Air Pollution Control Division

Technical Services Program

APPENDIX PM3

Standard Operating Procedure for the Determination of Particulate Matter in Ambient Air Using a TEOM

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1.0 GENERAL INFORMATION

1.1. Purpose

These procedures are intended to supplement the Rupprecht & Patashnick (R&P) Model 1400a Tapered Element Oscillating Microbalance (TEOM) Operating Manual (R&P Manual). It is recommended that the R&P Manual be utilized in conjunction with these written procedures during installation, operation, and calibration.

2.0 GENERAL DESCRIPTION

2.1. Safety

Only properly trained personnel should attempt installation, operation or calibration of these instruments. High voltages may be present in the TEOM sensor and control unit enclosures.

2.2. Overview

The Series 1400a Monitor incorporates the patented Tapered Element Oscillating Microbalance (TEOM) technology developed by Rupprecht & Patashnick Co., Inc. to measure particulate matter mass concentrations continuously. The Series 1400a Monitors set up by APCD to continuously monitor $PM_{2.5}$ have been configured with a standard PM_{10} sample inlet and a Very Sharp Cut Cyclone (VSCC) to establish the appropriate cut points. The microprocessor-based unit accommodates all siting requirements and provides internal data storage and analog and serial data input/output capabilities. Filter-based, direct mass measurements are considered the standard technique for determining particulate matter mass concentration. In December 1990 the United States Environmental Protection Agency (U.S. EPA) designated the TEOM Series 1400a PM_{10} Monitors as an equivalent method for the determination of 24-hour average PM_{10} concentrations in ambient air. For use as a designated equivalent method, the TEOM 1400a PM_{10} Monitors must be operated with a RP PM_{10} Inlet, a modified RP PM_{10} Inlet or a Sierra-Andersen Model 246b PM_{10} inlet, at a flow rate of 16.7 liters per minute, using Teflon coated glass fiber filter cartridges, with the total mass averaging time set at 300 seconds, and the mass rate/mass concentration averaging time set at 300 seconds.

Some of the TEOM units in Colorado configured to sample $PM_{2.5}$ have been augmented with Series 8500b Filter Dynamic Measuring System (FDMS) units. The FDMS system is composed of two major subsystems:

1. The sampling system consists of a size-selective inlet; flow splitter, air chiller/dryer, and a switching valve that is used to direct the sample flow through the 8500 module.

2. The analysis and control system is made up of a sample filter that is part of the TEOM microbalance, humidity sensors for the main and bypass flows, and a control unit containing flow controllers and data management hardware.

Based upon the adjusted change in the filter sample mass and sampled volume, the FDMS unit computes a one-hour running average of the PM mass concentration. The instrument updates this value every six minutes based upon the newest information. The unit calculates the mass concentration (MC) based on the slope of the frequency (mass) that is measured during each base/reference measurement period. Based upon mass concentration (MC) measurements obtained during the base and reference periods, the FDMS system updates a one-hour average of the following results every six minutes:

<u>Base mass concentration (Base MC)</u> = PM concentration of the particle laden sample stream (comparable to the Sample Equilibration System at 30° C).

<u>Reference mass concentration (Ref MC)</u> = PM concentration of the particle-free sample stream, after passing through the purge filter.

Mass concentration (MC) = Base mass concentration (Base MC) adjusted by the reference mass concentration (Ref MC) — Base MC (usually positive) minus Ref MC (negative when mass volatilizes from the filter).

Figure 1 - RP 1400a TEOM typical configuration, PM_{10} sampling.

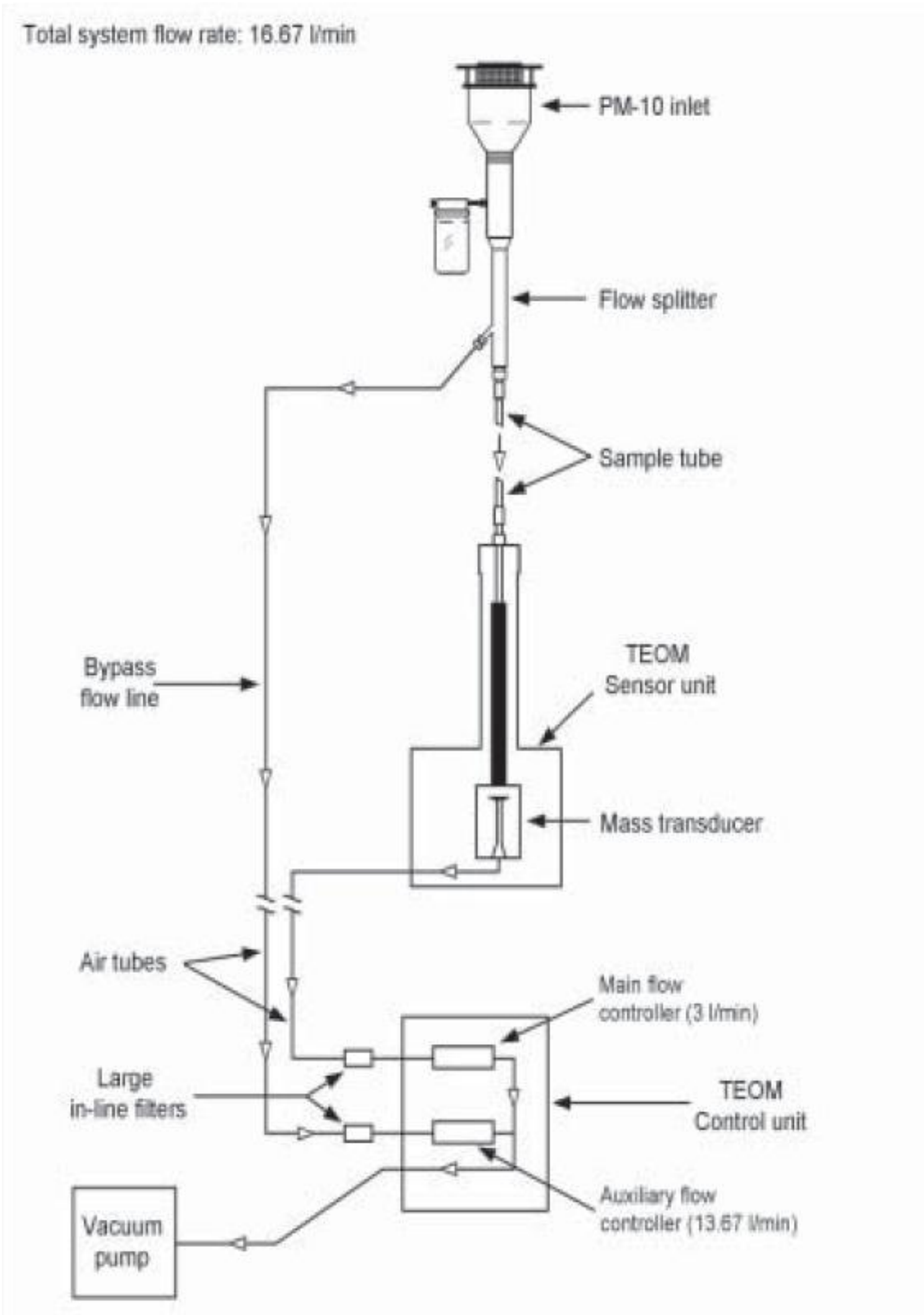
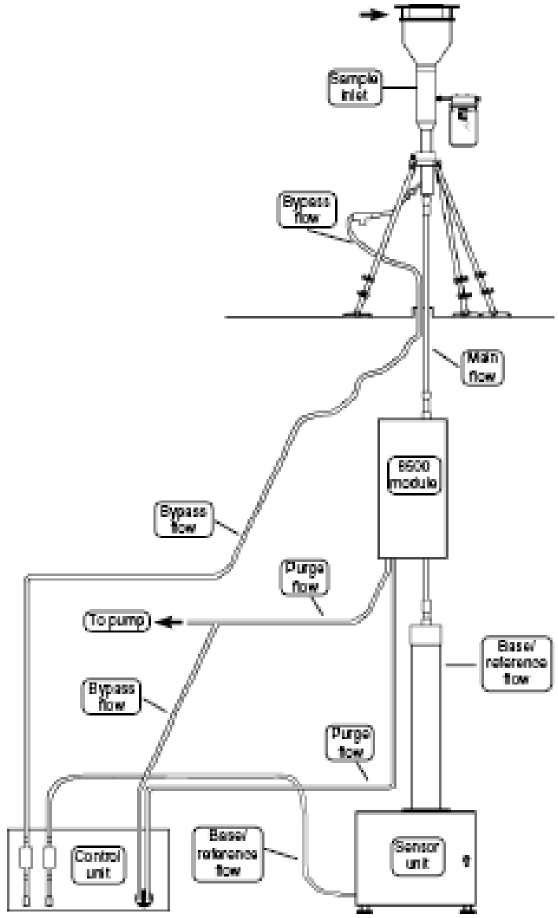


Figure 2 - RP 8500 FDMS/TEOM typical configuration, $PM_{2.5}$ sampling.



Note: The configuration for $PM_{2.5}$ sampling without the FDMS unit is the same as for PM_{10} sampling with the addition of a VSCC upstream of the flow splitter. Some additional changes in software settings are also necessary and are discussed below.

3.0 GENERAL OPERATION

3.1. Software Configuration

The software configuration consists of setting various parameters in the TEOM's software such as choice of analog outputs, temperatures, pressures, and flow rates. These procedures are detailed in the Operating Manual. Typical APCD installations have settings that may differ from examples shown in the Operating Manual. The following settings are currently being used at various APCD monitoring sites:

NOTE: If the TEOM is shut off, an internal battery will hold the configured settings.

Set Analog Outputs (Menu Screen 04)

Max Volt	10-VDC - Sets Output Range Voltage to 0-10.0 VDC
AO1 Var	TEOM Filter Loading, PRC 35 (TEOM & FDMS)
AO1 Min	0 - Selects 0% as the Minimum Reportable Filter Loading
AO1 Max	100 - Selects 100% as Maximum Mass Filter Loading
Jumpers 10-VDC	Reflects Internal Jumper Connections

Max Volt	10-VDC - Sets Output Range Voltage to 0-10.0 VDC
AO2 Var	TEOM Oscillating Frequency, PRC 12 (TEOM & FDMS)
AO2 Min	100 - Selects 100 as Minimum Frequency
AO2 Max	400 - Selects 400 as Maximum Frequency
Jumpers 10-VDC	Reflects Internal Jumper Connections

Max Volt	10-VDC - Sets Output Range Voltage to 0-10.0 VDC
AO3 Var	MassConc, PRC 8 (TEOM and FDMS)
AO3 Min	-10.00 - Selects -10 as Minimum Mass Concentration
AO3 Max	240.00 - Selects 240 as Maximum Mass Concentration
AO1 Max (PM_{10})	490.00 - Selects 490 as Maximum Mass Concentration
Jumpers 10-VDC	Reflects Internal Jumper Connections

NOTE: APCD collects multiple channels of instrument operational criteria via GSI interface through data loggers at the site. The configuration of those channels is separate from the instrument set up. However, the instrument must be in AK communications protocol and display a '+' on the Status Line to enable channel AO1 to go full scale in the event of a status condition.

These settings correspond to an output slope of 250 $\mu g/m^3$ for $PM_{2.5}$ (500 $\mu g/m^3$ for PM_{10}) and an intercept of -10. The purpose of this offset is to minimize inappropriate voltage outputs if the TEOM's mass concentration readings fall below zero.

3.2. Ambient Temperature Average and Set Values (T-A/S 99.00 99.00)

SET TEMPS/FLOWS screen

These are the average ambient and reference standard temperature settings for sampling $PM_{2.5}$, left to right respectively. If the average and reference standard temperature values are set to '99' the instrument will utilize the signal from the ambient temperature sensor to calculate volumetric flow. The consequent value will be representative of actual conditions. TEOM units configured to sample PM_{10} substitute 25°C for the set value, e.g.: (T-A/S 99.00 25.00). This configuration will adjust the measurement from actual conditions to standard conditions.

3.3. Ambient Pressure Average and Set Values (P-A/S 9.000 9.000)

SET TEMPS/FLOWS screen

These are the average and standard barometric pressure settings, left to right respectively. If the average and reference standard pressure values are set to '9' the instrument will utilize the signal from the ambient pressure sensor to calculate volumetric flow. The consequent value will be representative of actual conditions. TEOM units configured to sample PM_{10} should 1 atm for the set value. This configuration will adjust the reported values to standard conditions. Alternatively, TEOM units configured to sample PM_{10} may utilize the ambient pressure sensor to calculate volumetric flow and report at standard conditions, e.g.: (P-A/S 9.00 1.00).

3.4. Fadj Main 1.000 and Fadj Aux 1.000

SET TEMPS/FLOWS screen

These factors are used by the TEOM's software to adjust for deviations of the main and auxiliary flow rate set points from the actual flow rates. If either the actual Main or Auxiliary flow rate(s) differ from the indicated flow rate(s) by less than 10% (as measured with an appropriate transfer standard) then the Fadj factors can be used to correct the deviation. They are determined by a proportional comparison to the actual or true flow rates as measured with a transfer standard during the software calibration. Additional information on these factors is contained in the R&P Manual. The default settings are 1.000 for both $PM_{2.5}$ and PM_{10} sampling. Fadj Main and Fadj Aux may range from 0.9 to 1.1.

3.5. CASE, AIR, and CAP Temperatures

SET TEMPS/FLOWS screen

These temperatures for TEOMs configured to sample PM_{10} should always be set to 30.00 $\pm$ 0.1°C. TEOM units configured to sample $PM_{2.5}$ that are equipped with a FDMS unit should also have CASE, AIR, and

CAP temperatures always set to 30.00 ± 0.1°C. The TEOMs sampling $PM_{2.5}$ without a FDMS unit will be set to 30.00 ± 0.1°C from mid-October through end of March, and will be set to 40.00 ± 0.1°C from early April through mid- October.

3.6. Constant A & Constant B (PM_{10} Sampling)

SET TEMPS/FLOWS screen

These two values are data correction factors. Constant A is a zero offset and Constant B is a multiplication factor. The EPA tested and empirically determined that Constant A should be 3.00 and Constant B should be 1.03 in order for the TEOM 1400a to be a PM_{10} designated Reference Method. The EPA decided that these corrections could account for the volatilization of some compounds on the filter that is held at 30°C. These corrections do not work well for sampling in some geographical areas or for different size particles such as $PM_{2.5}$. For $PM_{2.5}$ applications Constant A should be set to 0.0 and Constant B to 1.0. Data generated by a TEOM 1400 instrument should be tagged with the value of the two Constants when the data is collected.

3.7. Data Logger Connection

The TEOM's analog output (A01-1-Hr mass concentration), as previously selected in the Software Configuration, should be connected to the selected analog input channel of the ESC data logger. Using the supplied 15-Pin D-Connector and signal cable, connect the front or rear (preferred) Analog I/O of the TEOM's Control Unit to the ESC's analog input. A schematic diagram of the TEOM analog output wiring assignments are shown in the R&P Manual. The reportable channels are variable from logger to logger depending on station requirements and data logger capabilities. Verify the correct channels that need to be disabled.

Inspection and Regular Maintenance Activities

Scheduled inspection and preventative maintenance (P.M.) to minimize downtime and ensure data quality is performed on all TEOM and FDMS-equipped TEOM samplers in the network as established by the APCD-TSP.

- The Weekly Inspection is performed during any site visit (at a minimum each site should be visited once per week).
- The Two-Week Inspection is performed on a once every two-week calendar period.
- The Six-Month Inspection is performed each April and October.
- Calibrations are performed annually or as needed (e.g. - with replacement of major component(s) such as mass flow controllers).

Upon completion of an inspection, the date of completion and the initials of the person completing the inspection are entered on the appropriate data sheet. Operators should document any work performed or work that needs to be performed as discovered during the inspection. Additionally, operators should take special care to note the time period(s) that the instrument was not generating valid data, either from an incorrect software setting or hardware inspection/maintenance issues. APCD-TSP maintenance and Quality Assurance personnel should note all maintenance and QA activities on the TEOM log form. The PM TEOM forms are presented below.

Each site is physically visited a minimum of once each week and is electronically contacted each day, typically by a computer/modem link. If the site operator (APCD-TSP employee or contracted operator) does not have a computer/modem link then the operator should visit the instrument twice per week. The purpose of the daily call-up is to determine, by review of the past 24-hours of data and current instrument performance, if an immediate site visit is necessary. All scheduled checks are minimum requirements. Individual site circumstances may dictate a more aggressive preventative maintenance schedule.

By contract agreement, it is the responsibility of all contracted site operators to notify the APCD-TSP of any unusual instrument/equipment performance, possible or outright malfunctions, and action taken, if any. The APCD-TSP in turn will take the appropriate corrective action as soon as workload and priorities permit.

Figure 3 – TEOM PM_{10} and $PM_{2.5}$ Maintenance Log

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Air Pollution Control Division - Technical Services Program

$PM_{2.5}$ SPM (Continuous) Regular Maintenance/Sampler Verification Form

SITE/SAMPLER DATA

Site Name: CAMP TEOM(PM2.5)

Sampler Model: 1400AFDMS

Sampler S/N: 2295+0003

AIRS ID: 08-031-0002

Site Visit	#1	#2	#3	#4	#5	#6	#7	#8
Operator								
Date								
Time								
Vis. Insp								
INSPECTION								
Inst. Mode								
Status								
Aux Flow								
Main Flow								
Temp.(T_a)								
Pres.(P_a)								
Jar Cond. (Y/N)								
Case Temp.								
Cap Temp.								
Frequency								
NOISE								
% Load								

FTS S/N: GN-003 FTS m = 0.3031 FTS b = 0.2571 Therm. S/N: 3500+2 Barometer S/N: Pretel/2675+

Four Week Instrument Verification

Site Visit #	Leak Rate OK?	Clock Current	Clock Standard ± 16 Minutes	Ambient Temp. Current	Ambient Temp. Standard ± 10 mm Hg	Ambient Pres. Current	Ambient Pres. Standard ± 4°C	Aux. FTS Pres	Aux. Flow Current	Aux. Flow Standard ± 4% RA	Main FTS Pres.	Main Flow Current	Main Flow Standard ± 4% RA

Visit #	Time	Describe Action Due/Action Taken	Time On	Initials

TIME PERIOD: 12.27.05 to 01.23.06

LIST OF SCHEDULED EVENTS/ SCHEDULED DATES:

Scheduled Events: #1 4-wk verification, Head Cleaning, SCC Cleaning SCHEDULED DATE: 12.27.05

Comments:

4.0 SITE INSPECTIONS

4.1. Weekly Inspection

Record the status on the log sheet. The R&P Manual offers a detailed description of all TEOM status codes. The TEOM status should be 'OK' for normal operation with no problems:

OK = normal operation
M = Mass transducer warning flag
T = Temperature out of limits warning flag
F = Flow out of limits warning flag
X = Filter Loading warning flag (loading ≥90%)

Record the mode on the log sheet. This should be '4' for normal operation with no problems:

1 = Temperature/flow stabilization period
2 = Begin total mass data collection
3 = Begin mass concentration calculations
4 = Normal operation
S = Setup/stop data mode
X = Stop all mode

The operator should note and record the filter loading percent on the log sheet. This value starts at 15% to 30% with a new filter. TEOM filters should be replaced when loading approaches 75% or higher, and must be replaced when the filter loading value reaches 85%. Additionally, the filter should be changed (or removed, set aside, and reinstalled) after performing a leak check, as discussed below. If the sample filter needs changing (filter loading 75% or higher) follow the procedures below to exchange the sample filter and record the new filter loading percent on the log sheet.

Inspect the inline filters for a high level of contamination (dark gray or black appearance). Replace these filters as required. At a minimum they should be replaced at least once every three months. Operators should take special note of the inline filter on the auxiliary sampling line as it filters much more contamination from the sampling stream than the filter on the main sample line.

Record the case (mass transducer), air (at base of heated air inlet) and cap (at the upper part of the mass transducer) temperatures on the log sheet.

Confirm that these indicated flows are within ±2% of their set points (3.0 ± 0.06 L/min for the "Main Flow" and 13.67 ± 0.27 L/min for the "Aux Flow"). Any greater deviation may indicate that the in-line filters are plugged or other blockages (or leaks) exist in the system.

Record the noise on the log sheet. This number should be less than 0.10 during normal operation for sites with monitoring shelters. For sites with enclosures on roofs expect about double this number due to the additional vibrations associated with being on a roof top. The noise level is less important for those units equipped with a FDMS unit.

Record the frequency on the log sheet. This is the oscillating frequency of the tapered element and should generally be between 150 and 400 Hz.

Press "TIME/DATE" and check that the date and time are correct. The data is time-stamped from the station data logger so the date and time aren't critically important. Nevertheless, the date and time should be within 15 minutes of local standard time. Press "MAIN/STATUS" to return to the main screen. Change if necessary by pressing "STEP SCREEN" and using the arrow keys to scroll down to "Set Time". Press "ENTER" to accept a new time value. Press "ESC" twice to return to the main menu.

If work that will affect the data needs to be performed, the TEOM channel of the data logger should be disabled. Disable the appropriate channel after logging in and record the time on the log sheet. The reportable channels are variable from logger to logger depending on station requirements and data logger capabilities. Verify the correct channels that need to be disabled.

NOTE: work the will affect the data includes anything that interferes with the collection of valid data including sample filter exchange, leak checks, and flow audits. The FDMS filter may be changed out during normal operation without disabling the data logger if the operator changes the filter during the six minutes of Base cycle sampling.

4.2. Two-Week Inspection

The operator should perform all the activities scheduled for the weekly inspection prior to performing the activities prescribed for the two-week inspection. Disable the appropriate channel on the data logger, if not already disabled. Operators should perform a VSCC cleaning, PM_{10} head cleaning, leak check, temperature check, pressure check, and flow rate verification every two weeks. The specific steps for each of these procedures are described below. Inspect the inline filters for a high level of contamination (dark gray or black appearance). Replace these filters as required. At a minimum they should be replaced at least once every three months.

4.3. Six-Month Inspection

Complete the Two-Week Inspection/Maintenance Procedures.
Disable the appropriate channel on the data logger, if not already disabled.
Replace the two large bypass in-line filters on the lines at the back of the control unit if they have not been changed in the last three months.
Inspect and clean the main and auxiliary sample line flow controllers.

4.4. Annual Inspection/Calibration

Complete the Six-Month Inspection Procedures.
Perform a hardware calibration.
Perform an Analog Output calibration.
Perform an Analog Input calibration.
Perform an ambient temperature sensor calibration.
Perform an ambient pressure sensor calibration.
Perform a flow calibration of the main and auxiliary sample mass flow controllers.
Perform a Mass Transducer Verification.

NOTE: Before performing the hardware calibration of the mass flow controllers ensure that the software values, Fadj(Aux) and Fadj(Main) are set to the default values of 1.000.

5.0 MAINTENANCE/VERIFICATION/CALIBRATION PROCEDURES

5.1. Verification Procedures

Verification Procedures	Interval
Batteries:	Test the batteries once every 6 months, and exchange them as necessary.
PM_{10} Head Assembly	Clean the PM_{10} head every two weeks
VSCC($PM_{2.5}$)	Clean the VSCC every two weeks
Leak check	Perform a leak check prior to every two-week verification procedure, every time any part of the flow system is interrupted or broken, and once per year prior to Mass flow controller hardware calibration.
Pump	Test the pump every two weeks while performing a leak check.
Ambient Temperature	Verify the ambient temperature measurement once every two weeks. Calibrate the sensor once per year or as needed.

Ambient Pressure	Verify the ambient pressure measurement once every two weeks. Calibrate the sensor once per year or as needed.
Flow Rate Verification	Perform flow verification once every two weeks and after every calibration.

Mass flow controllers:

Software	Calibrate the mass flow controller(s) software once per year.
Hardware	Calibrate the mass flow controller(s) hardware once per year.
Analog I/O	Perform an analog input/output calibration once a year.
Mass transducer	Verify the calibration of the mass transducer once a year.

5.2. Filter Removal

Follow these steps to remove a filter:

1. Press the <DATA STOP> key on the control unit's keypad; disable the TEOM channel of the data logger.
2. Open the door of the sensor unit.
3. Locate the silver handle on the front of the mass transducer. Note that there is a shipping latch in the middle of this handle.
4. Grasp the silver handle and move the shipping latch upward with your thumb.
5. Pull down on the silver handle.
6. Pull the holding rod off of the latch plate.
7. With the mass transducer unlatched, hold the black knob and swing the bottom of the mass transducer downward, exposing the filter. When the mass transducer is in the open position, the tapered element (TE) will automatically stop oscillating.
8. Carefully insert the lower fork of the filter exchange tool under the filter so that the filter disk is between the fork and the upper tab of the filter exchange tool. The tines of the fork should straddle the hub of the filter base.
9. Gently pull straight up, lifting the filter from the tapered element (TE). Do not twist or tilt the filter exchange tool from side-to-side while removing the filter from the TE. This could damage the TE.

NOTE: TEOM filters must be preconditioned to avoid excessive moisture buildup prior to their use in the system. Preconditioned filters are filters that have been placed on one of the two holders inside the sensor unit for a period not to be less than 24 hours prior to their use.

5.3. Filter Replacement

Follow these steps to install a new filter in the TEOM sensor unit:

1. Remove the old filter as described previously.
2. Pick up a new, conditioned filter from one of the filter holders with the filter exchange tool so that the filter disk lies between the fork and the upper tab of the tool and the hub of the filter lies between the tines of the fork. Do not touch the filter with your fingers while picking it up with the filter exchange tool.
3. Hold the filter exchange tool in line with the tapered element and lightly place the hub of the filter onto the tip of the tapered element.
4. Remove the filter exchange tool by slowly retracting it sideways until it clears the filter. Do not disturb the filter.
5. Place the bottom of the filter exchange tool on top of the filter and apply downward pressure (approximately 0.5 kg or 1 lb) to seat the filter firmly in place.
6. Place a new filter from the supply box onto the now vacant filter holder inside the sensor unit.
7. Raise the mass transducer to the closed position using the black knob.
8. Fasten the holding rod onto the latch plate.
9. Push the silver handle up until the shipping latch snaps into place.
10. Close and latch the door to the sensor unit. Keep the door open for as short a time as possible to minimize the temperature change in the system.

5.4. Filter Loading

The filter loading percentage value indicates the fraction of the TEOM filter's total capacity that has been used. You can check the filter loading percentage on the monitor's Main screen. Because this value is determined by the pressure drop of the main sample flow line, the instrument always shows a non-zero value even if no filter is mounted in the mass transducer. New filters generally exhibit filter-loading percentages of 15% to 30% at a main flow rate of 3.00 L/min, and less at lower flow rates. At some point of high filter loading the main flow drops below its set point. If the filter loading percentage is higher than 30% (at a main flow rate of 3.00 L/min) when a new TEOM filter is placed on the mass transducer, or if the lifetime of consecutive TEOM filters becomes noticeably shorter, you may need to replace the in-line filter in the main flow line.

5.5. Filter Life

Filter life depends upon the nature and concentration of the particulate matter sampled, as well as the main flow rate setting. TEOM filters should be replaced when loading approaches 75% or higher, and must be replaced when the filter loading value reaches 85%. This generally corresponds to a total mass accumulation on the filter of approximately 3-5 mg. Filter life at a main flow rate of 3 L/min is generally 63 days at an average $PM_{2.5}$ concentration of 15μg/m^3. Filter life is longer at lower flow rates because the particulate matter accumulation rate on the filter is smaller.

5.6. FDMS Filters

The 47 mm Teflon filter located in the chiller compartment of the FDMS unit is used to filter the air stream during the BASE sampling mode. This filter needs to be inspected and changed as necessary, and at least once every two weeks. After removing the FDMS filter for inspection the chiller chamber should also be inspected for condensation and cleared of condensate if present.

5.7. Cleaning the PM_{10} Head Assembly

Follow the steps discussed in Appendix G of the R&P Operating Manual to dissemble and clean the components of the PM_{10} head.

5.8. Cleaning the Sharp Cut Cyclone

Follow the steps discussed in Appendix G of the R&P Operating Manual to dissemble and clean the components of the Sharp Cut Cyclone.

5.9. Leak Check Procedure

Follow these steps to perform a leak check:
NOTE: Perform the weekly inspection activities as described above, if appropriate. Prior to performing a leak check, if no other work is being performed, the operator must ensure that the appropriate channel on the data logger has been suspended and that the instrument has been taken out of sampling mode by pressing the 'DATA STOP' key.

1. Remove the TEOM filter from the mass transducer as previously discussed. The operator may discard this filter or simply store it in the sensor unit on one of the provided tabs for later replacement.
2. When in the Main screen, press the up (<↑>) and down (<↓>) arrow keys to display the main flow and auxiliary flow values on the four-line display.
3. Remove the sample inlet from the flow splitter and replace it with the flow audit adapter equipped with a vacuum gauge.
4. Close the valve of the flow audit adapter
   NOTE: APCD has configured some TEOMs with valves on the auxiliary sample line to better differentiate flow/sources of leaks. This valve should also be closed during leak checks to isolate the sample lines. Additionally it can be closed during flow verifications to isolate the main flow rate from the auxiliary.
5. When in the Main screen, the main flow reading should read less than 0.15 L/min and the auxiliary flow reading should read less than 0.60 L/min. If the main flow reading is less than 0.15 L/min and the auxiliary flow reading is less than 0. 60 L/min, go to step 17. If the main flow reading is greater than 0.15 L/min and the auxiliary flow reading is greater than 0. 60 L/min, check

the hose fittings and other critical connections in the flow system for leaks and repeat step 5, and then go to step 8. While the flow audit adapter is closed note the vacuum gauge reading. If it is less than 16 inHg then the pump most likely needs to be replaced.

6. After checking the hose fittings and other critical connections in the flow system for leaks, repeat the leak check, then check the main flow reading and the auxiliary flow reading on the Main screen. Go to step 8.
7. When in the Main screen, the main flow reading should read less than 0.15 L/min and the auxiliary flow reading should read less than 0.60 L/min. If the main flow reading is less than 0.15 L/min and the auxiliary flow reading is less than 0.60 L/min, go to step 18. If the main flow reading is greater than 0.15 L/min and the auxiliary flow reading is greater than 0.60 L/min, the leak check procedure must be repeated using an offset value to account for the characteristic non-linearity of the mass flow sensor for flow values near 0 L/min. Go to step 10.
8. To determine the non-linearity offset value (NOV), *slowly* open the valve located on the flow audit adapter and disconnect or unplug the vacuum pump.
9. Wait 1 minute and observe the main flow and auxiliary flow readings. These are the NOVs for both the main flow and auxiliary flow; note these values.
10. Plug in or reconnect the vacuum pump, and wait 3-5 minutes to allow the main flow and auxiliary flow to stabilize.
11. When both flow rates have stabilized, close the valve on the flow audit adapter. When in the Main screen, the main flow reading should read less than 0.15 L/min plus the main flow NOV, and the auxiliary flow reading should read less than 0.60 L/min plus the auxiliary flow NOV. For example, if the NOV for the main flow was recorded as 0.08 L/min, add 0.08 to 0.15 for a total of 0.23 (0.08 + 0.15 = 0.23).
12. The main flow reading should be less than 0.23 L/min. If the NOV for the auxiliary flow was recorded as 0.12 L/min, add 0.12 to 0.60 for a total of 0.72 (0.12 + 0.60 = 0.72). The auxiliary flow reading should be less than 0.72 L/min.
13. If the flow readings exceed these calculated values (the NOVs plus 0.15 L/min for the main flow and 0.60 L/min for the auxiliary flow), perform an analog board calibration and mass flow controller calibration (refer to service manual). This also may indicate that there is a faulty connection or component (such as the mass flow controller or the vacuum pump) in the system. If the flow readings do not exceed these calculated values, go to step 17.
14. Slowly open the valve located on the flow audit adapter to gradually release the vacuum in the system.
15. Remove the flow audit adapter from the flow splitter.
16. Install the sample inlet and VSCC (if appropriate) onto the flow splitter.
17. Replace the TEOM filter in the mass transducer.
18. Close the mass transducer and the sensor unit door.
19. Note the results on the TEOM log sheet.

5.10. Ambient Air Temperature Verification

Perform the weekly activities and leak check verifying the ambient temperature.
Follow these steps to verify the ambient air temperature:

1. From the Main Screen, press the <1> and <9> keys, and then press the <ENTER> key to display the Set Temps/Flows screen.
2. When in the Set Temps/Flows screen, locate the current ambient temperature reading in the “Amb Temp” field.
3. Determine the current temperature (°C) at the ambient temperature sensor using an external thermometer, [°C = 5/9 x (°F - 32)].
4. Verify that the value of the “Amb Temp” field is within ± 2° C of the measured temperature. If this is not the case, perform the ambient temperature calibration procedure, described below, or notify APCD.
5. Note the results on the TEOM log sheet.

5.11. Ambient Pressure Verification

Perform the weekly checks, leak check, and ambient air temperature verification before verifying the ambient pressure.
Follow these steps to verify the ambient pressure:

1. Press the <1> and <9> keys, and then press the <ENTER> key to display the Set Temps/Flows screen.
2. When in the Set Temps/Flows screen, locate the current ambient pressure reading in the "Amb Pres" field.
3. Determine the current ambient pressure in mm Hg (absolute pressure, not corrected to sea level).
4. Verify the monitor's ambient pressure by measuring the current ambient station pressure with an external measurement device.
   - To convert from Atmospheres @ 0° C to mm Hg, multiply by 760.
   - To convert from millibars to mm Hg, multiply by 0.75012.
   - To convert from inches Hg @ 32° F to mm Hg, multiply by 25.4.
5. Verify that the value of the "Amb Pres" field is within ±10 mm Hg of the measured ambient pressure. If this is not the case, perform the ambient pressure calibration procedure.
6. Note the results on the TEOM log sheet

5.12. Flow Verification Procedure

The flow audit procedure checks and verifies that the flow rates in the Series 1400a Monitor are being calculated and reported correctly. The tolerances in this audit procedure should not be confused with the tighter specifications outlined in the calibration procedures below. Perform the weekly checks, leak check, ambient air temperature verification, and pressure verification before executing the flow verification procedure.

1. Press the <F1> or <RUN> key on the control unit's keypad.
2. Remove the sample inlet and the VSCC from the flow splitter.
3. When in the Main screen, press the up (<↑>) and down (<↓>) arrow keys until the "Main Flow" (SAMPLE FLOW) and "Aux Flow" (BYPASS FLOW) lines display on the screen. These values represent the actual volumetric flows as measured by the monitor's flow controllers.
4. Confirm that these indicated flows are within ±2% of their set points (3.0 ± 0.06 L/min for the "Main Flow" and 13.67 ± 0.27 L/min for the "Aux Flow"). Any greater deviation may indicate that the in-line filters are plugged or other blockages (or leaks) exist in the system.
5. Attach a reference flow transfer standard (FTS) to the top of the flow splitter. This FTS should have been recently calibrated to a primary standard, have an accuracy of ±2% at 3.00 L/min and 16.67L/min, and a pressure drop of less than 0.07 bar (1 psi).
6. Read the total flow (approximately 16.67 L/min) on the reference flow meter. The total volumetric flow measured by the reference flow meter must be within ±4% of the indicated flow of the sampler and within ±5% of the design flow rate of 16.67 L/min.
7. Disconnect the bypass flow line from the bypass extension on the bottom of the flow splitter (or close the valve as discussed above).
8. Cap the exit of the flow splitter bypass extension with the 3/8-inch Swagelok cap.
9. Read the main flow (approximately 3.00 L/min) on the reference flow meter. The volumetric flow measured by the reference flow meter must be 3.0 ± 0.2 L/min to be acceptable. If the main flow reading is within acceptable limits, go to step 11. If the main flow reading is not within acceptable limits notify APCD or perform the software and hardware calibrations for the mass flow controller and re-verify the flow rate.
10. Remove the 3/8" Swagelok cap from the flow splitter bypass extension (or open the valve as described above).
11. Install the bypass flow line onto the flow splitter bypass extension.
12. Perform a leak check as previously discussed.
13. Remove the flow audit adapter from the top of the flow splitter.
14. Install the sample inlet onto the flow splitter.

15. Install a new TEOM filter into the mass transducer.
16. Press the <F1> or <RUN> key.
17. Note the results on the TEOM log sheet.

6.0 CALIBRATION PROCEDURES

All calibration procedures must be done in the following order.

6.1. Hardware setup Prior to Calibrating

Follow these steps to set up the hardware prior to performing any calibration procedure:

1. Turn off the control unit.
2. Remove all the external cables from the back of the control unit EXCEPT the Ambient Temperature sensor connector.
3. Remove the cover of the control unit.
4. Detach the ribbon cables connected to P2, P3 and P4 on the L-shaped analog input/output board (see Operating Manual Figure 8-1).
5. Turn on the control unit.
6. Press <DATA STOP> to enter the Setup Mode.
7. Select "Analog Calibration" from the Menu Screen, or type <1>, <1> and <ENTER> when in any screen, to display the Analog Calibration Screen on the four-line display.
8. Enter "YES" on the "Calibrate" line by pressing <EDIT>, and then <YES>.
9. Move the cursor to the "A/O Value" line.
10. Place the "+" lead of the multimeter on the white analog output test point 0, and the "-" lead on a black GND (ground) test point.

NOTE: The readings on the Analog Calibration Screen are in percent of full scale (% FS) for both the inputs and outputs. Therefore, to output 6.500 VDC on a 0-10 VDC output channel, enter "65.00" on the "A/O Value" line. For a ±2 VDC input with 1 VDC applied to the channel, you would see "50.00" on the display for the analog input channel, indicating 50% of full scale.

NOTE: The potentiometers labeled TEMP and ALL GAIN should not be adjusted. They are preset at Thermo Electron Corp. (formerly R&P).

6.2. Calibrating the Analog Output (D/A)

Follow these steps to calibrate the analog output (D/A) section of the analog card:

1. Set the "A/O Value" to "90.00" by pressing <EDIT>, <9>, <0> and <ENTER>. This causes the output on all installed analog output channels to be 90% of full scale. Monitor the multimeter for the proper readout while adjusting the appropriate GAIN ADJUSTMENT potentiometer for the analog output channel being calibrated.
2. Move the "+" lead of the meter to successive analog output channels, and adjust the appropriate potentiometer if necessary.
3. After each analog outputs channel has been calibrated set the "A/O Value" to "0.00."

6.3. Calibrating the Analog Input (A/D)

Follow these steps to calibrate the analog input (A/D) section of the analog card:

1. Place the "+" lead of the meter on the "0" test point of one of the analog output channels. Also, place the jumper from the 0 test point of analog *outputs* to the red 0 test point of the analog inputs.
2. Select the analog input channel 0 on the Analog Calibration Screen by typing <EDIT>, <0> and <ENTER> when the cursor is on the "A/I Chan" line. Enter a 90% of full-scale output on the "A/O Value" line appropriate for the analog input channel being calibrated (e.g. 1.8 VDC, which is 90% of ±2 VDC or 9 VDC, which is 90% of ±10 VDC). Monitor the voltmeter to ensure that the proper voltage is being applied, and look at the 4-line display to see what percentage of full

scale the analog input is measuring. Adjust the appropriate potentiometer for the channel being calibrated to achieve the proper percentage of full scale.

3. Repeat step 2 for each analog input channel populated on the board. Remember to move the jumper to the new analog input channel.
4. Once the analog input calibration is complete, turn off the power to the instrument and replace all cables, connectors and the top panel before restarting normal operation.

6.4. Ambient Air Temperature Calibration

Follow these steps to calibrate the ambient temperature sensor:

1. Perform the analog calibration procedure as previously discussed.
2. Obtain the current temperature at the ambient temperature probe in degrees Celsius (°C).
3. Remove the top cover of the control unit.
4. Display the ambient temperature reading in the Set Temps/Flows Screen.
5. Locate the analog board. It is the L-shaped board mounted on top of the CPU.
6. Adjust the potentiometer for analog input 8 on the analog board until the ambient temperature matches the actual temperature reading.
7. Wait 30 seconds for the reading to stabilize and readjust, if necessary.
8. Replace the top cover on the control unit.

6.5. Ambient Pressure Calibration

Follow these steps to calibrate the ambient pressure sensor:

1. Perform the analog calibration procedure as previously discussed.
2. Obtain the current barometric pressure (absolute pressure, NOT corrected to sea level) in Atmospheres (atm).
   - To convert from mm Hg at 0°C to atmospheres, multiply by 0.001316.
   - To convert from inches Hg at 32°F to atmospheres, multiply by 0.03342.
   - To convert from millibars to atmospheres, multiply by 0.000987.
   3. Remove the top cover of the control unit.
4. Locate the interface board on the back panel of the control unit.
5. Place the positive lead of the digital multimeter on the test point labeled “+10 V” (red) and the negative lead on test point GND (black).
6. Locate potentiometer R304, and adjust it until the reading is 10.000 VDC ± 0.001 V.
7. Display the ambient pressure reading in the Set Temps/Flows Screen.
8. Adjust potentiometer R509 until the display matches the actual pressure reading.
9. Wait 30 seconds for the reading to stabilize and readjust, if necessary.
10. Replace the top cover on the control unit.

6.6. Flow Controller Calibration (Software)

This software procedure allows the user to calibrate the sample and bypass flow rates without having to adjust any hardware. The software calibration can be performed if the actual flow rates are ± 10% of their set flow rates; otherwise a hardware calibration is needed.
The follow steps are used to calibrate the software of the flow controllers:

1. Turn off the control unit.
2. Disconnect the electric cable that links the control unit with the sensor unit (and FDMS unit, if applicable).
3. Remove the main and bypass flow lines from their connections on the back panel of the control unit.
4. Turn on the control unit and pump. Allow the instrument to warm up for 30 minutes from a cold start, or 5 minutes if it has just been operated.
5. Display the Set Temps/Flows Screen on the instrument by selecting “Set Temps/Flows” from the Menu Screen, or by typing <19> and <ENTER>. Then press <↑> and <↓> keys to position the screen so that “F-Main” and “F-Aux” appear on the screen, note the values displayed here.

6. Press <↑> and <↓> to position the cursor so that the "T-A/S" and "P-A/S" line appear on the screen. Note the existing settings for Average Temperature (on the left) and Average Pressure (on the left).
7. If the monitor is not in the Setup Mode, press <DATA STOP>.
8. If the TEOM is configured to sample according to an average site temperature and pressure then the operator should set these values to the current local conditions at the flow meter (the average pressure reading should be actual pressure NOT corrected to sea level). Disconnect the Ambient Temperature Sensor from the back of the control unit and reconnect a different sensor so that the value being reported reflects conditions at the flow meter.

   NOTE: Do NOT leave the temperature and pressure settings at 99 °C and 9 atm during a mass flow controller calibration.

9. Press the <↑> or <↓> key to position the cursor so that the "FAdj Main" and "FAdj Aux" lines appear on the screen.
10. Attach a FTS to the location labeled "Sensor Flow" on the back panel of the control unit. Do not attach the flow meter to the large bypass in-line filter, and do not attach any system components to the air input side of the flow meter. The FTS should have been recently calibrated to a primary standard, and should have an accuracy of 2% at 3.00 L/min.
11. Compare the TEOM's set point recorded in step 5 with the flow rate indicated by the FTS. If necessary, edit the values for "FAdj Main" so that the volumetric flow rates indicated by the flow meter match the set point recorded in step 5. The value for "FAdj Main" can be incremented and decremented by pressing the <↑> and <↓> keys during editing.
12. If a step adjustment greater than ±10% is necessary to calibrate the mass flow controller, you must perform a hardware flow controller calibration (see Flow Controller Hardware Calibration, below).
13. Repeat steps 11 to 14 for the Auxiliary Flow. Connect the flow meter to the port labeled "Bypass Flow" on the rear panel of the control unit.
14. Change the values for Average Temperature and Average Pressure back to their original values recorded in step 6 and connect the external ambient temperature sensor (the values for $PM_{2.5}$ sampling, or the seasonal average temperature and barometric settings for PM_{10} sampling).
15. Turn off the control unit.
16. Reattach the air lines to the back panel of the control unit.
17. Reconnect the electric cable that links the control unit with the sensor unit.
18. Turn on the control unit.
19. Perform a system leak test.

6.7. Flow Controller Calibration (Hardware)

Follow these steps to perform a hardware calibration of the main and auxiliary mass flow controllers: Perform an analog board calibration as previously discussed. Perform an ambient temperature and ambient pressure calibration as above.

1. Turn off the instrument.
2. Disconnect the cable that connects the control unit and the sensor unit.
3. Remove the top cover of the control unit.
4. Ensure that all connectors are fully seated on the mass flow controller board.
5. Turn on the instrument and the pump. Allow the instrument to warm up for 30 minutes from a cold start, or 5 minutes if it has been in operation.
6. Place the positive lead of the digital multimeter on the test point labeled "+10 V" (red) and the negative lead on test point AGND (black) on the main flow board.
7. Locate potentiometer R116 on the main flow board, and adjust it until the reading is 10.000 ± 0.001 VDC.
8. Place the positive lead of the digital multimeter on the test point labeled "+10 V" (red) and the negative lead on test point AGND (black) on the bypass flow board.
9. Locate potentiometer R116 on the bypass flow board, and adjust it until the reading is 10.000 ± 0.001 VDC.

10. Note the settings for Average Pressure shown on the Set Temps/Flows Screen. Press <DATA STOP> to place the instrument in the Setup Mode.
11. Unplug the ambient temperature sensor from the RS-232 port on the back of the instrument and replace it with a spare sensor so that the newly installed sensor is measuring the ambient temperature near the flow standard.
12. If you're calibrating a TEOM configured for PM_{10} sampling set the values of the Ambient Temperature Average and Set values to 99 after noting the current values.
13. Set the Average Pressure to the current local conditions at the flow meter (the average pressure reading should be actual pressure NOT corrected to sea level). Install a spare ambient temperature sensor near the flow controller so that the mass flow controller provides volumetric flow at these conditions.
    NOTE: Do NOT leave the temperature and pressure settings at 99 °C and 9 atm during a mass flow controller calibration.

14. Reset the adjustment factors for both mass flow controllers by changing the settings for "FAdj Main" and "FAdj Aux" on the Set Temps/Flows Screen to "1.000."
15. Connect the reference flow meter directly to the sensor flow fitting on the control unit. Do not attach the flow meter to the large bypass in-line filter, and do not attach any system components to the air input side of the flow meter. The reference flow meter should have been recently calibrated to a primary standard, and should have an accuracy of 1% at 3.00 L/min.
16. Set the main flow to 0.5 L/min on the front panel of the control unit and observe the actual reading on the flow meter. After approximately 10 seconds, adjust the zero potentiometer R119 on the main flow board until the flow is correct within ±0.03L/min.
17. Set the main flow to 4.5L/min on the front panel of the control unit and observe the actual reading on the flow meter. After approximately 10 seconds, adjust the span potentiometer R126 on the bypass flow board until the flow is correct within ±0.03 L/min.
18. Repeat steps 13 and 14 until both conditions are met.
19. Set the main flow to its operational rate (3, 2 or 1 L/min) on the front panel of the control unit and observe the actual reading on the flow meter. After approximately 10 seconds, adjust potentiometer R119 on the mass flow controller board until the flow is correct within ±0.03 L/min.
20. Connect the reference flow meter directly to the bypass flow fitting on the control unit. Do not attach the flow meter to the large bypass in-line filter, and do not attach any system components to the air input side of the flow meter.
21. Set the bypass flow to 2.0 L/min on the front panel of the control unit and observe the actual reading on the flow meter. After approximately 10 seconds, adjust the zero potentiometer R119 on the bypass flow board until the flow is correct within ±0.2 L/min.
22. Set the bypass flow to 18.0 L/min on the front panel of the control unit and observe the actual reading on the flow meter. After approximately 10 seconds, adjust the span potentiometer R126 on the bypass flow board until the flow is correct within ±0.2 L/min.
23. Repeat steps 18 and 19 until both conditions are met.
24. Set the main flow to its operational rate (13.67 L/min) on the front panel of the control unit and observe the actual reading on the flow meter. After approximately 10 seconds, adjust potentiometer R119 on the mass flow controller board until the flow is correct within ±0.2 L/min.
25. Change the values for the ambient pressure average and set back to '9'.
26. If the TEOM is configured to sample PM_{10} change the values for the ambient temperature back to their original values.
27. Turn off the control unit.
28. Reattach the air lines to the back panel of the control unit.
29. Reconnect the all electrical and sensor cables.
30. Replace the top cover and turn on the control unit.
31. Perform a system leak test.

6.8. Mass Transducer Calibration Verification

The calibration of the mass transducer in the Series 1400a monitor is determined by the mass transducer's physical mechanical properties. Under normal circumstances, the calibration does not change materially over the life of the instrument. Contact Thermo Electron Corp. (formerly R&P) if the results of the verification procedure indicate that the calibration constant has changed by more than 2.5% from the original R&P (now Thermo Electron Corp.) calibration constant. You can locate the original R&P (now Thermo Electron Corp.) calibration constant inside the mass transducer.

Follow these steps to confirm the system's K_0 calibration:

1. When in the Main screen, press the <DATA STOP> key on the monitor's keypad.
2. Press the <STEP SCREEN> key. The Menu screen will display on the four-line display.
3. When in the Menu screen, press the up (<↑>) and down (<↓>) arrow keys to select "K0 Confirmation."
4. Press the <ENTER> key. The "K_0 Confirmation" screen will display. You also can display the K_0 Confirmation screen by pressing <1>, <7> and then the <ENTER> key.
5. Press the <EDIT> key.
6. Press the up and down arrow keys to select the "Filt Wght" field.
7. Using the monitor's keypad, enter the weight of the pre-weighed calibration verification filter in the Filt Wght field.
8. Press the <F1> or the <RUN> key to operate the system without a filter and wait for the oscillating frequency shown in the upper right-hand corner of the screen to reach a maximum value.
9. Wait for the oscillating frequency value on the "K_0 Confirm" line to stabilize (maximum value is reached).
10. When the frequency stabilizes, press the <FIRST/LAST> key to record the frequency, (f_0).
11. Install the pre-weighed calibration filter in the instrument and wait for the frequency to stabilize again (maximum value is reached).
12. When the frequency stabilizes, press the <FIRST/LAST> key to record the frequency (f_1). The instrument will now automatically compute and display the audit value of the calibration constant (K_0) in the "Audit K0" field.

7.0 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 criteria set forth by the manufacture. Quality control covers specific procedures established for obtaining and maintaining data collection within those limits.

7.1. Quality Assurance

Quality Assurance (QA) refers to an integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process is of the type and quality needed and expected. Quality assurance analysts are typically independent from the program staff and have the authority to institute change within the system. Evaluation of the system occurs through routine audits. There are six commonly used data quality indicators for pollutants. The data quality indicators are discussed in the following sections.

7.1.1. Precision Procedure

7.1.1.1. Precision Introduction

Precision is defined as the measure of agreement among individual measurements of the same property taken under the same conditions. For TEOM analyzers, this refers to testing the TEOM analyzer's total (16.67 Lpm) and main (3.00 Lpm) flow rates. The biweekly flow rate verification must be performed at least once every two weeks, and is used to calculate the probability limits for the data.

After completing the flow rate verification test, a comparison is made between the known reference flow transfer standard flow rate (actual value) and the analyzer's reported flow rate (indicated value).

7.1.1.2. Precision Flow Test

1. Place the flow transfer standard, reference thermometer and reference barometer near the analyzer and allow the devices to equilibrate to ambient conditions.
2. Record Site and Date information on the TEOM Log Sheet.
3. If applicable, disable datalogger communications.
    a. Enter the appropriate ESC datalogger login and privilege-setting commands.
    b. Disable the TEOM channel on the station's datalogger.
    c. Read the datalogger time. Record the time on the station analyzer log and on the Audit Datasheet.
4. Perform flow rate verification as per Section 5.12.
5. Remove all audit equipment from the analyzer.
6. Verify that all components of the analyzer are properly reconnected.
7. From the Main screen press the <Stop All> button.
8. From the Main screen press the <F1> button.
9. If applicable, enable datalogger communications.
    a. Enable the TEOM channel on the station's datalogger.
    b. Read the datalogger time. Record the time on the station analyzer log and on the Audit Datasheet.
10. At the End of the month, collect all TEOM Log Sheets and enter the precision information into the appropriate (particulate) database.

7.1.2. Precision Data Procession

PM TEOM Data

The Continuous Monitoring Data System Support Unit maintains a database on the Air Pollution Control Division (ACPD) Local Access Network (LAN) for all PM TEOM data. This program records the results of all PM TEOM precision verifications conducted by Division personnel. Site information, sampler information, and parameter codes used in this database are consistent with those used in the Air Quality System (AQS) maintained by the EPA. This separate database allows the Division to more closely control the quality of the precision data before they are submitted to AQS.

Within 90 days of the end of a calendar quarter, all PM TEOM flow rate verifications are downloaded to an ASCII-format data file and then uploaded into the AQS database. The Particulate Monitoring Unit staff performs these data processing operations.

7.1.3. Accuracy Audit Overview

Accuracy is defined as the degree of agreement between a measured value and the true, expected, or accepted value. Quantitative comparisons are made between these two values during audits. The audit procedures described in this section outline the steps for implementing a performance audit for the Rupprecht & Patashnick Series 1400 TEOM monitor operated the by APCD. The primary objective of an auditing program is to identify system errors that may result in suspect or invalid data. Parameters evaluated include: time, leak, ambient temperature, ambient pressure, total flow, main flow, and mass verification (K_0).

For State and Local Air Monitoring Stations (SLAMS), audits shall be conducted on at least 50 percent of the operational samplers in the PM_{10} and $PM_{2.5}$ monitoring networks each quarter such that each sampler is audited at least twice per year. APCD's goal is to audit every TEOM within its network at least once per calendar quarter.

An audit is performed by challenging each parameter against a known NIST traceable standard. The instrument's main and total flow rates are challenged with a calibrated volumetric flow transfer standard. The actual instrument flow rate (3.00 Lpm) and total flow rate (16.67 Lpm) is measured with the transfer standard and reported for accuracy. The instrument clock is checked to verify it is within ±15 minutes of Standard Time. The temperature sensor is challenged with a NIST traceable thermometer to verify it is within ±2 °C. The pressure sensor is challenged with a NIST traceable barometer to verify it is within ±10 mmHg of the audit measurement.
For more complete information on the accuracy audit conducted by the QA unit please see SOP QA1 which can be found in the appendicies of the APCD TSP QAPP

7.1.4. 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.

7.1.5. 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.

7.1.6. 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. While there is no completeness criteria for TEOM analyzers, APCD believes 75% completeness is an achievable goal.

7.1.7. 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. For sites where TEOMS are collocated with FRMs, the APCD routinely compares TEOM data with the corresponding FRM to develop a measure of comparability.

7.2. Quality Control

Quality Control (QC) refers to procedures established for collecting data within pre-specified tolerance limits. Program staff responsible of the operation of the TEOM network is typically responsible for the implementation of a quality control program. Almost all QC procedures have already been covered under specific topics throughout this document. Quality Control includes tasks such routine maintenance, analyzer verifications, data verifications and calibrations.

7.2.1. Documentation

Documentation is important in all measurements. Extensive certification paperwork must be rigorously maintained for each standard and analyzer.

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.

7.2.2. System of Quality Control

Currently an APCD staff services the TEOMS on a weekly, 2-week, 6-month and annual schedule. Maintenance is performed on both the control and sensor units. For more information regarding what tasks are routinely performed on a weekly and monthly schedule, refer to section 5 in this SOP.

Figure 5 – Audit Datasheet

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Air Pollution Control Division - Technical Services Program

TEOM Accuracy Audit

Site Name: Chatfield

Site Info.		Auditor Site Info.		Date Time		Status Line Info.	
AQS ID:	080350004	Action Description:	Quarterly Audit	Audit Date (mm/dd/yy)	5/29/2014	Status Code:	ok
SamplerType:	PM2.5	Auditors Initials:	cws	Audit Time (hh:mm)	1:46	Operating Mode:	4
Cyclone Type:	VSCC	Conditions:	Acceptable	Sampler Date (mm/dd/yy)	5/29/2014	A/O 1 Mode:	
Case Temp Set:	30	Cyclone Clean?:	Yes	Sampler Time (hh:mm)	1:45	% Filter Loading:	29
AQS Parameter:	88501			Difference (hh:mm)	0:01	RS-232 Mode:	A
AQS Method:	715					Protection Level:	U
AQS Units:	118 POC: 3						

Upload to AQS ☑

Main Screen Information	
Noise:	.031
Initial Frequency:	234.62304
QA Pressure (inHg):	24.56

Set Hardware Information	
Cal. Constant. Hardware (K0):	12826
Cal. Constant Software (K0):	12826
Control Unit SN:	
* Sensor Unit SN:	173320304
Type:	1400a
Version:	

* (information inside sensor box on a tag near sensor electronics)

Set Flow/Temp Screen Info.		
Case Temp:	40	
Air Temp:	40	
Cap Temp:	40	
Aux. Flow:	13.67	0.0%
Main Flow:	2.99	-0.3%

Temperature Pressure Verification			
Parameter	Units	Sampler	Audit Standard
Ambient Pres.	(atm)	0.820	0.821
Ambient Temp.	(C)	27.5	28.1
Aux. Temp.	(C)	0.0	0.0

Leak Check Verification	
Parameter	l/min
Aux. (< 0.60 L/min)	0.11
Main (< 0.15 L/min)	0.03

Mass Transducer Calibration Verification			
Initial Freq.	320.53520	True K0:	12826
Final Freq.	235.08940	Audit K0:	12987
		% Diff.	-1.2%

Flow Rate Verification							
Parameter	Units	Sampler	Audit Standard	Delta H2O	Ta (C)	Audit %Diff	Design %Diff
Total Flow (16.67 lpm)	(Lpm)	16.66	16.69	16.90	28.0	-0.2%	-0.1%
Main Flow (3.00 lpm)	(Lpm)	2.99	2.90	0.580	28.0	3.3%	3.6%
Aux. Flow (13.67 lpm)	(Lpm)	13.67	13.80	na	na	-0.9%	-0.9%

Standards Information	
Barometer Make:	Pretel
Barometer SN:	26668
Thermometer Make:	VWR
Thermometer SN:	341803
Thermometer Probe:	None Visible
Manometer Make:	Dewyer
Manometer SN:	K002809A
FTS Make (High):	Inflow
FTS SN (High):	JD263H
FTS Cert Date (High):	5/6/2014
Slope (High):	0.2097
Intercept (High):	0.1817
FTS Make (Low):	Inflow
FTS SN (Low):	JD263L
FTS Cert Date (Low):	5/7/2014
Slope (Low):	0.2177
Intercept (Low):	-0.2804
MCV Filter ID:	QA006M #2
MCV Filter Weight (g):	0.10858
MCV Filter Cert. Date	3/18/2014

Audit Results			
Parameter	Value	Pass / Fail	Criteria (PM10)
Temperature Pressure Verifications			
Pressure (atm)	-0.001	Pass	+/- 0.013 atm
AmbientTemperature (C)	-0.6	Pass	+/- 2 C
Aux. Temperature (C)	0.0	Pass	+/- 2 C
Date/Time Leak Verifications			
Date Time (hh:mm):	0:01	Pass	< 20 min
Aux. Leak Check:	0.11	Pass	< 0.60 lpm
Main Leak Check:	0.03	Pass	< 0.15 lpm
Flow Verifications (l/min)			
Main Flow Check:	3%	Pass	<+/- 4%
Main Design Flow Check:	0.10	Pass	<+/- 0.15 lpm
Total Flow Check:	0%	Pass	<+/- 4%
Total Design Flow Check :	-0.02	Pass	<+/- 0.83 lpm
MCV:	-1.2%	Pass	< +/- 2.5%

Comments: