace the head top pan and fasten in place with the eight (8) thumb bolts.

Enter head cleaning information (date, operator initials and comment) onto the Site Evaluation Addendum form located in the front of all site files.

11.2.5 Timer Maintenance and Certification

The timer is certified every year (May/June time frame) to ensure accuracy of ± 15 minutes in a 24-hour period. If at any time the timer is found to operate outside this range, or not operating at all, the defective timer is replaced with an operational unit. Timers running outside this range will be shop tested, adjusted and recalibrated, or replaced.

11.2.6 Manometer Maintenance

Operators should periodically verify the level of oil in the manometer is sufficient to cover the entire range of static pressure generated when the sampler is running. For the manometer to register static pressure correctly the oil must be in good condition and debris free. If the operator observes the manometer oil to changed color (shade) or to contain any debris the oil should be changed.

11.3 Site File Maintenance

11.3.1 Site Evaluation Addendum

It is the responsibility of the individual who travels to any mass flow controlled PM₁₀ monitoring site to enter all detailed information onto the Site File Addendum form ([Figure EOD-7](#)). The Site Evaluation Addendum form is located in the front of each site file. The date, maintenance and/or other information should be filled out in ink on one line of the form. As a matter of permanent record, the following information is entered onto the form, whenever a site visit is made or sampler maintenance is performed:

1. A monitoring site is installed or removed.
2. A monitor is installed or removed.
3. A monitor is moved to a new location at the same site.
6. An operator is trained or replaced.
7. When the flow controller is adjusted or replaced, or in any way altered. Include sampler identification number (i.e., 1, 2, 3, 4) if applicable, motor number, flow rate before adjustment and flow rate after adjustment.
8. When flow rates are checked during a routine stop at a sampling site:
 - Prior to traveling to any PM₁₀ site, look up and record the current motor number and flow rates for the sampler(s) at that site.
 - At the site, turn on the sampler and record the flow as described in the operator instructions.
 - Upon return from the field, enter date, sampler identification number, motor number and flows onto the form.
9. Make a note of all significant operator problems that may affect data quality found during a site visit. These include incorrect sampling procedures, or incorrectly set timer, as noted by incorrect time/day on the timer faceplate. E-mail a detailed report to the Particulate Matter Monitoring Supervisor and the PM₁₀ Field Leader.
10. Any other pertinent site information, which is not available through another permanent record.

11.3.2 Network Modification Request Form

1. Whenever a network site modification is proposed, a “Network Modification Request Form” ([Figure EOD-7](#)) must be submitted through U.S. EPA Region VIII, and approved in writing, prior to any network changes being made. Also, the site modification form must be e-mailed to the Particulate Matter Monitoring Supervisor. These changes include:

- New monitoring sites proposed.
- Removal of an existing monitoring site.
- Frequency changes at a monitoring site.

2. A copy of Sections 1 and 2 sent to EPA Region VIII are permanently kept in the site file.

12.0 SAMPLE HANDLING AND PRESERVATION

Please refer to the Gravimetric Laboratory SOP located as an appendix LSD1 of APCD's QAPP.

13.0 SAMPLING PREPARATION AND ANALYSIS

Please refer to the Gravimetric Laboratory SOP located as an appendix LSD1 of APCD's QAPP.

14.0 TROUBLESHOOTING

Cone

When air leakage is detected in the sampler, it is possible that the cone is not seated properly to the motor, or that the rubber gasket is missing between the motor and cone. If the leakage is due to a cracked or broken cone, replace the cone with an operational unit.

Elapsed Time Meter (ETM)

The elapsed time meter on each sampler is certified every year (usually in the May/June time frame) to ensure accuracy of ± 15 minutes in a 24-hour period. If at any time the ETM is found to operate outside this range, or not operate at all, the defective unit is replaced with an operational ETM.

Electrical Cords/Power Outlets

Power cords used for rooftop samplers are routinely exposed to vast temperature fluctuations, and must be rated for exterior usage. Cords are periodically inspected for wear and cracking which could lead to failure of the cord. Replace defective cords as soon as detected.

Power outlets are ground fault protected in order to eliminate the risk of electrical shock. A licensed electrician shall repair or replace defective GFI outlets.

Flow Controller

A sampler that exceeds the flow range specified by the motor calibration must be adjusted within its flow range. Adjust the flow controller using the flow adjustment pot inside the case. At any time when the flow controller fails to maintain the desired set point, the flow controller is removed and replaced with an operational unit.

Gaskets (cassette/inlet)

Gasket material which seals the filter cassette or the sampler inlet to ensure airflow only through the filter (normal intake route) must be inspected and maintained in good working order. Poorly maintained gaskets can void the sampled filters and negate the monitoring effort.

Gaskets (motor)

Gasket material which seals the motor or motor housing to the sampler intake must be pliable and in place to ensure proper flow through the sampler.

Manometer

All oil filled manometers must be clear of obstructions and provide accurate readings of the indicated flow. Manometers that are obstructed by foreign matter, are not readable, or are not in working condition are replaced with an operational manometer.

Metal Sheeting/Hinges

Sample metal sheeting or hinges that may be defective require the replacement of the shelter unit or minor repairs will be undertaken on a case-by-case basis.

Motor

A sampler motor showing signs of excessive arching or an electrical short is removed and replaced with an operational motor as soon as possible upon notification.

Timer

The timer is certified every year (or more frequently if needed) to ensure accuracy of ± 15 minutes in a 24-hour period. If at any time the timer is found to operate outside this range, or not operating at all, the defective timer is replaced with an operational unit. Timers running outside this range will be shop tested, adjusted and recalibrated, or discarded.

15.0 DATA ACQUISITION, CALCULATIONS, AND DATA REDUCTION**15.1 Data Acquisition and Analysis**

See sections 9.3 and 17.1.2.1

15.2 Symbols and Calculations**15.2.1 Symbols**

A	Factor from orifice transfer standard calibration
B	Exponent from orifice transfer standard calibration
b	Intercept of linear regression calibration relationship
b'	Intercept of linear regression for provisional calibration for audit of MFC sampler
ΔH_2O	Pressure drop across a transfer standard orifice, mm (or in.) of water column
ΔP_{ex} (meter)	Differential pressure at inlet to standard volume meter, mm H ₂ O
m	Slope of linear regression calibration relationship
m'	Slope of linear regression for provisional calibration for audit of MFC sampler
P _a	Current ambient barometric pressure, mm Hg
P _{av}	Average ambient barometric pressure for the sample period, mm Hg
ΔP_{ex}	Pressure in exit orifice plenum of sampler, measured with respect to atmospheric pressure in water column
ΔP_{ex} (avg)	Average of initial and final ΔP_{ex} readings in H ₂ O
ΔP_{ext}	Transformed exit orifice plenum pressure, for calibration relationship in water column
PM ₁₀	PM ₁₀ mass concentration, $\mu\text{g}/\text{m}^3$
PM ₁₀ (std)	PM ₁₀ mass concentration, $\mu\text{g}/\text{std m}^3$
Q _a	Sampler flow rate measured in actual volumetric units, m ³ /min
Q _a (avg)	Average sampler flow rate for the sample period measured in actual volumetric units, m ³ /min
Q _a (audit)	Sampler flow rate in actual volumetric units determined by a flow rate audit, m ³ /min
Q _a (orifice)	Flow rate measured by an orifice transfer standard in actual volumetric units, m ³ /min
Q _a (sampler)	Flow rate in actual volumetric units indicated by sampler's calibration relationship during flow-rate audit or QCX flow check, m ³ /min
SFR	Set-point flow rate in actual volumetric units for MFC sampler, m ³ /min
SSP	Sampler set-point manometer reading for MFC sampler needed to obtain SFR in H ₂ O
t	Total elapsed sampling time, min

T _a	Current ambient temperature, K (K= °C + 273)
T _{av}	Average ambient temperature during the sample period, K
ΔTime	Elapsed time during which a flow rate is measured by a standard volume meter, min
V _a	Actual air volume measured by standard volume meter at ambient temperature and barometric pressure, m ³
ΔVol	Uncorrected air volume measured by standard volume meter, m ³
W _g , W _t	Gross and tare weights of the HI-VOL PM ₁₀ filter, respectively, g

15.2.2 Calculations

Calculation	Formula
Uncorrected air volume measured by standard volume meter	$\Delta Vol = Final\ Volume - Initial\ Volume$
Correction of air volume measured by standard volume meter to ambient barometric pressure	$V_a = \Delta Vol \times \left(\frac{(P_a - \Delta P_{ex})}{P} \right)$
Actual volumetric flow rate measured by standard volume meter	$Q_a = \frac{V_a}{\Delta Time}$
Actual volumetric flow rate measured by orifice transfer standard	$Q_a (orifice) = A(\Delta H_2O)^B \times \sqrt{\left(\frac{760}{P_a} \right) \times \left(\frac{T_a}{298.15} \right)}$
Transformed exit orifice pressure for MFC sampler calibration relationship	$\Delta P_{ext} = \sqrt{\left(\Delta P_{ex} (sampler) \times \left(\frac{(T_a + 30)}{P_a} \right) \right)}$
Regression model (y=mx+b) for calibration of MFC sampler	$\Delta P_{ex} = (m \times Q_a (orifice)) + b$
Calibration relationship for MFC sampler	$Q_a (avg) = \left(\sqrt{\frac{\Delta P_{ext (avg)} \times (T_{av} + 30)}{P_{av}}} - b \right) \times \left(\frac{1}{m} \right)$
Set-point manometer reading for MFC sampler	$SSP = \left(\frac{P_{av}}{(T_{av} + 30)} \right) \times ((m \times 1.13) + b)^2$
Conversion of manometer reading in inches of H ₂ O to mm Hg	$mmHg = \frac{25.4\ inH_2O}{13.6}$
Audit or QC flow check of sampler calibration	$\% Difference = \left(\frac{Q_a (sampler) - Q_a (orifice)}{Q_a (orifice)} \right) \times 100$
Audit or QC flow check of sampler operational flow rate	$\% Difference = \left(\frac{Q_a (sampler) - 1.13}{1.13} \right) \times 100$
Correct sampler flow rate under normal operating conditions during audits and QC flow checks	$Q_a (corrected\ sampler) = Q_a (sampler) \times \left(\frac{100 - \% difference}{100} \right)$
Audit or QC flow check of sampler design flow rate	$\% Diff (Design\ Flow) = \left(\frac{Q_a (corrected\ sampler) - 1.13}{1.13} \right) \times 100$
Total air volume sampled	$V_a = Q_a (avg) \times \Delta Time$

$$PM_{10} \text{ mass concentration} \quad PM_{10} = (10^6) \times (W_{gross} - W_{tare}) \times W_{std}$$

$$\text{Regression model (y=mx+b) for calibration of MFC sampler} \quad \frac{P_1}{P_a} = \left(\frac{(m \times Q_a \text{ (orifice)})}{\sqrt{T_a}} \right) + b$$

$$\text{Calibration relationship for MFC sampler} \quad Q_a \text{ (sample)} = \left(\left(\left(\frac{P_1}{P_{av}} \right) - b \right) \times \sqrt{T_{av}} \right) \times \left(\frac{1}{m} \right)$$

15.3 Data Reduction

Please refer to the Particulate Data Handling section of this QAPP or Appendix D3.

16.0 COMPUTER HARDWARE AND SOFTWARE REQUIREMENTS

Please refer to the Particulate Data Handling section of this QAPP or Appendix D3.

17.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

Please refer to the Particulate Data Handling section of this QAPP or Appendix D3.

18.0 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance (QA) and quality control (QC) are two terms commonly discussed, but often confused. Quality assurance refers to the overall process of ensuring that the data collected meet previously stated measurement quality objectives (MQOs). Quality control covers specific procedures established for obtaining and maintaining data collection within those limits. For information regarding QA/QC methods used in the PM₁₀/TSP network refer to Tables 1 – 9. (From Quality Assurance Handbook, Vol. II, Part II, Modified 2103) For the most up to date version of high volume sampler auditing procedures see Appendix QA1.

18.1 Quality Assurance

There are six commonly used data quality indicators for pollutants. The data quality indicators are discussed in the following sections.

18.1.1 Precision

The APCD is required by EPA to conduct a precision assessment program for the PM₁₀ monitoring network. The precision testing program is based on comparisons of a primary sampler to a concurrently operated collocated sampler. The primary sampler represents the "actual value" and a collocated sampler represents the "indicated value". A sampler identical to the primary sampler is used as the collocation sampler and is operated on an every sixth day sampling schedule, and the resulting measurements are used as precision checks. Calibration, sampling and analysis procedures must be identical for both the primary and collocated samplers and the same as for all other samplers in the network.

Annually, the APCD evaluates the previous year's precision data and publishes the precision results in the Annual Data Quality Assessment (DQA) section of the Annual Data Report. The DQA documents all precision and accuracy results for all monitoring networks managed by the APCD. For additional information on how the precision data is processed please refer to APCD's "Precision and Accuracy Data Handling SOP" appended as an appendix D4 in APCD's QAPP and also the data assessment section of the QAPP.

18.1.2 Accuracy

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between the measured value and the true, standard value during audits.

Persons independent of the particulate program conduct field audits quarterly on all High Volume PM₁₀ samplers. The APCD Quality Assurance staff typically performs the field audits. The field audit is performed by measuring flow, temperature, pressure and time of the sampler with standards that are independent of those used in the calibration of the sampler. Audit standards must be certified against a NIST traceable standard and be of the same or of high quality than of those being certified. The frequency of these audits is given in [Table EOD-8](#) of this document.

To ensure a quality audit, it is important that the audit is performed during a period of good weather and stable conditions. If the weather and/or conditions are not suitable, the audit should be rescheduled.

The APCD utilizes an Access database to enter and process audit results. A printout of the data entry form is used as a datasheet in which raw data is hand entered (see [Figure EOD-8](#)). Data from the datasheet is then entered into the Access database via the use of a data input form. The hand written datasheets are archived in case the electronic copy is lost or damaged. The Access database is typically located on the auditor's standalone laptop version of the program. The QA Audits Database is used to store audits for several particulate monitoring networks. The main screen will be displayed once the database is opened. Select the button that pertains to the audit being performed. There is only one version of the Access data input form of each audit type, however it can be configured to input new audit records or to view old archive records. Upon opening the appropriate form, the data entry form is displayed and a new audit record can be entered into the form. Data from the form can be saved to an archive table as an audit record by pressing the <Save to Archive> button. To view archive records navigate to the archive version of the database located on APCD's LAN. All archived audits are stored here and can be pulled up on request.

See Appendix QA1 of this QAPP for specific details on how to conduct accuracy audits.

18.1.3 Bias

Bias is defined as a systematic error in measurement wherein the measured value displays a consistent positive or negative error as compared to a true value. Bias measurements are calculated either as a percent difference or as a mean arithmetic difference. The signed arithmetic difference is used for assessment where values are too small or too close to the limit of detection to calculate a meaningful percent difference. Bias is assessed quarterly but reported annually in APCD Annual Quality Assessment. The calculations used to determine bias is given in Section D3.3 of APCD's QAPP.

18.1.4 Representativeness

Representativeness refers to whether the data collected accurately reflect the conditions being measured. It is the data quality indicator most difficult to quantify. Unless the samples are truly representative, the other indicators are meaningless. Representativeness is assured, as best as possible, by precise definitions of monitor siting criteria.

18.1.5 Completeness

Completeness is defined as the amount of data collected compared to a pre-specified target amount. Ideally, 100% of the target amount of data would always be collected; in practice, that value is less for many reasons, ranging from calibration time and site relocation to power outages and equipment failure. For PM₁₀ and TSP, EPA requires a minimum completeness of 75% (40 CFR, 50, App. H.3). APCD believes 90% completeness is an achievable goal.

18.1.6 Comparability

Comparability is defined as the process of collecting data under conditions that are consistent with those used for other data sets of the same pollutant. The goal is to ensure that instruments purchased and operated by states and local agencies produce comparable data. All PM₁₀ and TSP samplers utilized by the

APCD for compliance monitoring have been pre-designated as Federal Reference Method (FRM) samplers by EPA. Samplers that achieve the FRM designation have been thoroughly evaluated against other PM₁₀ and TSP samplers and have met EPA's criteria for comparability. Additionally, for sites that have collocated automated PM₁₀ analyzers, the APCD will compare data from manual FRM samplers with data from automated analyzers.

18.2 Quality Control

As stated earlier, quality control (QC) refers to procedures established for collecting data within pre-specified tolerance limits. Quality control procedures include any maintenance that benefits the PM₁₀/TSP operations and verification performed by the PM₁₀/TSP program staff that ensure all equipment are operating under pre-specified tolerances.

18.2.1 Documentation

Documentation is important for all measurements. Extensive certification paperwork must be rigorously maintained for each standard and analyzer. All calibration, audit and certification data are stored electronically in addition to hardcopies.

APCD takes special care to prepare and preserve backup copies of all data, including calibration data. All data and supporting documentation should be held for a minimum of five years.

18.2.2 System of Quality Control

Currently all quality control procedures are performed by staff members from the PM₁₀/TSP monitoring group. All QC maintenance and verification procedures are covered under Section 10.3 of this document. The frequencies at which these procedures are performed are also contained in Section 10.3.

Absent from APCD's verification procedures are routine flow verifications performed by individual site operators. This is primarily due to the extensive size of sampling network and the lack of funds to procure verification equipment for all operators. To account for these quality control deficiencies, the APCD has increased its quality assurance oversight of the program by increasing the required number of performance audits performed by the APCD. The goal for auditing each sampler in this network is once per quarter.

REFERENCES

1. U.S. Environmental Protection Agency, 1990. “Quality Assurance Guidance Document 2.11 “Monitoring PM₁₀ in Ambient Air using a High-Volume sampler method.”
2. 40 Code of Federal Regulations (CFR), Pt. 50 Appendix B: Reference method for the determination of particulate matter as PM₁₀ in the atmosphere”.
3. U.S. Environmental Protection Agency. *Code of Federal Regulation*. Title 40, Chapter I, Subchapter C, Part 53, Subpart D. Washington, D.C. Office of the Federal Register
4. Guidance for the Preparation of Operating Procedures for Quality Related Operations. 2001. EPA QA/G6. U.S. Environmental Protection Agency, Washington, DC 20460. March, 2001.
5. Quality Assurance Handbook for Air Pollution Measurement Systems. 2017. Volume II Part 2.0 Ambient Air Quality Monitoring Program.
6. U.S. Environmental Protection Agency, 2004a. “Air Quality Criteria for Particulate Matter: Volume I of II.” October, 2004.
7. U.S. Environmental Protection Agency, 2004b. “Air Quality Criteria for Particulate Matter: Volume II of II.” October, 2004.

Table EOD-1: Acceptance Test and Limits of Equipment and Supplies

Equipment	Acceptance check	Acceptance limits	Action if requirements are not met
Field operations			
Sampler	Sampler complete, no Evidence of damage. Model designated as reference or equivalent method	Specifications outlined in 40 CFR Part 50, Appendix. J	Reject sampler
Calibration quality assurance/quality control (QA/QC) supplies	Check against <i>National Institute of Standards and Technology (NIST)</i> – traceable standards	Within accuracy limits presented in text	Adjust or reject
Laboratory operations			
Filter	Meets requirements. Filter undamaged and suitable for sampling	Specifications outlined in 40 CFR, Part 50, Appendix. J Compatible with individual samplers	Reject filter
Filter handling materials	No evidence of damage	Allows for minimum filter damage and loss of particles	Reject materials or improve method for transporting filters
Lab equipment and instrumentation	Check against <i>American Society for Testing and Materials (ASTM)</i> or <i>NIST</i> traceable standards	Within accuracy limits presented in text	Adjust or reject

Table EOD-2: Minimum HI-VOL PM₁₀ Sampler Siting Criteria

Scale	Height above Ground (m)	Distance from Supporting Structure (m)		Other spacing criteria
		Vertical	Horizontal ^a	
Micro	2 to 7		>2	1. must be >10m from the dripline of trees, when the tree(s) act as an obstruction.
Middle, neighborhood, urban, and regional scale	2.15		>2	2. Distance from sampler to obstacle, such as buildings, must be twice the height that the obstacle protrudes above the sampler, except for street canyon sites. 3. Must have unrestricted airflow of at least 270° around the sampler inlet except for street canyon sites. 4. No furnace or incineration flues should be nearby. ^b 5. Spacing from roads varies with traffic (see 40 CFR Part 58, Appendix E). 6. Sampler inlet is at least 2 m but not >4 m from any collocated PM ₁₀ sampler (see 40 CFR Part 58, Appendix A).

^a When inlet is located on rooftop, this separation distance is in reference to walls, parapets, or penthouses located on the roof.

^b Distance depends on the height of furnace or incineration flues, type of fuel or waste burned, and quality of fuel (sulfur, ash, or lead content). This is to avoid undue influences from minor pollutant sources.

Table EOD-3: Equipment Calibration Requirement

Equipment	Acceptance limits	Frequency and method of measurement	Action if requirements are not met
Sampler	Indicated flow rate = true flow rate ± 0.04 m ³ /min.	Calibrate with certified transfer standards upon receipt, after maintenance on sampler, and any time audits or flow checks deviate more than $\pm 7\%$ from the indicated flow rate or $\pm 10\%$ from the design flow rate.	Recalibrate.
Analytical balance	Indicated weight = true weight ± 0.0005 g.	Gravimetrically test weight at purchase and during periodic calibration checks; use three to five standard weights covering normal range of filter weights.	Have balance replaced and/or recalibrated.
Mass reference standards	Individual tolerance no greater than 25 μ g.	Working standards checked every 3 to 6 months against laboratory primary standards.	Obtain proper standards.
Relative humidity (RH) indicator ^a	Indicator reading – psychrometer reading $\pm 6\%$ RH.	Compare with readings of wet/dry bulb psychrometer on receipt and at 6-month intervals.	Adjust or replace to attain acceptance limits.
On/off timer	± 15 min/24 h.	Check at purchase and routinely on sample recovery days and annually.	Adjust or repair.
Elapsed-time meter	± 15 min/24 h.	Compare with a standard time/place of known accuracy at receipt annually.	Adjust or replace time indicator to attain acceptance limits.
Flow rate transfer standard (orifice device)	Indicated flow rate (from previous calibration) = true flow rate $\pm 2\%$.	Check at receipt and at 1-year intervals against positive-displacement standard volume meter; recalibrate or replace orifice unit if damage is evident.	Adopt new calibration curve.
Thermometer	± 2 °C – traceable to NIST or ASTM, Range: -10 to 50° C.	Upon receipt and annually.	Recalibrate or replace.
Portable aneroid Barometer	± 0.2 in Hg check – traceable to NIST or ASTM, Range: 18 to 28 in Hg.	Upon receipt and annually.	Recalibrate or replace.

^aThe RH indicator is required for filter equilibration before weighing.

Table EOD-4: Routine Maintenance Activities

Equipment	Frequency and/or method	Acceptance limits	Action if requirements are not met
Sampler inlet	Dismantle and clean at manufacturer-specified intervals.	No obvious particulate deposits or damage.	Clean, replace damaged equipment before sampling.
Sampler base			
Power Lines	Check for crimps or cracks.	No obvious damage.	Replace as necessary.
Filter screen and throat	Visually check on sample-recovery days.	No obvious deposits; clean with wire brush.	Clean.
Gaskets	At 3-mo intervals, inspect all gaskets in the sampler.	No leaks; no compression; damage evident.	Replace as necessary.
Brushes	Replace after 600 to 1,000 h of operation.	Stable flow rate.	Replace as necessary.
Motor	Replace if needed.	Correct model must be used.	Obtain correct model.
Flow controller	Check when flow rate changes are evident.	Stable flow rate throughout sample run.	Replace or repair if possible.
Tubing, fittings	Visually inspect on sample-recovery days.	No crimps, cracks, or obstructions; no cross-threading.	Replace as necessary.

Table EOD-5: Sampling Procedures Checks

Procedure	Frequency and method	Requirements	Action if requirements are not met
Filter installation	Visually check each filter. Inspect gaskets after each sample.	Filters must be undamaged and provided with ID numbers; cassette must be centered on sampler; filter must be centered on cassette screen with edges parallel to edges of screen and to faceplate gasket; gasket must be tightened to prevent leakage.	Void the filter; install substitute filter.
Sample validation and documentation	Visually check each sample and the sample data sheet for completeness.	Record on data sheet must show the sampling date, filter ID, station location, flow rate, sample time, and any unusual conditions.	Complete or correct the documentation; if unavailable, void the sample.
Post-sample inspection	Visually check each sample for missing pieces or leakage.	There must be no evidence of filter damage or sampler malfunction.	Void the sample; correct the cause of malfunction.

Table EOD-6: Summary of Filter Acceptance Criteria

Criteria	40 CRF 50, Part Appendix M	Explanation
Collection efficiency	>99 percent as measured by the dioctyl phthalate (DOP) test with 0.3- μm particles at the sampler's operating face velocity.	The apparatus needed to perform this test is not available for a typical analytical laboratory. The operating agency must ensure that the filter manufacturer has complied with this guideline (see ASTM 1993).
Integrity	5 $\mu\text{g}/\text{m}^3$, measured as the concentration equivalent corresponding to the difference between the initial and final weights of the filter, assuming a 24-h sample volume of 1,600 m^3 .	During a simulated sampling test, all sampling procedures are followed except the HI-VOL PM ₁₀ sampler is not turned on. The tare weight of the equilibrated filter must agree with ± 8 mg of final weight. Refer to Section 3.0, "Field Operations," for recommended HI-VOL PM ₁₀ sampling procedures.
Alkalinity	<25 microequivalents/g of filter	A typical analytical laboratory is capable of conducting this test measurement of alkalinity.

Table EOD-7: Filter Preparation and Analysis Checks

Activity	Method and frequency	Requirements	Action if requirements are not met.
Handling	Observe handling procedure.	Place filters in protective envelopes or boxes and number sequentially.	Improve technique.
Visual check	Visually inspect each filter.	Make sure there are no pinholes, tears, etc.	Discard filter.
Identification	Visually check each filter number assigned.	Make sure the filter ID number is legible and recorded on the laboratory data/coding form and the filter.	Make proper identification.
Equilibration (tare and gross desiccation)	Observe and record the equilibration room or chamber conditions. Observe the minimum equilibration period for each sample.	Equilibrate in controlled environment for ≥ 24 h; RH between 20 and 45 percent, with $< \pm 5$ variation; and temperature between 15 and 30 °C, with $< \pm 3$ °C variation.	Repeat equilibration.
Tare weighing procedure	Observe the weighing procedure; perform all internal QC procedures.	Determine filter weight to nearest 0.1 mg.	Reweigh after equilibration.
Post-sampling inspection, documentation, and verification	Visually check all samples and documentation.	Make sure there are no pinholes, tears, etc.; complete documentation; make sure there is no evidence of malfunction or sample loss.	Void the affected samples; report to supervisor.
Gross weighing procedure	Observe the filter weighing procedure; perform all internal QC procedures.	Obtain weight to nearest 0.1 mg.	Reweigh after equilibration

Table EOD-8: Auditing Requirements (Accuracy)

Procedure	Frequency and/or methods	Acceptance limits	Action if requirements are not met
Flow rate audit	Once each quarter for PSD monitoring. MINIMUM of 75% of entire network quarterly for SLAMS. With each sampler getting minimum of 3 audits per year.	<ol style="list-style-type: none"> 1. Percentage difference between the sampler-indicated flow rates and the audit-measured flow rate is within $\pm 7\%$. 2. $\pm 10\%$ of inlet design flow rate. 	<p>Evaluate and repair, if necessary. Recalibrate before resuming sampling. Invalidate data back to last valid calibration or audit if difference is $>\pm 10\%$.</p> <p>Replace motor. Recalibrate. Invalidate data back to most recent valid flow check.</p>
System audit	At beginning of a new monitoring system and periodically as appropriate, observe procedures and use checklist.	Method described in Reference # and QAPP.	Initiate improved methods and/or training program.
Filter weighing	Perform 7 audits/100 filters, or 4 audits/ ≤ 50 filters; use analytical balance; condition filters for at least 24 h before weighing.	Audit weight = original weight ± 5 mg for exposed filters and ± 2.8 mg for unexposed filters.	Reweigh all filters in the lot.
Balance	Observe weighing technique; review balance maintenance and calibration log.	Balance is maintained and calibrated at least annually.	Reweigh all filters, calibrate balance.

Table EOD-9: Collocated Sampler Requirements (Precision)

Criteria	Acceptance Limits	Action if Requirements are not met
Location of samplers	2-4 meters between inlets.	Move samplers
# In network	3 or more sites for networks with > 20 monitoring sites.	
Data used	Values > 15 µg/m ³ .	
Precision requirement	± 5 µg/m ³ for values < 80 µg/m ³ ± 7% for values ≥ 80 µg/m ³ .	
Frequency of collocated sampling	Minimum of every 6 days spaced regularly.	
Sampler operation	1° and 2° must be run concurrently. Must be operated, calibrated, and have samples analyzed same as each other and rest of network.	

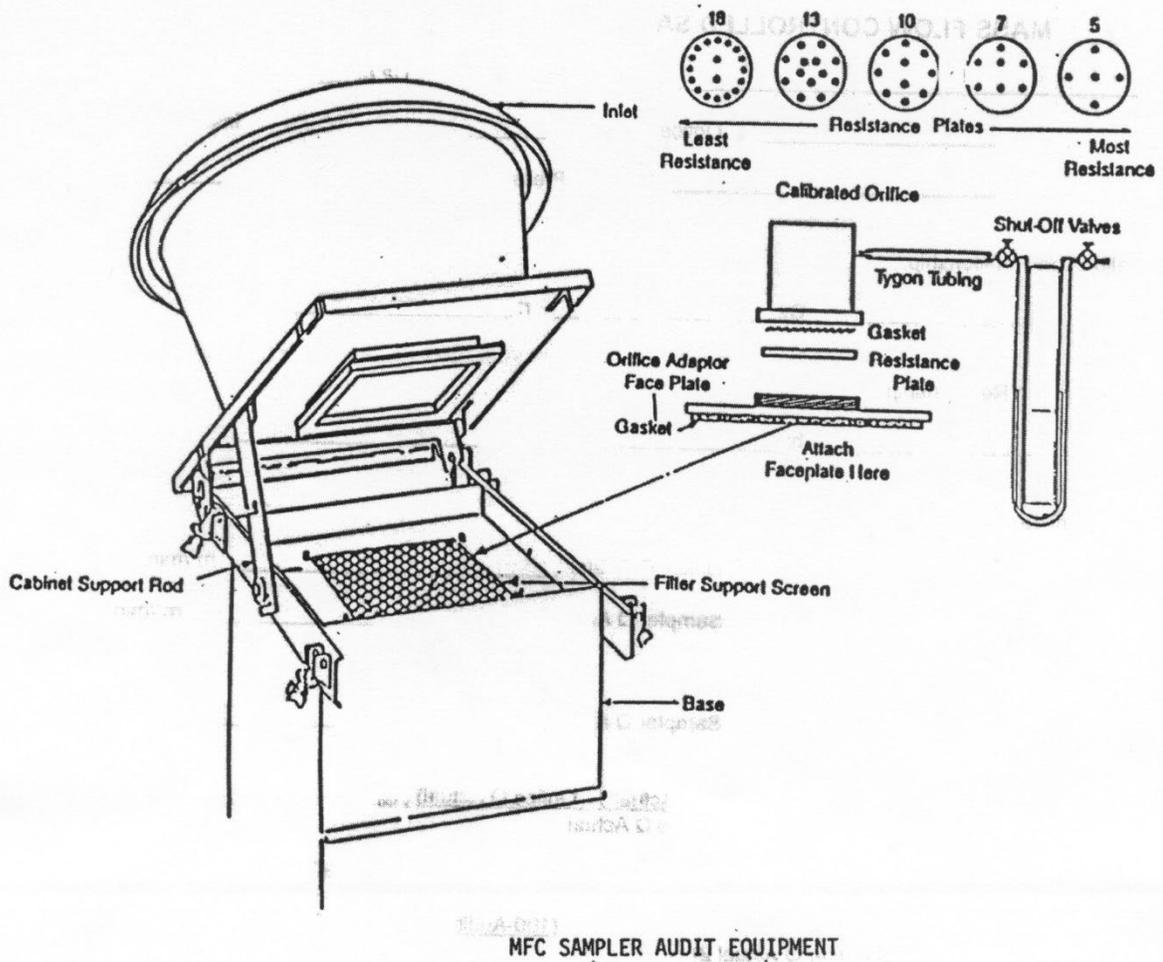


Figure EOD-1: Audit/Calibration Setup

MASS FLOW CONTROLLED INLET

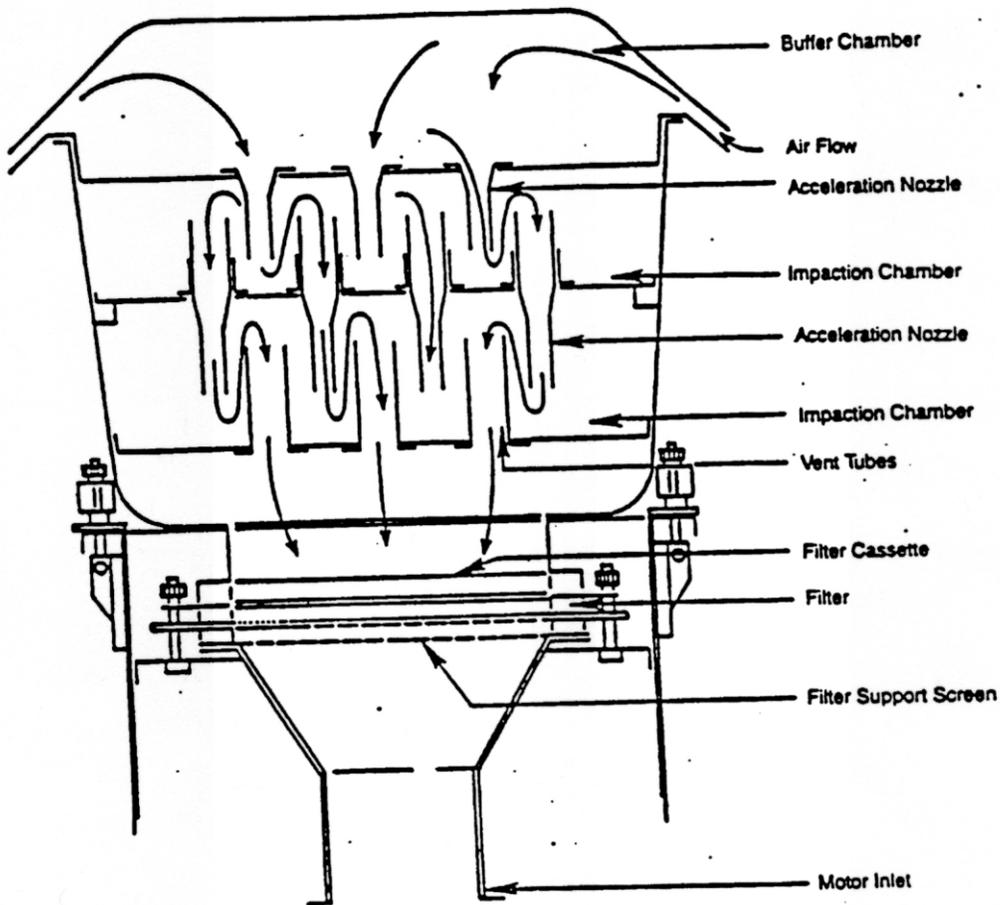


Figure EOD-2: Sampler Inlet

Figure EOD-3: High Volume MFC Sampler Calibration Data Sheet



COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Air Pollution Control Division - Technical Services Program

High Volume TSP Sampler Calibration Data Sheet



Site Info.	Site Name: <input type="text"/>	Date (mm/dd/yy): <input type="text"/>
	AQS ID: <input type="text"/>	Time (h:mm): <input type="text"/>
	Instrument No.: <input type="text"/>	Action Description: <input type="text" value="Calibration"/>
	Sampler Type: <input type="text"/>	Calibrators Initials: <input type="text" value="SAW"/>
	Motor No.: <input type="text"/>	Conditions: <input type="text" value="Acceptable"/>
Notes: <input type="text" value="None"/>	Filter Type: <input type="text" value="Quartz"/>	

Orifice Info.	Orifice ID: <input type="text"/>	Orifice Make: <input type="text"/>
	Orifice Cal. Date: <input type="text"/>	Orifice Model: <input type="text"/>
	Orifice SN: <input type="text"/>	Orifice "A" Factor: <input type="text"/>
		Orifice "B" Exponent: <input type="text"/>

Temperature and Pressure Info.	
Ta (deg F):	<input type="text"/>
Opt. Plenum Temp (deg F):	<input type="text" value="0"/>
Pa (inHg):	<input type="text"/>
Annual Avg. Pa (mmHg):	<input type="text"/>
Seasonal Temperature Averages	Seasonal Avg. <input type="text"/>

Test Point ID and Target Delta H (in H2O)	Delta H2O Orifice (in H2O)	Qa Orifice (X) (m3/min)	Delta Pex Samp (in H2O)	Delta Pex Trans (Y) in H2O ² K/mmHg	% Difference from Orifice Qa	Cal Corrected (m3/min)	Pass/ Fail
#Error		#Error		#Error	#Error	#Error	#Error
#Error		#Error		#Error	#Error	#Error	#Error
#Error		#Error		#Error	#Error	#Error	#Error
#Error		#Error		#Error	#Error	#Error	#Error
#Error		#Error		#Error	#Error	#Error	#Error
#Error		#Error		#Error	#Error	#Error	#Error

[Go To Archive](#)

[Capture Data](#)

SAMPLER SET POINT (SSP)	
	(inH2O)
Upper Limit:	#Error
Set Point	#Error
Lower Limit	#Error

LINEAR REGRESSION RESULTS	
Y=mX+b	
= m	#Error
= b	#Error
= r (>=0.990)	#Error

TSP SET POINT CHECK W/FILTER IN PLACE & DESIGN FLOW CHECK				
Delta H2O Orifice (in H2O)	Qa Sampler (m3/min)	Qa Corrected (m3/min)	Design Flow Rate % Difference	Check on Qa Design (+/- 10%)
	#Error	#Error	#Error	#Error

VERIFICATION OF TSP SET POINT W/ORIFICE FULLY OPEN & FILTER IN PLACE (>7%=Fail, >5% Warning)					
Delta H2O Orifice (in H2O)	Qa Orifice (m3/min)	Delta Pex Samp (in H2O)	Qa Sampler (m3/min)	% Difference [100*(Samp-Orf)/Orf]	Check on % Difference
	#Error	#Error	#Error	#Error	#Error

Notes:

"A" Factor - Resultant factor from the linear regression of $\ln(Qa[(Pa/Pstd) \times (Tstd/Ta)]^{exp1/2})$ vs $\ln(\text{delta H orifice})$

"B" Exponent - Resultant exponent from the linear regression of $\ln(Qa[(Pa/Pstd) \times (Tstd/Ta)]^{exp1/2})$ vs $\ln(\text{delta H orifice})$.

Ts - Average seasonal temperature at the current site in Kelvin (K).

Ps - Average annual barometric pressure at the current site in millimeters of mercury (mmHg).

Ta - Ambient temperature during calibration in Kelvin (K).

Pa - Ambient barometric pressure during calibration in millimeters of mercury (mmHg).

Plenum T - An "optional" measurement of the exit orifice plenum (default being 30K in Kelvin (K)).

delta H - Pressure drop across the certified calibration orifice in inches of water (in H2O)

Qa Orifice - Calculated actual-condition flow rate from certified orifice in cubic meters per minute (M3/min), according to:
 $Qa = Ax(\text{delta H})^{exp B} \times [(Pstd/Pa) \times (Ta/Tstd)]^{exp1/2}$

delta Pex - Sampler manometer reading of exit orifice plenum in inches of water (in H2O).

delta Pex T - Transformed sampler manometer reading to account for plenum exit temperature using the following equation:
 $\text{delta Pex T} = [\text{delta Pex} \times (Ta + 30) / Pa]^{1/2}$

SSP - Sampler Set Point for the sampler delta Pex in inches of water (in H2O)

m - Resultant slope from the linear regression of delta Pex T vs Qa orifice.

b - Resultant intercept from the linear regression of delta Pex T vs Qa orifice.

r - Resultant correlation coefficient from the linear regression of delta Pex T vs Qa orifice (should be >0.990).

Qa Sampler - Calculated actual-condition flow rate of sampler in cubic meters per minute (m3/min), using the following equation:



CDPHE-LSD Air Resources Laboratory
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Denver, Colorado 80230
(303) 692-3090
www.coloradostatelab.us

Particulate Sampler Field Envelope

Site: **DENVER - VISITOR CENTER**

Filter Number: Q5506262

*CDPHE HV
4.440 50

Sampler Number: PM10-2-7777

Sample Date: 6/9/15

Time Off: 49035

Time On: 47591

RunTime: 1444

Technician: J/J

Manometer Readings	
Before	After
2.9	2.9

Comments: _____

Figure EOD-4: Particulate Sampler Field Envelope (PSFE)

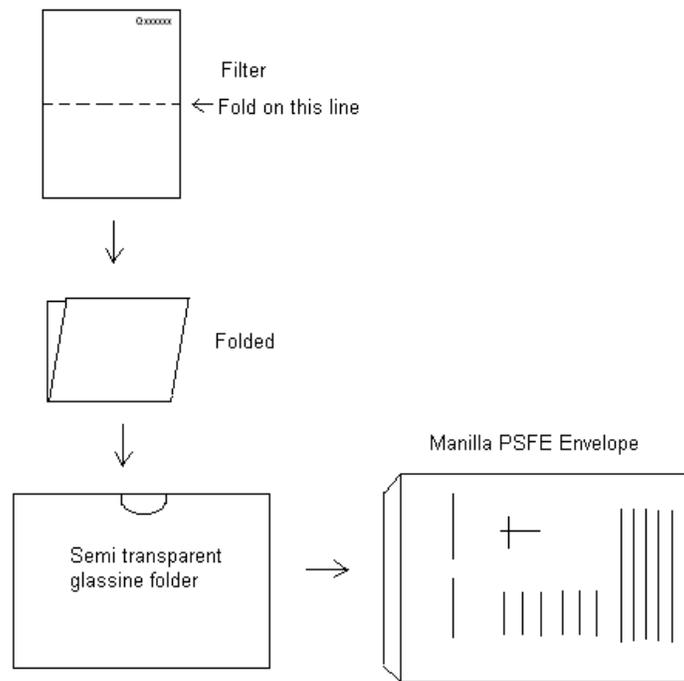


Figure EOD-5: Placing a Filter into Glassine Sleeve and the Glassine Sleeve into a PSFE Envelope

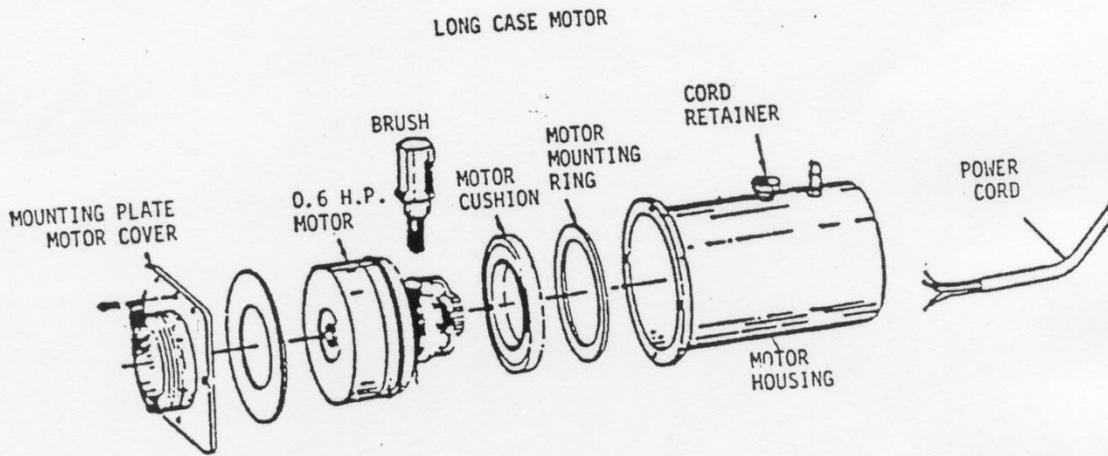
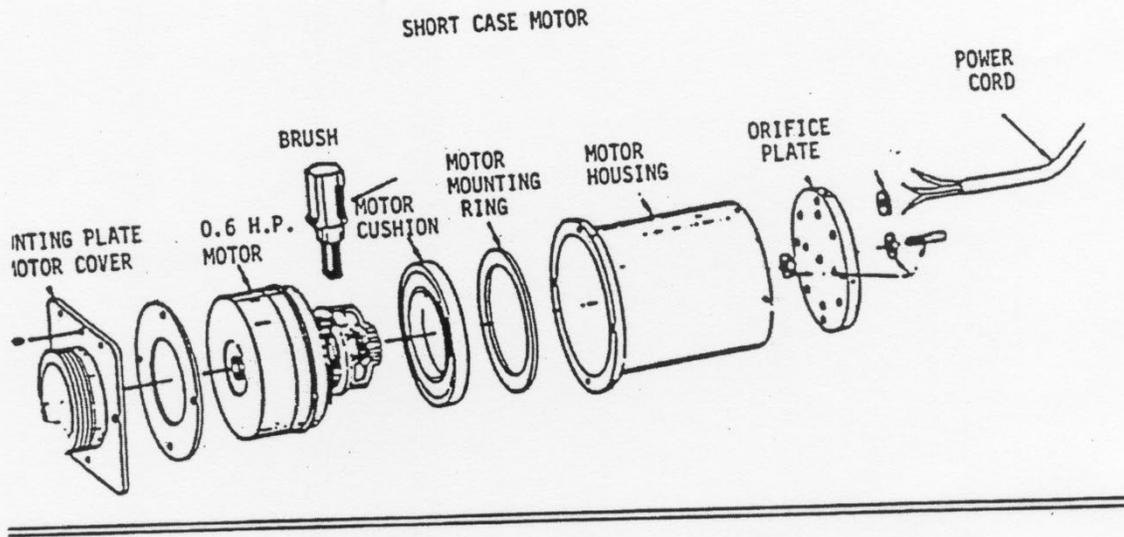


Figure EOD-6: Short Motor Case and Long Motor Case

EPA REGION 8 AMBIENT AIR MONITORING NETWORK MODIFICATION REQUEST FORM						
(VERSION 2, 4/1/04)						
DATE:		CITY:			STATE: CO	
AQS SITE ID:			SITE NAME:			
PROPOSED MODIFICATION/REASON WHY:						
AIR QUALITY PARAMETER (PM10, SO2, CO, NO2, ETC.)	MONITOR TYPE (NAMS, SLAMS, SPM, TRIBAL, etc.)	CHECK ONE OR MORE OF THE APPLICABLE CATEGORIES BELOW:				LIST SAMPLER EQUIPMENT
		MAX CONC	SOURCE IMPACT	POPULATION EXPOSURE	BACKGROUND	
PROPOSED SAMPLING START / REMOVAL DATE OR DATE STARTED / REMOVED:						
ESTIMATED MEASUREMENTS FOR AIR QUALITY PARAMETERS:						
LOCATION (LAT./LONG. OR UTM'S):						
SITE ELEVATION (M. MSL):				PROBE HEIGHT (M. AGL):		
DISTANCE TO TREE DRIPLINE (M)	DIRECTION TO TREE	DISTANCE TO OBSTACLE (M)	DIRECTION TO OBSTACLE	OBSTACLE HEIGHT ABOVE PROBE (M)	OBSTACLE COMMENTS	
UNRESTRICTED AIR FLOW: >270 DEG. >180 DEG. <CRITERIA _____ DEG. = 270 Degrees						
DISTANCE TO FLUES/INCINERATORS (M):						
DISTANCE TO INTERSECTIONS (M):			DISTANCE FROM SUPPORTING STRUCTURES (M): VERT. _____ HORIZ. _____			
DISTANCE TO EDGE OF NEAREST ROADWAY	NAME OF ROADWAY	DIRECTION	DAILY TRAFFIC ESTIMATES	YEAR OF TRAFFIC ESTIMATES	TYPE OF ROADWAY	COMMENTS
DISTANCE TO NEAREST POINT SOURCES (MILES)		DIRECTION TO POINT SOURCES	DISTANCE TO NEAREST AREA SOURCES (MILES)		DIRECTION TO AREA SOURCES	COMMENTS
CERTIFICATION: I certify the network modification proposed above meets all 40 CFR 58, Appendix E siting criteria, except as noted with submittal.						
Printed Name: _____ Signature: _____						
FOR EPA USE ONLY: Received Date: _____ Follow-up Actions: _____ Approval Status Given: _____ Email Response Date: _____ Letter Response Date: _____						

Figure EOD-7: Ambient Air Monitoring Network Modification Request Form

Hi-Vol PM Analyzer Audit



COLORADO
 Air Pollution Control Division
 Department of Public Health & Environment

Site: 080310002

Site Name: DENVER - CAMP

Method: HI-VOL SA/GMW-1200 - GRAVIMETRIC

Parameter: 81102 POC 2 Method Code: 63

Auditor: CWS Audit Date: 11/17/2022 Audit Time: 1:20

Audit Orifice: BG3-PM10

Cal. Date: 10/11/2022 "A" Factor: 0.61726 "B" Factor: 0.4946019

Ambient Pressure		
(inches Hg)	(atm)	(mm Hg)
	0.8365	636

Ambient Temperature		
(Fahrenheit)	(Celsius)	(Kelvin)
	-4.6	268.6

Upload to AQS?

Sampler Info						Manometer Readings (inches H2O)			
Sampler Number	Cal. Date	Motor Number	Motor Type	Slope	Int.	Pre-Audit Manometer	Audit Manometer	Sampler Manometer	Post-Audit Manometer
PM10-B	8/18/2022	12141	MFC	1.0460	-0.0345	2.85	3.1	2.85	2.85

Audit Flow Rate Verification Results (cubic meters/min)									
Sampler Number	Audit Flow	Audit Flow @ STP	Sample Flow	Sample Flow @ STP	% Relative Error	Pre-Audit Flow	Post-Audit Flow	Bias Corr. Flow	Design Flow % Rel. Error
PM10-B	1.121	1.041	1.139	1.058	1.6%	1.139	1.139	1.121	-1.0%

Comments

Figure EOD-8: PM₁₀/TSP Field Audit Data Sheet

ACCURACY DATA ENTRY SUBSYSTEM - PARS

PARAMETER	PARAM CODE	INTERVAL	UNITS	METHOD	AUDIT TYPE	LOCAL STD	AUD CLASS	DEC PLACE
CO	42101	1	007	054	2	C	A	1
O3	44201	1	007	053/087	1	F	A	3
NO2	42602	1	007	074/082/099	2	C	A	3
NO	42601	1	007	074/082/099	2	C	A	3
SO2	42401	1	007	060/092	2	C	A	3
PM10 - CONT	81102	1	073	079/081	1	P	F	2
PM2.5 - CONT	88101	1	073	703	1	P	F	2
PM10 - STP	81102	7	083	062/063/064	1	P	F	3
PM10-LTP	85101	7	083	062/063/064	1	P	F	3
TSP	11101	7	083	091	1	P	F	3
Pb	12128	7	083	090	1	P	F	3
Pb-Lab	12128	7	077	090	2	W	A	0
PM2.5	88101	7	073	117/118	1	P	F	2
WS	61101	1	012	050	2	X	A	0
WDIR	61102	1	014	050	2	X	A	0
TEMP	62101	1	015	040	1	X	A	0

PRECISION DATA ENTRY SUBSYSTEM - PARS

PARAMETER	PARAM CODE	INTERVAL	UNITS	METHOD	DEC PLACE
CO	42101	1	007	054	1
O3	44201	1	007	053/087	3
NO2	42602	1	007	074/082/099	3
NO	42601	1	007	074/082/099	3
SO2	42401	1	007	060/092	3
PM10 - CONT	81102	1	001	079/081	0
PM2.5 - CONT	88101	1	001	703	1
PM10-STP	81102	7	001	062/063/064	0
PM10-LTP	85101	7	105	062/063/064	0
TSP	11101	7	001	091	0
Pb	12128	7	001	090	2
PM2.5	88101	7	105	117/118	1

Note: CO: 054 = TECO 48
 Ozone: 053 = ML8810; 087 = API400/400A
 NO2: 074 = TECO 42; 082 = API200; 099 = API200a
 SO2: 060 = TECO 43A; 092 = ML9850
 PM10 - Cont: 079 = TEOM 1400; 081 = WEDDING Beta
 PM10: 062 = Wedding; 063 = SA1200; 064 = SA321B
 PM2.5: 117 = R&P single; 118 R&P sequential

Figure EOD-9: P&A Database Codes

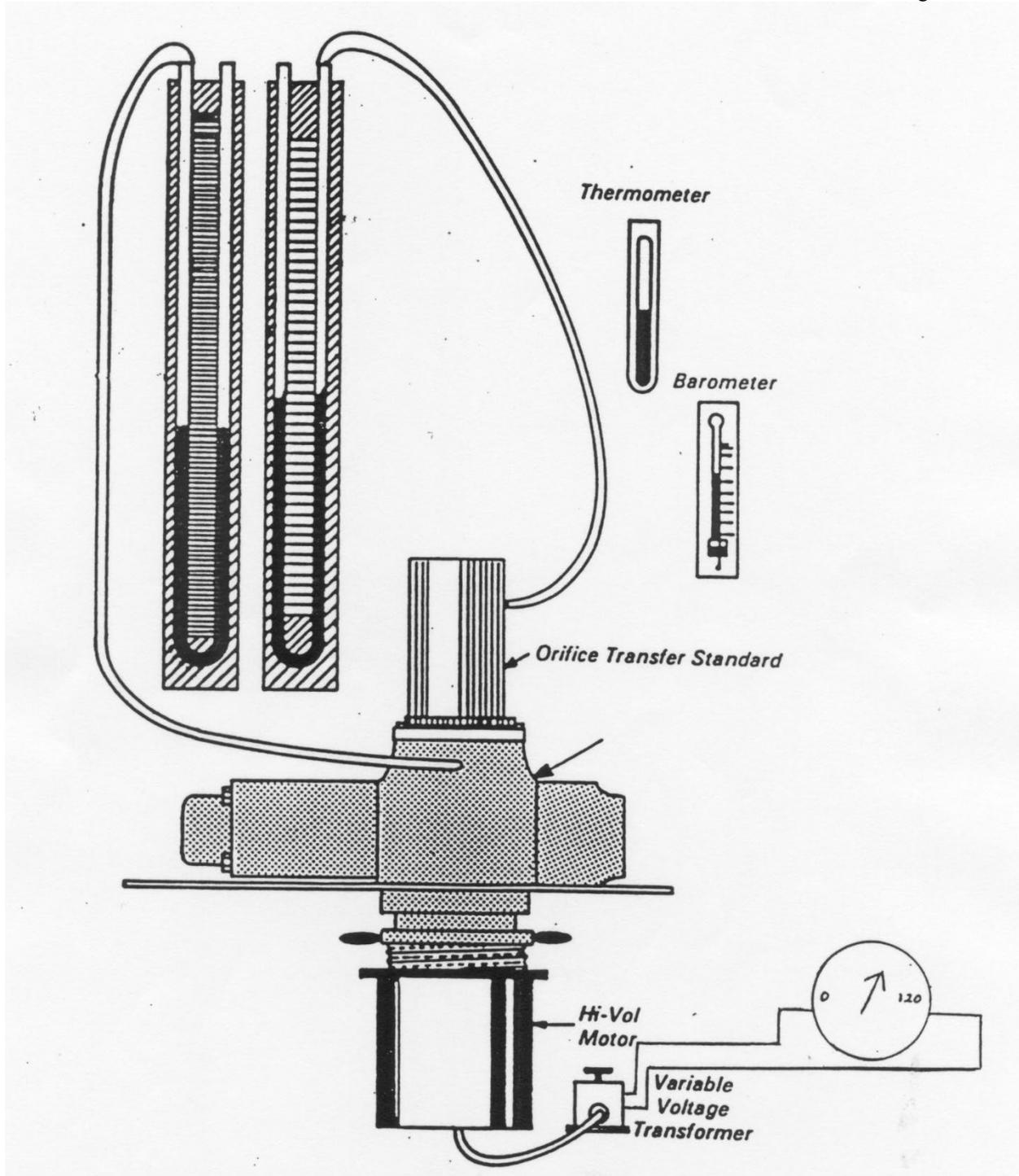


Figure EOD-10: Orifice Flow Transfer Standard Calibration Setup

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT Air Pollution Control Division - Technical Services Program PM10 High Volume Orifice Calibration Form															
Date (mm/dd/yy)		10/6/2017		Cal Type:		PM10		Rootsmeeter S/N:		7807140		Pa (inHg):		24.6	
Operator Initials:		cws		Orifice S/N:		BG3-pm10		Roots Cert. Date:		10/18/2016		Pa (mmHg):		624.84	
Company:		CDPHE / APCD / QA													
Contact Person:		Cindy Wike													
Address:		4300 Cherry Creek Drive South													
City and ZIP:		Denver, CO 80246-1530													
(Target flowrate is 1.13 m3/min; the calibration should have at least three points within 1.02 - 1.24 m3/min.)															
Nominal (m3/min)	Volts (AC)	Ta - Initial (C)	VI (m3)	H2O - root (Inches)	H2O - Orifice (Inches)	Vf (m3)	Time (entry) (min)	(sec)	t (total) (min)	Ta - final (C)					
1.30	63	22.94	517.70	4.850	3.550	524.90			5.580	23.37					
1.24	60	23.37	526.50	4.550	3.300	532.20			4.561	23.56					
1.20	57	23.56	534.20	4.175	3.025	539.60			4.511	23.67					
1.13	53	23.67	540.40	3.715	2.700	544.90			3.987	23.73					
1.05	48	23.73	545.90	3.175	2.300	550.50			4.425	23.76					
1.02	44	23.76	551.40	2.715	1.975	556.10			4.869	23.76					
0.90	38	23.76	556.80	2.100	1.500	560.10			3.907	23.72					
All calculated values have been rounded to the displayed values!															
Vnet (m3)	Ta - avg (K)	Va (m3)	Qa (m3/min)	(Y) (see below)	(X) ln(H2O-orifice)	Qa - Calc (m3/min)	%D (+/- 2%)	(Y') (see below)	(X') ln(H2O-orifice)	Qa-Calc' (m3/min)	%D' (+/- 2%)				
7.30	296.3	7.09562	1.272	0.14681	1.26695	1.274	0.16%	1.297	1.272	1.275	0.24%				
5.70	296.6	5.62248	1.233	0.11416	1.19392	1.230	-0.24%	1.252	1.233	1.231	-0.16%				
5.40	296.8	5.33261	1.182	0.07158	1.10691	1.180	-0.17%	1.199	1.182	1.180	-0.17%				
4.50	296.9	4.48003	1.116	0.01396	0.99328	1.116	0.00%	1.133	1.116	1.116	0.00%				
4.60	296.9	4.55635	1.030	-0.06624	0.83291	1.032	0.19%	1.048	1.030	1.032	0.19%				
4.70	296.9	4.66186	0.957	-0.13975	0.68057	0.958	0.10%	0.969	0.957	0.958	0.10%				
3.30	296.9	3.27929	0.839	-0.27134	0.40547	0.838	-0.12%	0.844	0.839	0.838	-0.12%				
Notes: (Y) = ln[Qa Sqrt((Pa/760)*(298.15/Ta))], Units in ln(m3/min); (Y') = Sqrt[H2O-orifice(Ta/Pa)], Units in Sqrt((lnH2O)(K/lnHg)) Vnet = Vf - Vi; Ta = [(Ta-Initial+Ta-final)/2]+273.15; Va=Vnet*[Pa-(H2O-root/13.6)]/Pa Qa=va/t; Qa-calc = A(H2O-orifice)expB* Sqrt((760/Pa)*(Ta/298.15)) where Pa is in mmHg and Ta is in Kelvin															
CDPHE Method) Plot ln[Qa Sqrt((Pa/760)*(298.15/Ta))] against ln(H2O-orifice)						EPA 2.11 Method) Plot Sqrt[H2O-orifice(Ta/Pa)] against Qa									
Linear Regression Results of Plot: m= 0.48813 b= -0.47070 r= 0.9999			Power Regression Results: B = m = 0.48813 A = (e)expb = 0.62457			Linear Regression Results of Plot: m= 1.03767 b= -0.02534 r= 0.9999									
For subsequent flow rate calculations: (H2O = H2O-orifice) Qa= A(H2O)expB* Sqrt((760/Pa)*(Ta/298.15)) Qald=A(H2O)expB* Sqrt((Pa/760)*(298.15/Ta))						For subsequent flow rate calculations: (H2O=H2O-orifice) Qa=(Sqrt(H2O(Ta/Pa))-b)/(1/m) Qald=Qa(Pa/760)/(298.15/Ta)									
Comments: <div style="border: 1px solid black; height: 20px; width: 100%;"></div>															
Signature _____															

Figure EOD-11: PM₁₀ Flow Transfer Standard Calibration Form

STATE OF COLORADO

Bill Owens, Governor
 Jane E. Norton, Executive Director

Dedicated to protecting and improving the health and environment of the people of Colorado

4300 Cherry Creek Dr. S. Laboratory and Radiation Services Division
 Denver, Colorado 80246-1530 8100 Lowry Blvd.
 Phone (303) 692-2000 Denver, Colorado 80230-6926
 Located in Glendale, Colorado (303) 692-3090

<http://www.cdphe.state.co.us>



Colorado Department
 of Public Health
 and Environment

CERTIFICATE OF CALIBRATION

The orifice number _____ was calibrated on the Dresser ROOTSMETER,
 Serial # 7807140 on _____.

The calibration was performed by personnel of the Colorado Department of Public Health & Environment, Air Pollution Control Division, Technical Services Program in accordance with the Quality Assurance Guidance Document 2.11, Monitoring PM₁₀ in Ambient Air Using a High Volume Sampler Method, Sep. 1997, EPA-600/4-77-027a.

The calibration is valid for one year from the above calibration date.

The orifice calibration curve is expressed by the following three equations for theoretical flow rate (Qr, provided for historical significance), actual flow rate (Qa), and standard flow rate (Qstd):

CDPHE Method	Qr (m ³ /min) = A (ΔH) ^B	EPA 2.11 Method
Qa (m ³ /min) = A (ΔH) ^B {2.54897 (Ta/298.16) / (760/Pa)} ^{1/2}		Qa (m ³ /min) = {1/m} {[ΔH(Ta/Pa)] ^{1/2} - b}
Qstd (m ³ /min) = A (ΔH) ^B {0.39232 (Pa/760) / (298.16/ Ta)} ^{1/2}		Qstd (m ³ /min) = Qa (Pa/760)(298.16/Ta)
The calibration coefficients for the calibration data are: A = _____ B = _____		The calibration coefficients for the calibration data are: m = _____ b = _____
The correlation coefficient for the calibration is: r = _____		The correlation coefficient for the calibration is: r = _____

where,
 ΔH is the orifice manometer reading in inches of water (in H₂O),
 Ta is the ambient temperature in Kelvin (K, K = C + 273.16),
 Pa is the local barometric pressure in millimeters of mercury (mm Hg = in Hg * 25.4)

QA Unit Name: _____ Signature: _____

Figure EOD-13: Certification of Calibration