Alaska Department of Environmental Conservation

Air Quality Division

FDMS
(FILTER DYNAMICS MEASUREMENT SYSTEM)
Standard Operating Procedure

September 2009

____ **Date:**____________________
Alice Edwards, Air Quality Program Director

____ **Date:**____________________
Barbara Trost, Air Monitoring

____ **Date:**____________________
Dan Fremgen, Quality Assurance

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1 INTRODUCTION

This document describes the procedures used by the Alaska Department of Environmental Conservation Air Quality Program to sample PM2.5 (particulate matter with an aerodynamic diameter of 2.5 micrometers or less) using the Rupprecht and Patashnick (R&P) 1400a Tapered Element Oscillating Microbalance (TEOM)®.

The TEOM, configured to sample PM2.5 and generate continuous concentrations under actual conditions, can be recognized as an EPA correlated acceptable continuous (CAC) monitor per 40 CFR 58, App. C; it is therefore collocated with an FRM filter-based sampler. The TEOM provides continuous data that is used to supplement FRM data to determine diurnal cycles, identify the need to increase FRM sampling frequency, evaluate real-time data to issue alerts or implement control strategies, and provide data when the FRM sampler is not sampling.

This section of the Quality Assurance Manual covers the operation and maintenance of the R&P 1400a TEOM. This document is intended to be used together with the sampler-specific information and instructions provided by the manufacturer of the PM2.5 monitor. It is the responsibility of an operator to be familiar with the operating manual so as to ensure the greatest level of quality assurance possible.

1.1 THEORY OF OPERATION

Particle separation in a TEOM occurs by drawing a controlled volume of air (16.67 L/min) through a cyclone inlet. Figure 1.1 is a schematic drawing showing the cyclone head of the PM2.5 sampler. It depicts the cyclone head that removes particles greater than 2.5 um and allows particles 2.5 um in diameter and smaller to be collected on a Teflon® coated glass fiber filter surface. The design flow rate through the inlet is 16.67 L/min. At the exit of the inlet, the flow is split isokinetically into a main flow of 3.0 L/min and an auxiliary bypass flow of 13.67 L/min. The main flow, which contains the analyte fraction of particulate, is sent to the instrument's mass transducer

The mass transducer in the sensor unit has a thin, hollow ceramic tapered tube fixed at the downstream end and a filter attached on the upstream end. As air is drawn through it, the element oscillates like a tuning fork. The frequency of oscillation is dependent upon the physical characteristics of the tapered tube and the mass on its free end, i.e,. the filter. As the filter progressively loads with particulate matter, the oscillation frequency of the element changes proportionally. The sensor unit computes the oscillation frequency into a particulate concentration by dividing the mass rate by the flow rate.

To minimize a bias caused by atmospheric moisture, the sample stream entering the TEOM sensor unit is heated to 30° C. to minimize water collection on the sample filter. As the air is drawn into the TEOM, the sample stream (main flow) is heated at the base of the air inlet (Air temperature). The temperature of the upper part of the mass transducer (Cap temperature) and the rest of the mass transducer (Case temperature) and the temperature inside the sensor/control unit (Enclosure temperature) are all controlled at specific temperature set points.

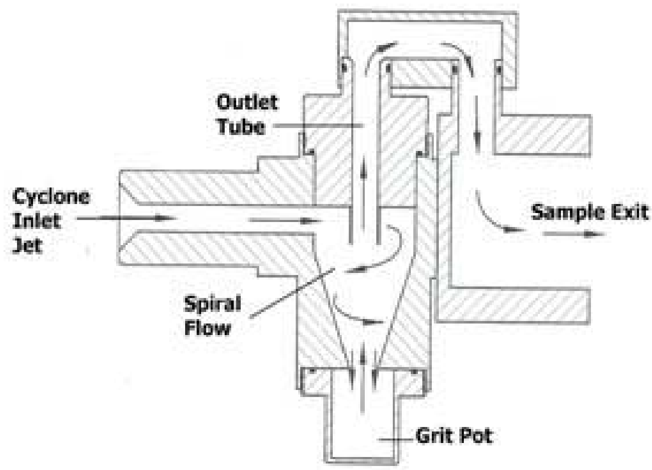


Figure 1-1 Particulate flow path through PM 2.5 Sharp Cut Cyclone
Note: This inlet is oriented horizontally; Installations of monitors should have a vertical flow path

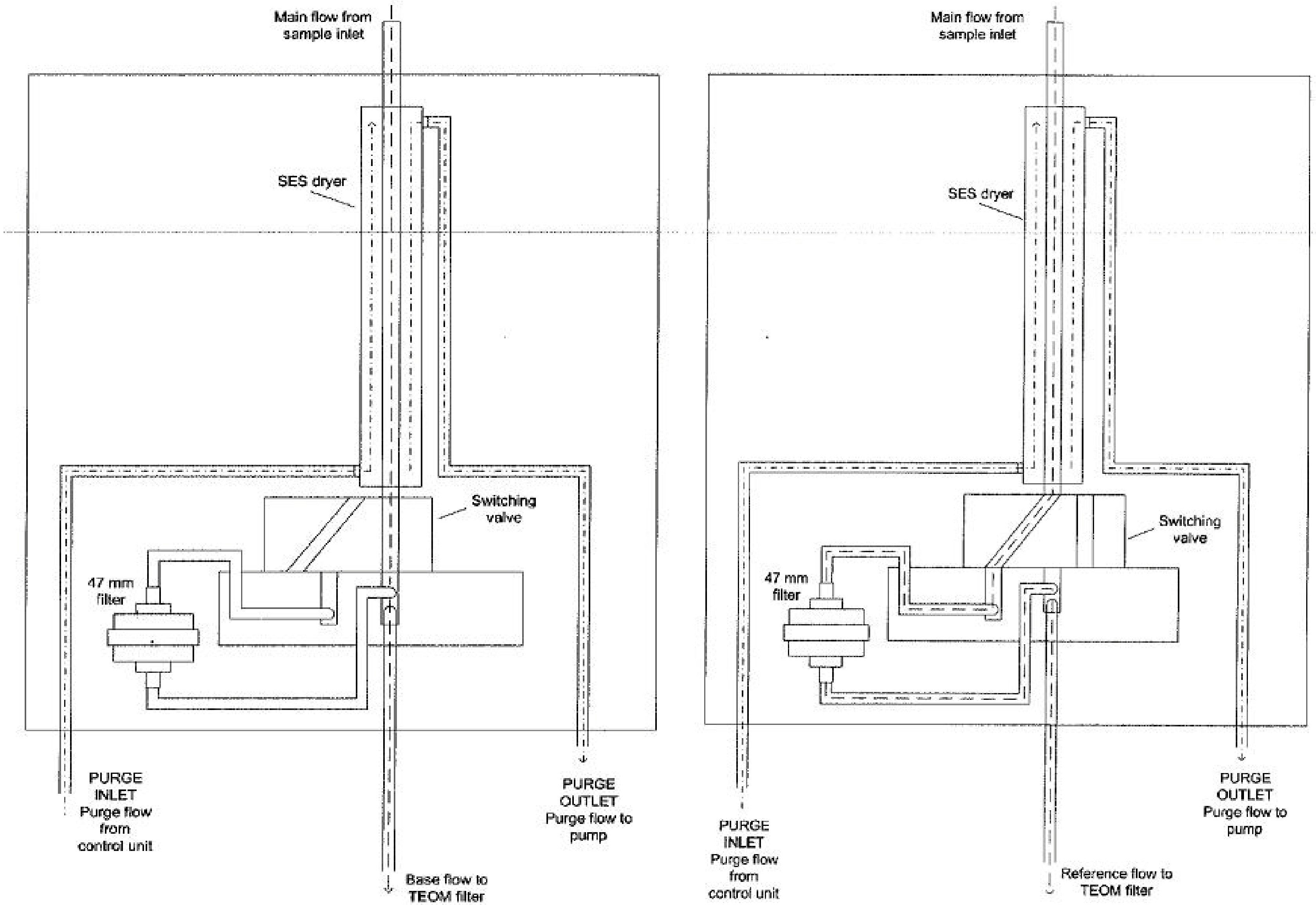


Figure 1-2 Schematic Diagrams of FDMS with switching valve in Base and Reference Flow positions

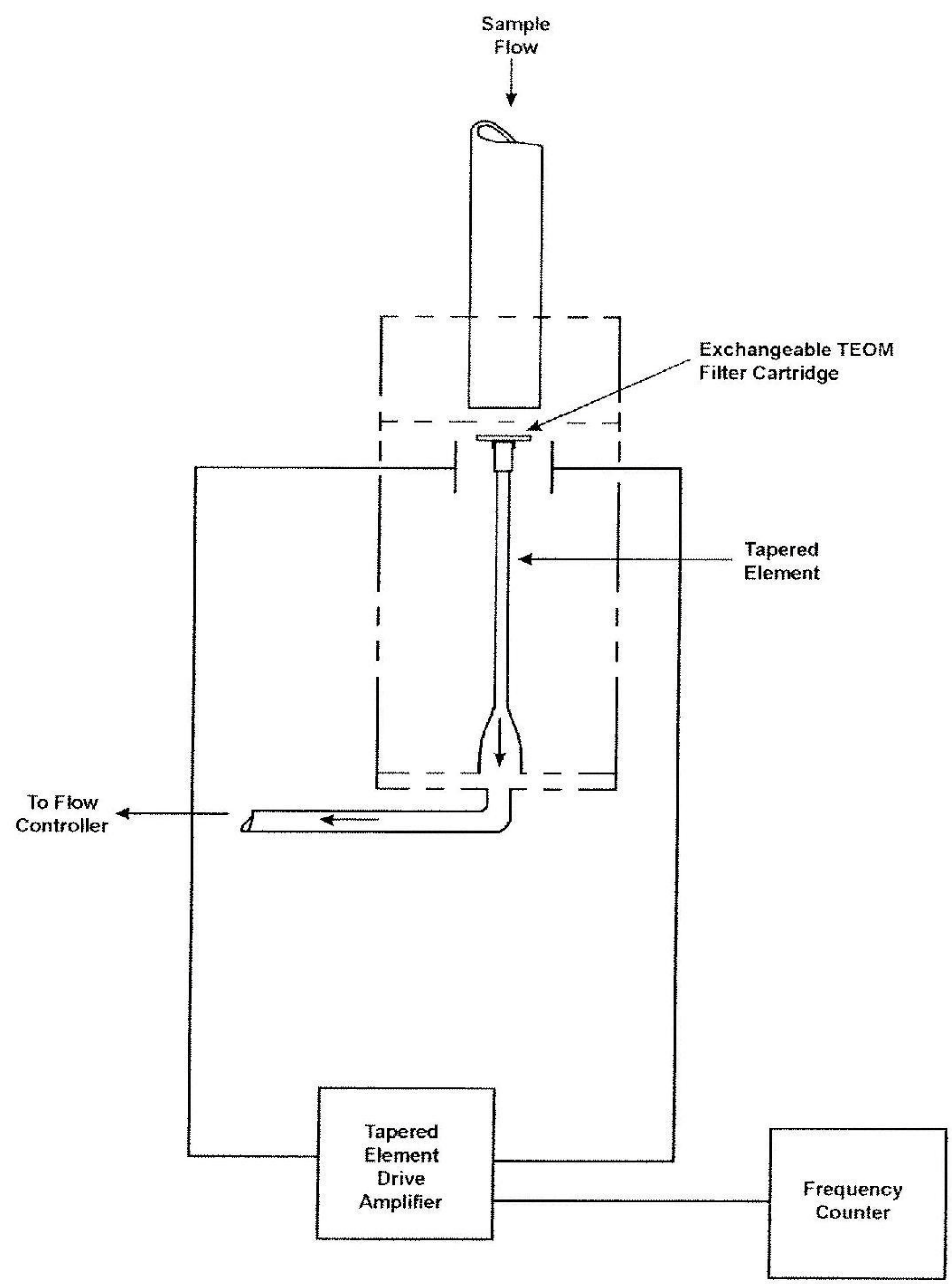


Figure 1-2 Schematic Diagram of Mass Transducer
Image taken from TEOM Manual Rev. B.001 Page 1-12

2 EQUIPMENT & SUPPLIES

- ✓ The TEOM Series 1400a Monitor.
- ✓ FDMS Series 8500 module
- ✓ Additional monitor parts and supplies consisting of TEOM filter, filter exchange tool, bypass in-line filters, flow controller filters, sample tube extensions.
- ✓ Calibration equipment as defined in Section 3.0.
- ✓ Periodic maintenance equipment as defined in Section 6.0.
- ✓ Miscellaneous hand tools, miscellaneous monitor spare parts including additional gaskets/seals, flat screwdriver, soft brushes & cotton swabs, calculator, Kimwipes, and worksheets.
- ✓ Copies of the most up-to-date TEOM Service manual and TEOM operating manual.
- ✓ On-site logbook

3 CALIBRATION PROCEDURES

This section describes the procedures involved in calibration of the TEOM 1400a monitor. Because PM2.5 concentration standards are not available for determining calibration relationships, individual components of the sampling method must be calibrated to ensure integrity of reported data.

Discussion Of Flow-Rate Measurement And Calibration

The monitor's mass flow controllers operate under the control of the monitor's microprocessor which maintains the total sampled air stream at a constant volumetric flow rate of 16.67 L/min. through the use of ambient temperature and pressure sensors.

4.1 TEOM Calibration Procedure

Calibration Equipment

- ✓ A deltaCal field audit calibrator transfer standard with current documented NIST traceability
- ✓ A thermometer capable of accurately measuring temperature over the range of -30°C to +50°C (243 K to 323 K) to the nearest ± 0.1°C and referenced to an NIST thermometer within ± 0.5°C at least annually.
- ✓ A portable, aneroid barometer (e.g., a climber's or engineer's altimeter), capable of accurately measuring ambient barometric pressure within ± 1 mm Hg resolution and referenced within ±5 mmHg to a barometer referenced to a NIST standard.
- ✓ Table 3-2 TEOM PM2.5 Calibration Sheet and Table 3-1 Calibration And Verification Check Intervals
- ✓ A clean filter.

Flow Controller Calibration (Software)

The required interval to perform the software procedure to calibrate the main and auxiliary flow rates is every six months. Follow the steps below to perform a software calibration of the flow controllers.

1) Turn off the TEOM Control Unit.
2) Disconnect the electric cable that links the control unit with the sensor unit.
3) Remove the main and bypass flow lines from their connections on the back panel of the TEOM Control Unit.

4) Turn on the TEOM Control Unit, and make sure the pump is on.

5) Display the Set Temps/Flows Screen on the instrument by selecting "Set Temps/Flows" from the Menu Screen. This can also be accomplished by entering 19<Enter>. Press <↓> and <↑> to position the screen so that "F-Main" and "F-Aux" appear. Record the set points for the main and auxiliary flows.

6) Press <↓> and <↑> to position the cursor so that the lines entitled "T-A/S" and "P- A/S" appear on the screen. Record the existing settings for Average Temperature and Average Pressure. If the monitor is not in the Setup Mode, press <Data Stop>. Then set the Average Temperature and Average Pressure to the current local conditions at the station.

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

7) Press <↓> and <↑> to position the cursor so that the lines "FAdj Main" and "FAdj Aux" appear on the screen. Attach a flow meter to the location labeled "Sensor Flow" on the back panel of the TEOM Control Unit.

8) Compare the set point recorded in step 5 above with the flow rate indicated by the flow meter. This set point indicator is in volumetric liters per minute.

9) If necessary, edit the values for "FAdj Main" so that the volumetric flow rates indicated by the flow meter matches the set point recorded in step 5 above. The value for "FAdj Main" can be incremented and decreased by pressing <↓> and <↑> keys during editing.

10) If a step adjustment of greater than ±10% is required then it is necessary to calibrate the mass flow controller: a hardware calibration must be performed.

11) Repeat steps 7 to 10 above, replacing the references to the Main Flow with Auxiliary (Bypass) Flow. Connect the flow meter to the port labeled "Bypass Flow" on the rear panel of the TEOM Control Unit.

12) Change the values for Average Temperature and Average Pressure back to their original values recorded in step 6.

13) Turn off the TEOM Control Unit and re-attach the air lines to the back panel of the TEOM Control Unit. Reconnect the electric cable that links the control unit with the sensor unit and turn on the TEOM Control Unit.

14) Perform a system leak test as described in section 3.2.3.

Leak Check

Perform the following steps to test for leaks.

1) Operate the monitor in the usual fashion with the sample pump running.

2) Remove the TEOM filter cartridge from the mass transducer to prevent accidental damage from occurring to the sample filter when exposed to the high pressure drop in the sample line that the leak check creates.

3) With the instrument displaying the Main Screen, press the keys to show the Main Flow and Auxiliary Flow on the four line alphanumeric display.

4) Remove the size-selective inlet from the flow splitter and replace it with the Flow Audit Adapter and close the valve.

5) For the 16.7 l/min system, both the Main Flow and Auxiliary Flow readings on the display should read less than 0.15 l/min and 0.60 l/min respectively.

6) If the leak test indicates a problem, check hose fittings and other critical locations in the flow system for leaks.

7) Remove the Flow Audit Adapter.

8) Replace the sample inlet.

9) Replace the TEOM filter.

Mass Transducer Calibration Verification

This procedure is used to confirm the mass calibration of the monitor using a single pre-weighted filter as a calibration weight. Since the mass of the filter with particulate differs from the mass of a new filter by only a small fraction, calibrating the system with a calibration mass equivalent to the filter mass allows all measurements to be made at essentially the same operating point as the original calibration. The monitor is calibrated using a Calibration Verification Kit consisting of a pre-weighed calibration filter, filter exchange tool, desiccant for humidity protection and a humidity indicator is available from R&P under part number 59-002017. Perform the following steps to confirm the system's mass calibration using the Mass Calibration Verification Kit with the K0 Calibration Screen displayed on the monitor:

1) Check the humidity indicator included in the Kit before proceeding with the mass transducer calibration verification.

2) From any screen press 17<Enter> to access the K0 Confirmation screen. Confirm the Calibration Constant shown on the Set Hardware Screen is the same as that

shown on the nameplate located on the left side of the mass transducer support cage.

3) Warm up the system with any filter cartridge that is not the calibration filter so that all the temperatures are at their normal operating conditions for at least one hour. The airflow through the system should be at its normal value during this period.

4) Disable the average for the TEOM at the data logger. Enter the Setup Mode on the control unit by pressing the keypad "Data Stop". Turn off the air tube heater by setting the set point to 0 on the Set Temps/Flows Screen.

5) Unplug the vacuum pump so there is no flow through the instrument. This prevents particulate contamination of the calibration filter.

6) Scroll through the Menu Screen (using "Stop Screen" and the down arrow on the keypad of the control unit) and select the last item, "KO Confirmation".

7) When KO Confirmation is selected, the following screen will appear:

    KO confirm 251.54104 (This is the current frequency output and will vary by instrument.)
    Hit Wght 0.00000
    0.00000 0.00000
    Audit KO 0

8) Use the down arrow keypad to move to the "Filt Wght" Input the weight of the pre-weighed calibration filter, as recorded on the Kit data, on the line labeled “Filt Wght” by pressing the "Edit" keypad and then the value.

9) Open the mass transducer and remove the media filter from the tip of the tapered element using the filter exchange procedure. Close the mass transducer and sensor unit door. 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. Observe the frequency output next to "KO confirm' on the first line of the KO Confirmation screen. The frequency will increase, peak and then start to decrease in value. When the frequency peaks, press the 'First/Last" keypad (in the center of the arrow keys) to record this frequency fO value in the first slot an the third line of the screen. (Note: If you miss the peak you can open and close the transducer again and observe the frequency a second time to catch the peak value.)

10) Remove the filter tool and filter box containing the calibration filter from the Mass Transducer Calibration Verification Kit. (Note: The calibration tool can be distinguished from a normal filter tool by its red handle. Do NOT use the calibration filter tool to remove or install any filters except for the calibration filter.)

11) Install the calibration verification filter with the filter exchange tool provided with the kit, in the instrument. Note that the filter exchanges are normally performed with the pump on to help the filter become properly seated on the tapered element. Since the pump is not on, take special care to ensure that the filter is properly seated. Close the mass transducer and sensor unit door. Replace the calibration tool immediately to the Kit and reseal the bag. Again watch the frequency output and the control units screen and when it peaks to reach a new maximum value.

12) Press the <First/Last> key again to record the frequency f1.

13) The instrument then automatically computes and displays the audit value of the calibration constant, K0 on the line entitled "Audit K0". An example of the final screen display is as follows.

    KO confirm 252.36530
    Filt Wght 0.08226
    336.67858 252.36538
    Audit KO 11957

14) The K0 confirmation Screen also displays the current K0 value entered in the monitor and the percentage difference between the audit and currently entered value. Contact a DEC monitoring technician if the results of the verification procedure indicate a difference of more than 2.5% from the original R&P calibration constant.

QC % Difference =

$$\left(\frac{AuditKO - CalConst.}{CalConst.} \right) * 100$$

15) Record this information on Initial Calibration Sheet Table 3-2 .

Analog and Flow Controller Hardware Calibration

For analog and mass flow controller hardware calibration refer to section 3.5 of the TEOM service manual.

Ambient Air Temperature Sensor Calibration

For ambient air temperature sensor calibration refer to section 3.2.3 of the TEOM service manual.

Ambient Pressure Sensor Calibration

For ambient pressure sensor calibration refer to section 3.2.4 of the TEOM service manual.

Setting and Verifying the TEOM Clock

The time on the data logger will be used to verify accurate time on the TEOM monitors. The system time and date can be verified in the Set Time Screen. To enter this screen, press 03<Enter> from any screen. Verify the time on the screen with the time on the data logger and that the time on TEOM is within ± 1 minute of the time on data logger.

If the time is not within ± 1 minute of the data logger, then follow the steps below to adjust the time.

1) The time can be only changed when the instrument is in Setup Mode. Press <Data/Stop> to enter the Setup Mode.

2) Use the <↓>and <↑> keys to adjust the time.

3) Allow the unit to run for at least 48 hours. If, after 48 hours, the clock has drifted from the reference time, press the <Data Stop> key on the instrument keypad to enter Setup Mode.

4) Press the <Time/Date> key on the instrument keypad to enter the Set Time Screen.

5) Press the <CTRL> and <INIT> keys simultaneously on the instrument keypad. An asterix will appear in the upper left corner of the screen.

6) Set the hour, minute and second variables to a time one minute later than the reference time: the time on the data logger.

7) At the very moment the data logger time reaches the time set on the instrument, press the <CTRL> and <INIT> keys simultaneously on the instrument keypad.

8) The system then calculates the rate of change constants ("Soft Rate" and Hard Rate") for the clock. These constants can be viewed from the Setup Screen.

9) Return the instrument to normal operation.

NOTE : If it is found that the clock on the 1400a monitor is drifting significantly, software version 3.009 or higher should be downloaded into the instrument and then the clock adjustment procedure should be performed.

4.2 Monitor Calibration Frequency

Table 3.1, below summarizes the calibration and verification frequencies.

Table 3-1 Calibration And Verification Check Intervals

	Frequency	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Acceptance Criteria
Flow Rate Verification Main Flow Auxiliary Flow	Once a month													± 10% of the Transfer Standard
Flow Controller Calibration (Software)	Twice a year													
Temperature Verification	Once in 30 days													± 4 °C of Standard
Pressure Verification	Once in 30 days													± 10 mm Hg.
Clock/timer Verification	Once in 30 days													1 min/month
Mass transducer calibration verification	Once a year													
Leak Check	Once in 30 days													0.15 L/min

Table 3-2 FDMS PM 2.5 Calibration Sheet

AIRS Station # ______________________ Date: ______________________

Location: ______________________ Time: ______________________

Monitor # ______________________

Operator Name and Initials: ______________________

Flow Calibration

Total Actual________L/min Indicated________L/min % Difference ________%

Main Actual________L/min Indicated________L/min % Difference ________%

Aux. Actual________L/min Indicated________L/min % Difference ________%

$$\textbf{QC \% Difference} = \left[\frac{\textbf{Ind} - \textbf{Act}}{\textbf{Act}}\right] \times \textbf{100}$$

Mass Flow Controller Calibration (Software) ______________________

Ambient Temperature Sensor Calibration

Actual________°C Indicated________°C Difference________°C

Ambient Pressure Sensor Calibration

Actual________mm Hg Indicated________mm Hg Difference________mm Hg

Time Calibration

Actual Time________ Indicated________ Soft & Hard Rate________

Mail to Quality Assurance Unit

4 FIELD OPERATIONS

This section presents information pertinent to the routine operation of the FDMS. It covers an array of topics, ranging from site selection to monitor installation to filter exchanges.

4.1 Siting Requirements

FDMS's will be collocated with a PM2.5 FRM sampler so in most cases siting criteria will have already been met. The monitor can be installed at the site in the R&P shelter or in the monitoring station. Complete siting criteria are presented in 40 CFR 58, Appendix E.

4.1.1. Installation Considerations And Other Requirements

The Series 8500 FDMS consists of three basic components: the TEOM sensor unit (containing the sample inlet and mass transducer), the TEOM control unit (containing the operator terminal and control electronics) and the FDMS module containing the switching valve and . There are 2 configurations for network installations. When installing the FDMS in a shelter located with reference or equivalent method sampling equipment, the monitoring station must be maintained between 20 and 30 °C. Otherwise the shelter must be maintained between 10 and 30 °C. These units are connected by a 10 meter (optionally 2 or 20 m) cable/ tube assembly. A sampling tube is fed through the roof to the sampler inlet. The sample line must be in a straight line from the inlet to the inlet of the sensor unit through a 4 cm diameter hole in the roof.

The second installation configuration requires the use of the R&P environmentally controlled outdoor enclosure, maintained between 10 and 30 °C, located atop the monitoring station. The monitor should be located so that the operator can load the filter without rain or snow landing on the filter.

Several additional factors must also be considered in determining placement of the monitor. For installation in the R&P outdoor enclosure the primary factor of concern determining the placement of the sensor unit is the need for sturdy, vibration free mounting that will be as independent as possible from other activities in the area. Since the TEOM sensor unit operates on the principle of an oscillating element, it is vibrationally sensitive and hence consideration of nearby vibrational sources must be addressed. Also, when locating the TEOM Sensor Unit inside a monitoring station, avoid locations with direct exposure to sun or in proximity to an air conditioning outlet.

Accessibility under all weather conditions, availability of adequate and stable power source of 110 Volt, security of the monitoring personnel and equipment must be taken into consideration. The site must be able to provide sufficient power for the FDMS, a FRM, and a FRM performance evaluation monitor.

The monitor must be situated where the operator can reach it safely despite adverse weather conditions. If the monitor is located on a rooftop, care should be taken that the operator's personal safety is not jeopardized by a slippery roof surface during inclement weather. Consideration also should be given to the fact that routine operation (i.e., calibrations, filter installation, flow checks, and audits) involves transporting supplies and equipment to and from the monitoring site.

The security of the monitor itself depends mostly on its location. Rooftop sites with locked access and ground-level sites with fences are common. The security of the operating personnel, as well as that of the monitor must always be considered.

4.2 Monitor Installation

4.2.1. Installation of a FDMS

1) On receipt of a FDMS monitor, visually inspect it to ensure that all components are accounted for. Notify the laboratory immediately of any missing or damaged equipment.

2) Carefully transport the monitor to the field site. Secure the monitor in its location keeping it level.

3) Install the FDMS brace stand on onto the top of the TEOM sensor unit on the left side of the sample inlet.

4) Install the 8500 Module on the sensor unit by placing the main flow outlet port onto the sample inlet and tightening the Swagelok fitting, and placing the purge flow inlet and outlet ports into the top of the brace stand and inserting the set screw.

5) Install the insulation sleeve onto the exposed sample inlet between the sensor unit and the 8500 module.

6) Mount the Flow Splitter Adapter on the end of the inner tube inside the Flow Splitter and adjust the inner tube of the Flow Splitter so that the end of the inner tube is 15 cm from the open end of the outer tube. This distance is labeled “A” in Figure 4-1. The adjustment is made by loosening the ½” nut (labeled “C” in Figure 4-2) holding the sample tube, and sliding the tube into the proper position. Avoid crimping the sample tube by over-tightening the nut during re-assembly.

7) Connect the exit of the Flow Splitter with the inlet of the FDMS module by installing additional lengths of sample tube, as needed, through the roof opening. The connecting sample tube may be cut to length as necessary. The Flow Splitter may be moved vertically in the optional tripod mount to make final height adjustments.

8) Connect a short section of green tubing (~5”) to the “SENSOR FLOW” port on the back of the control unit. Next connect a large in line filter on the end of the green tube so the arrow points away from the control unit. Insert the 3/8 inch to ¼ inch reducer fitting into the inline filter and connect to the sensor unit using the ¼ inch black tubing.

9) Connect a short section of green tubing (~5") to the "BYPASS FLOW" port on the back of the control unit. Next connect a large in line filter on the end of the green tube so the arrow points away from the control unit. Connect a section of green tubing long enough to reach between the control unit and the flow splitter to the inline filter and to the flow splitter using the Swagelok fitting. If necessary, the moisture trap will be installed between the flow splitter and the control unit.

10) Connect a length of green tubing long enough to reach the sample pump to the bypass pump port on the dual flow fitting (the port without the dimple next to it).Cut a 2 inch length of tubing and install it into the sample pump, then connect the single port of the the Y shaped push connect fitting. Install the other end of the tube that is connected to the bypass pump port to one side of the Y fitting.

11) Connect a section of green tubing long enough to reach between the FDMS module and the control unit. Connect one end to the Purge inlet on the FDMS Module and the other end to the main flow port on the dual flow fitting (the port with the dimple next to it)

12) Connect a section of green tubing long enough to reach between the FDMS module and the sample pump. Connect one end to the Purge outlet on the FDMS Module and the other end to the main flow port on the dual flow fitting (the port with the dimple next to it)

13) Install the 9 to 15 pin valve signal cable to 9 pin VALVE CONTROL port on the back of the FDMS module and the 15 pin ACCU port on the back of the control unit.

14) Install the 15 to 15 pin data interface cable to 15 pin STATUS port on the back of the FDMS module and the 15 pin EXT ANALOG port on the back of the control unit.

15) Install the electrical connector cable to SENSOR unit port on the back of the control unit and the 25 pin connection port on the side of the sensor unit

16) Thread the continuous ambient temperature sensor cable from the sampling location to the TEOM Control Unit. Install the connector at the other end of the cable at the location labeled "Ambient Temp" on the backside of the control Unit.

17) Connect the ambient temperature sensor to the Flow Splitter or at a representative outdoor location.

18) Install the sample inlet over the open end of the Flow Splitter and verify that the entrance to the sampling head is 1.8 to 2.1 m above the roof. Weather seal the opening in the roof.

4.2.3. Installation of a FDMS with the R&P Enclosure

1) Follow the R&P instruction manual.

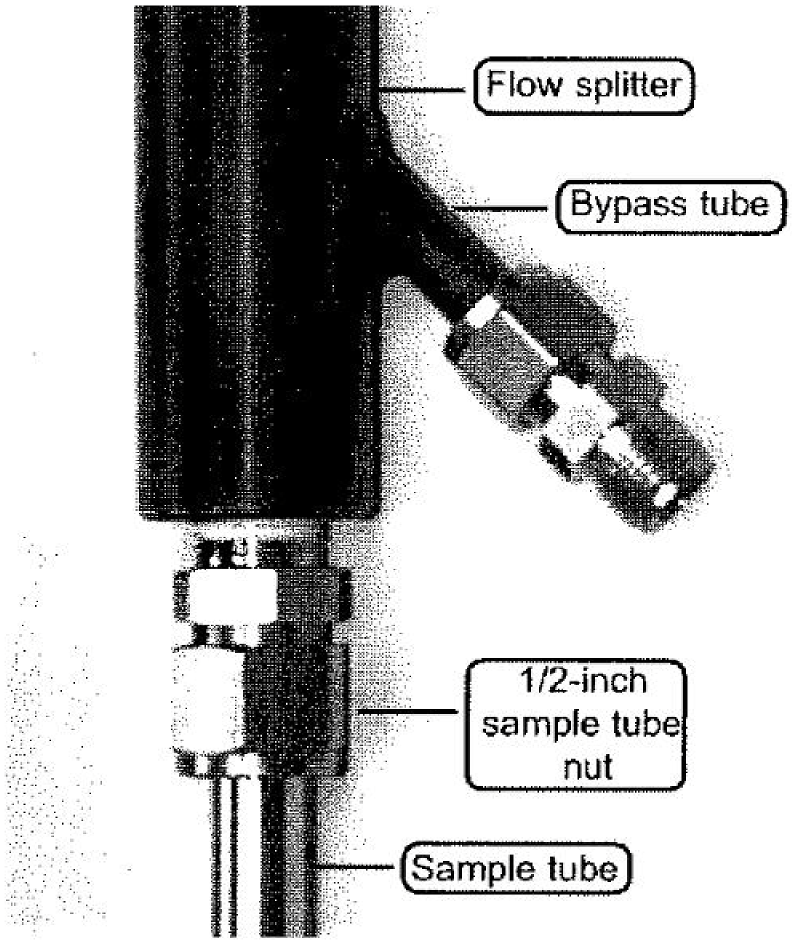


Figure 4-1 Flow Splitter and Associated Parts

4.3 System Operation And Setup Of Internal Data Storage

This section describes the operation of the FDMS Series 8500 Monitor including topics such as changing the instrument operating parameters and how to store data in the unit's internal data logger.

After the system installation is completed, turn the instrument ON by pressing the "Power" button on the front panel of the TEOM Control Unit. A screen appears on the instrument's four line display showing the name of the instrument and then the Main Screen appears.

Turn on the pump to draw the sample stream through the system. The monitor is always in operating mode 1 when it is first turned "ON". In this mode, the instrument waits until temperature and flows have equilibrated before entering modes 2, 3, and finally mode 4. The unit normally resides in operating mode 4 and this is the fully operational setting.

The operator will set the instrument to automatically measure and utilize the ambient temperature and pressure. To measure the outdoor ambient temperature automatically, the ambient temperature cable and sensor are installed as described in section 4.2. The ambient pressure sensor is built into each control unit.

4.3.1. Automatic Operation

Follow the steps below to make use of the monitor's ambient temperature and pressure sensors to maintain correct volumetric flow rate:

1) To enter the "Set Temps/Flows" Screen, Type 19<Enter> from any screen.

2) Set the Average Temperature (T-A/S) to 99° C .

3) Set the Average Pressure (P-A/S) to 9 Atmospheres.

4) The temperatures for case, air, cap and enclosure will be set according to following table.

Seasonal Parameters	November 1 to March31 Winter / Spring	April 1 to October 31 Summer / Fall
Case Temperature	30°C	50°C
Air Temperature	30°C	50°C
Cap Temperature	0°C	50°C
Enclosure Temperature	25°C	40°C

4.3.2. Setting Hardware Parameters

Enter the "Set Hardware" screen by typing 13<Enter> from any screen.

1) The Total mass averaging time (TM) is set at 300 seconds.
2) The mass rate/mass concentration averaging time (Mc) is set at 300 seconds.
3) The wait time is set at 1800 seconds.

4.3.3. Set Internal Data Storage

This section describes the Set Storage Screen which determines which variables are stored in the data logger, how many data fields exist per record and the interval at which records are stored.

The instrument transmits the values of three chosen variables in analog format through its 3 user-defined analog outputs. Analog output channel 1 can be defined to act as a status watch indicator. Define the analog output one field so that "+" appears in the A/O 1 field. Press <F5> to toggle the "+" in the A/O 1 field. When defined this way, analog output 1 transmits a full scale signal if a status condition exists in the temperatures, flow or oscillation frequency of the mass transducer which is indicative of the filter loading.

Enter the “Set Storage Screen” by pressing 09<Enter> from any screen. Set the first line Stor Var1 to Mass Conc.

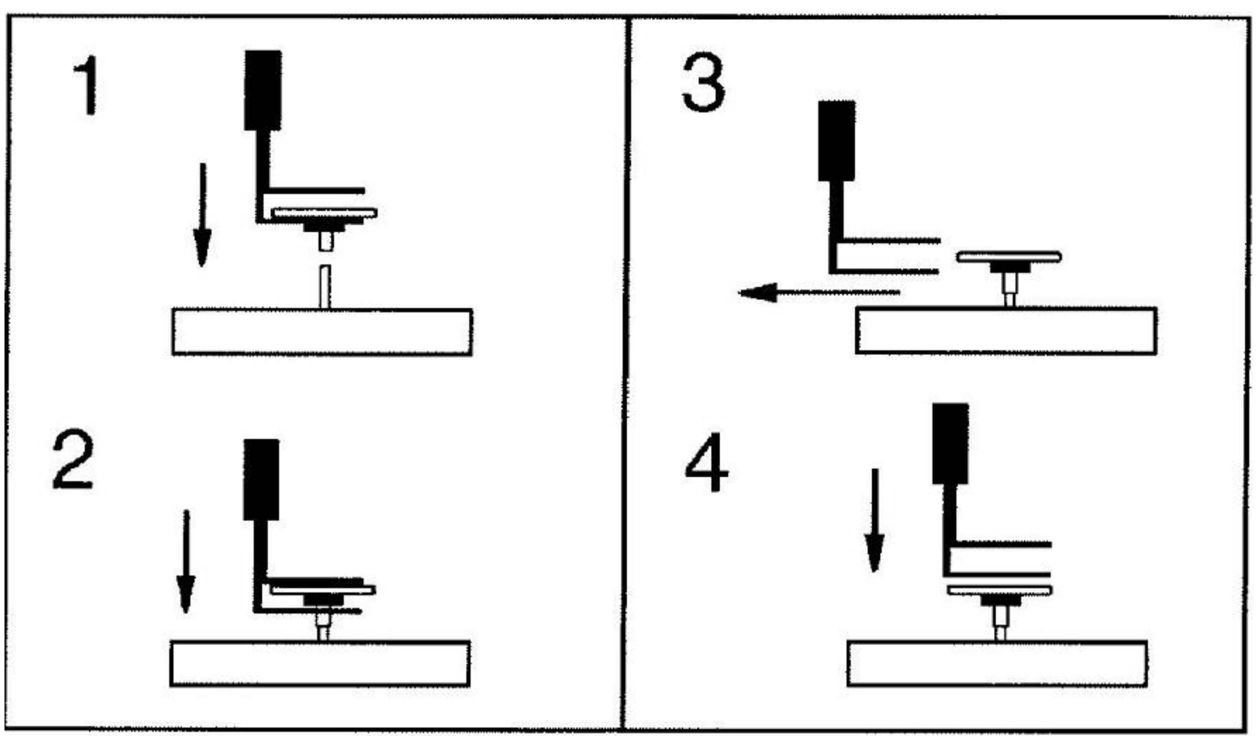
4.3 Sample Filter Installation and Exchange

This section discusses the steps to take to install and exchange filters and the sample filter lifetime. The Series 1400a monitor must always (except when performing certain maintenance and diagnostic procedures) be operated with a filter, made of Teflon coated glass fiber filter paper, installed on the mass transducer.

The TEOM filter cartridge must be exchanged when the “Check Status” light turns on and status code X is shown on the status line of the Main Screen when the filter loading percentage is greater than 90%. TEOM filter cartridges must be exchanged before the filter loading percentage reaches 100% to ensure the validity of the data generated by the TEOM.

4.3.1 Filter Exchange

When replacing old TEOM filter cartridges, care must be taken not to handle the new TEOM filter cartridge with fingers. Always store the TEOM filter box within the heated sensor unit enclosure for pre-conditioning to avoid moisture build-up. Use the filter exchange tool provided with the instrument to exchange filters. Keep the sample pump running to facilitate filter exchanges.



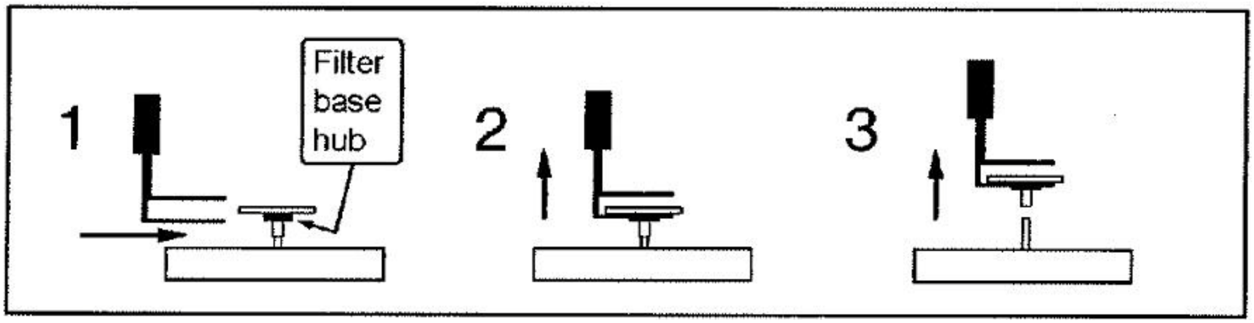


Figure 4-3 Filter Insertion and Removal

Exchange filter cartridges in the following manner:

1) Press the <Data Stop> on the Control Unit.

2) Open the door of the Sensor Unit.

3) Locate the silver handle mounted on the front surface of the mass transducer. Move the latch upwards and lift up on the bottom of the handle. Gently swing the mass transducer downward using the black knob. The mass transducer then swings into its filter changing position.

4) Refer to the Figure 4-3 to remove a filter using the filter exchange tool. Place the filter exchange tool so that the filter straddles between the tines of the filter exchange tool and gently lift the filter from the tapered element with a straight pull without twisting or applying lateral force to the tapered element.

5) During the filter removal process, the filter may be heavily loaded with particulate and when the tool comes in contact with the filter, the particulate will transfer to the tool. Cleaning the filter exchange tool will prevent any particulate from being transferred to a new filter and thus increase filter life. Use a Kimwipe to remove any particulate from the back side of the metal disc and the tines of the fork on the filter exchange tool.

6) Grab a new filter in the filter exchange tool so that the filter disk lies between the fork and upper disk of the tool with the hub of the filter between the tines of the lower fork. Do not touch the filter with fingers.

7) Hold the filter exchange tool in line with the tapered element and lightly insert the hub of the filter onto the tip of the tapered element. Ensure that the filter is seated properly and apply light downward pressure to set it firmly in place.

8) Remove the filter exchange tool by retracting it sideways, without disturbing the filter.

9) Gently raise the mass transducer to the closed position using the black knob. Position the silver handle so that it engages the latch plate and push the handle down until the latch is secure.

10) Close and latch the door to the Sensor Unit. Keep the door open for as short time as possible to minimize the temperature upset to the system.

11) Reset the FDMS by pressing <F1:Run>on the keypad of the TEOM Control Unit.

12) **IMPORTANT:** After five minutes have elapsed, open the sensor unit and mass transducer again. Press gently straight down on the filter cartridge with the bottom of the filter exchange tool. This ensures that the filter cartridge is properly seated after it has experienced an increase in temperature. Then close the mass transducer and enclosure. New filters generally exhibit figures of 15-30% for initial filter loading.

NOTE: If the filter loading percentage is high when a new TEOM filter is placed on the mass the transducer, or if the lifetime of TEOM filter cartridges becomes noticeably shorter, this indicates that the in-line filter in the main flow line needs to be exchanged.

5 QUALITY CONTROL

Essential to acquiring quality data are scheduled visits to the monitoring station to verify the operational status of the monitoring system. Weekly visits are made to the station to inspect the shelter and monitoring equipment. Ensure Table 5-1 is filled and mailed to Quality Assurance Unit once a month.

5.1 Logbook Requirements

All stations are required to maintain site specific instrument logbooks. They are used as an official record for documenting all FDMS maintenance activities, quality control checks, site visits etc. The documentation will indicate the date and time of site visit. Also note the status condition and operating mode, filter loading percentage and mass concentration. The operator will also indicate all activities such as filter exchange, any maintenance, and QC checks that are performed in the logbook and operators initials. Keeping the logbook up to date is imperative for data validation requirements.

5.2 QC Flow-Check Procedure

The following describes the procedures involved in performing the flow rate QC check. The flow rate checks must be performed upon installation and after any maintenance activity. Flow rate checks must be performed at least once every 30 days.

1) Disable the data logger and reset the monitor by pressing the <DATA STOP>keys on the front panel of the control unit.

2) Remove the sample inlet and replace it with Flow Audit Adapter. Turn the valve of the Flow Audit Adapter to open position to allow for air flow before installing the adapter. This step must be performed to avoid damage to the filter.

3) Scroll the Main Screen using <↓>and <↑> keys until the Main Flow and Auxiliary Flow appear on the four-line display. Confirm that these flows are within ± 2% of their set points (3.0 l/min for the Main Flow and 16.7 l/min for the Main Flow plus Auxiliary Flow). Any greater deviation may indicate plugged in-line filters, air blockages in the system or other malfunctions.

4) Connect the Flow Audit Adapter to a flow transfer standard such as a Gilibrator.

5) Read the total flow (nominally 16.7 l/min) on the flow meter and record it on the QC check form. The volumetric flow measured by the audit flow meter must be 16.7 ± 1.7 l/min.

6) Disconnect the Auxiliary Flow Line where it connects to the Flow Splitter. Plug the exit of the Flow Splitter with the 3/8" Swagelok cap supplied as part of the Flow Audit Adapter kit.

7) Read the Main Flow on the flow meter and record on the QC check form. The volumetric flow indicated by the audit flow meter must be 3.0 ± 0.3 l/min to be acceptable.

8) Connect the audit device to the Auxiliary flow line.

9) Read the Auxiliary Flow on the flow meter and record it on the QC check form. The volumetric flow indicated by the audit flow meter must be 13.7 ± 1.4 l/min to be acceptable.

10) If either the Main or Auxiliary Flow is outside the acceptable limits, a leak check must be performed. If necessary follow with repairs and a flow check. If this doesn't rectify the problem, then a calibration must be performed.

11) Remove the cap from the exit of the Flow Splitter and replace the Bypass Flow Line.

12) Optional: To perform a system leak check, Remove the sampling filter and close the valve on the Flow Audit Adapter. Both the Main Flow and Auxiliary Flow should read less than 0.15 l/min on Main Screen. If one of the flows is greater than 0.15 l/min then the system is not leak tight. In this case, check hose fittings and other critical locations in the flow system for leaks.

13) Remove the Flow Audit Adapter and replace the inlet on the top of the Flow Splitter.

14) Insert a new TEOM filter into the mass transducer if installing a new filter and reset the monitor by pressing <F1> or <Run>. The instrument will automatically begin data collection after temperature and flow rates have remained stable at their set points for one-half hour. Then enable the data logger.

Changes in flow rate calibration of more than 10% as determined by a monthly field flow rate verification check may cause invalidation of all data collected since the last acceptable flow rate check.

Deviation of 10% or greater from the design value in flow rate during sampling require that the data be flagged for potential invalidation.

1) Record the actual flow rate measured by the flow verification check device and the flow rate indicated by the sampler.

2) Using the above information, calculate the percentage difference for both the Total , Main and Auxiliary flow as:

$$\textbf{QC \% Difference (Total Flow)} = \left[\frac{\textbf{16.67 - Act}}{\textbf{Act}}\right] * \textbf{100}$$

$$\textbf{QC \% Difference (Main Flow)} = \left[\frac{\textbf{3.0 - Act}}{\textbf{Act}}\right] * \textbf{100}$$

$$\mathbf{QC\ \%\ Difference\ (Auxiliary\ Flow)} = \left[\frac{\mathbf{13.0 - Act}}{\mathbf{Act}}\right] * \mathbf{100}$$

3) If the monitor flow rate is within 90 to 110 percent of the measured flow rate at actual conditions and if the monitor flow rate is within 90 to 110 percent of the design flow rate of 16.67 L/min, the monitor is operating properly.

If either limit is exceeded, repeat leak check procedure, as described in Section 3.2.3. Investigate and correct any malfunction and recheck the flow. If necessary, recalibrate the flow controller (Software and then if necessary perform hardware calibration) before sampling again.

5.3 Temperature Sensor QC Check Procedure

The temperature verification consists of the following steps. The ambient temperature can be viewed in “Set Temps/Flows” screen. To enter this screen, type 19<Enter> from any screen.

1) Determine the current ambient temperature (°C) using a NIST traceable external thermometer outside the control unit.

2) Verify that the value of Amb Temp displayed in the Set Temps/Flows Screen is within ± 4 °C of the measured temperature and record it on the QC Check Sheet. If not, contact a DEC monitoring technician to calibrate the temperature sensor .

5.4 Pressure Sensor QC Check Procedure

The ambient pressure represents the value measured by the sensor located inside the control unit.

The pressure sensor verification consists of the following steps. The ambient Pressure can be viewed in “Set Temps/Flows” screen. To enter this screen, type 19<Enter> from any screen.

Verify the ambient pressure in the following manner:

1) Determine the current ambient pressure in mm Hg. using a certified NIST traceable barometer.

2) Verify that the value for Amb Pres in the “Set Temps/Flows” Screen is within ± 10 mm Hg of the measured ambient pressure. If not, contact a DEC monitoring technician to calibrate the pressure sensor.

Table 5-1 TEOM PM 2.5 QC Check Data Sheet

Station # ________________________ Date: ________________________

Location: ________________________ Time: ________________________

Monitor # ________________________ Operator: ________________________

Thermometer Serial # ________________________

- Certification Date: ________________________

Barometer Field

Standard Serial #________________________

- Certification Date________________________

Flow Standard Serial #________________________

- Certification Date: ________________________

QC Check

Temperature Check

Ambient

Actual_________°C Indicated_________°C Difference_________°C

Pressure Check

Actual_________mmHg Indicated_________mmHg Difference_________mmHg

Leak Check

Main_________L/min Auxiliary_________L/min (< 0.15 L/min)

Flow Check

Main Actual_________L/min Indicated_________L/min % Difference_________%

Aux Actual_________L/min Indicated_________L/min % Difference_________%

Total Actual_________L/min Indicated_________L/min % Difference_________%

$$\textbf{QC \% Difference} = \left[\frac{\textbf{Ind} - \textbf{Act}}{\textbf{Act}}\right] * \textbf{100}$$

$$\textbf{Design \% Difference} = \left[\frac{\textbf{Actual} - \textbf{16.67}}{\textbf{16.67}}\right] * \textbf{100}$$

Mail to Quality Assurance Unit

6 MAINTENANCE PROCEDURES

This section presents the routine maintenance procedures for the TEOM Series 1400a monitor. The operator may find that routine maintenance is site-specific and can vary from location to location. Increases in the routine maintenance frequencies might be necessary due to the operational demands on the samplers. All maintenance activities are to be documented in the monitor logbook. Table 6-1 is a summary of required maintenance procedures and frequencies.

6.1 Supplies And Tools Recommended For Maintenance

1) Ammonia based general purpose cleaner
2) Cotton swabs
3) Small soft-bristle brush
4) Paper towels
5) Distilled water
6) Silicone-based stopcock grease
7) Small screwdriver
8) Small crescent wrench
9) Pocket knife
10) Flat tip and Phillips head screwdriver
11) Adjustable wrench

6.2 Cleaning The PM 2.5 Inlet

The PM2.5 Inlet must remain free of significant contamination to ensure a correct particulate size cut-off at 2.5 µm. The cyclone inlet of the R&P PM2.5 must be cleaned periodically to prevent buildup of particulate matter and contaminants. The cyclone inlet cleaning is best done before an exchange of a TEOM filter cartridge. This allows for the cleaning procedure to be carried out during the one-half hour flow and temperature stabilization period following the instrument reset.

Follow the procedure below to maintain the PM2.5 inlet:

1) Disassemble the cyclone inlet and the cyclone bottom from the main cyclone body.

2) Soak in soapy water. Do not scrub, since scrubbing may damage the Teflon coating.

3) Rinse with deionized water several times and the last rinse may be with alcohol to facilitate drying. The inlet can also be dried with air.

4) Resemble and cap until ready for re-use, or reinstall on the 1 ¼" OD sample tube.

6.3 Replacing The Large Bypass In-Line Filter

There are two large bypass in-line filters used with the TEOM 1400a monitor. Both are located on the back of the TEOM control unit, one on the main and one on the Auxiliary flow lines. These filters prevent contamination from reaching the flow controllers. Replacement of the filter is best done immediately following an exchange of the TEOM filter cartridge. The maximum interval for replacing the large bypass in-line filter is six months.

To replace the filters, remove the existing filters with their quick-connect fittings and replace them with the new filter assemblies. Ensure that the arrows on the filters point away from the control unit. If the filters are installed in this way, the user can visually see the dust as it is collected in the filter.

NOTE: If the filter loading percentage is high when a new TEOM filter is placed on the mass the transducer, or if the lifetime of TEOM filter cartridges becomes noticeably shorter, this indicates that the in-line filter in the main flow line needs to be exchanged.

6.4 Replacing The Flow Control Filters

The flow controller filters attached to the mass flow controllers in the control unit provide a particle free air supply to the flow regulation hardware, and are essential for reliable, long-term instrument operation. Replacement of the filter is best done immediately following an exchange of the TEOM filter cartridge.

To replace the filters, unscrew and remove the existing filters from the mass flow controllers in the TEOM control unit and assemble the new filters to the mass flow controller.

6.5 Pump Test

This test is intended to help the user determine whether the pump is still capable of providing adequate vacuum to run the series 1400a monitor. The average lifetime of the pump is 1 to 1.5 years. This test is performed every 6 months or if any of the following is true:

- The main flow drops off at filter loading of less than 90%.

- The filter loading percentage fluctuates.

To check the pump, perform the following steps.

1) Operate the Series 1400a monitor in the usual fashion with the sample pump running.

2) Remove the TEOM filter cartridge from the mass transducer.

3) Remove the size selective inlet from the flow splitter and replace it with the flow audit adapter contained in the flow audit adapter kit supplied with the instrument.

4) Display the main and auxiliary flows on the main screen of the four line display.

5) Begin slowly closing the valve on the flow adapter so the incoming flow is restricted.

6) Watch the filter loading percentage along with the main and auxiliary flow readings. Note the percentage at which either or both flows begin to decrease.

7) If either flow begin to decrease at a filter percentage of less than 90% the pump should be rebuilt.

6.6 Rebuild Sample Pump

The instructions for rebuilding the pump are provided with the compressor service kit. Follow the assembly procedures provided with the kit to rebuild the pump.

6.7 Cleaning The Air Inlet System

The heated Air Inlet in the monitor must be cleaned periodically to remove the build-up of particulate on its inner walls.

Perform the following steps to clean the Air Inlet System:

1) Turn off the TEOM control unit.

2) With the mass transducer in its closed upright position, carefully remove the air thermistor from the "cap" of the TEOM mass transducer by pressing in on the metal locking clip. The cap is located immediately above the part of the mass transducer that swivels downward.

3) Open the mass transducer by pulling upward on its silver handle.

4) Place plastic or any protective material over the exposed part of the mass transducer.

5) Using alcohol, clean the Air Inlet. A soft brush may also be used to remove particulate on the inside walls.

6) Allow the Air Inlet to dry.

7) Remove the plastic or any protective material from the exposed part of the microbalance.

8) Pivot the mass transducer into its closed position by pressing the closing mechanism.

9) Carefully re-insert the air thermistor into the cap of the mass transducer assembly.

10) Turn on the TEOM Control Unit.

6.8 TEOM Shelter Maintenance

TEOM shelter maintenance and the air conditioner on the TEOM shelter. The air conditioner has an external filter on it to keep the dust out. This filter needs to be taken out and cleaned on a monthly basis. To clean this filter is to blow it out with compressed air or vacuum it out. It can be washed out with water, but it has to be completely dry when it is re-installed. Replace this filter about every 2 years.

6.9 Leak Testing

Refer to Section 3.2.3

6.10 Software Update

The operator should update software to the latest version of software available when deemed appropriate by DEC QA officer and/or the Air Monitoring program manager.
For more information consult Appendix D of the TEOM Operating Manual

Table 6-1 Routine Maintenance Activities

ACTIVITY	REQUIRED FREQUENCY
Clean PM2.5 inlet	With each TEOM filter exchange
Replace large bypass in-line filters	Every six months
Replace flow controllers filters	Every six months
Pump Test	Every six months
Clean air inlet system	Once a year
Clock adjustment procedure	Check monthly and adjust as needed
Resetting the system	As needed
Updating system software	As needed
Perform leak test	Once a year
Rebuild sample pump	Once in eighteen months

7 DATA VALIDATIONS AND REPORTING OF PM2.5 DATA

This section discusses validations and reporting of PM2.5 data.

7.3 Data Assessment and Validation

Data must be validated to ensure that all reported PM2.5 measurements are accurate relative to the overall scope of the quality assurance program. The data validation process is based on specific criteria and when found to satisfy all the criteria, will be considered valid. The data that does not meet all the criteria will be invalidated.

7.1.1 Monthly

The station operator will generate the preliminary, "Monthly Average Report", Table 7-1 1-hour running averages with flags. The Report will be reviewed for reasonableness and comparability.

1. Invalid data will be marked on the printout with an "X" through all-inclusive hours. These invalid data include periods of calibrations, QC activities, missing data, excessive negative drift (values > -5 µg/m3, values > -5 µg /m3 but < 0 will be assigned a 0), spiking, analyzer malfunctions, etc. Anomalous data periods will be reviewed and investigated with logbook entries, compared to other data parameters that maybe measured at the monitoring station, and any other tool available to ensure validity.

2. Submit the Report to the Quality Assurance Unit. All Reports must be submitted no later than the 10th of the following month. If the Report cannot be submitted on time notify the Quality Assurance Unit immediately and make arrangements for submittal.

3. The Quality Assurance Unit will review the Report, validate the data utilizing all Quality Control and Quality Assurance information, and then submit it to the Data Management Unit for online editing. The Quality Assurance Unit will review and certify the final Report.

7.1.2 Quarterly

1. For each quarter complete the PM2.5 FDMS/FRM Regression Analysis worksheet Table 7-2 and calculate the slope, intercept and correlation coefficient. The linear regression analysis will be performed to determine method comparability and to assess TEOM data quality. The regression will be setup where the independent (x) variable is the 24-hour average PM2.5 FDMS data, and the dependent (y) is the PM2.5 FRM sampler data. All paired values greater than 2 µg/m3 will be used in completing these calculations. Submit the worksheet to the Quality Assurance Unit.

7.1 3 Final Data Validation

Data that have been reviewed by the Quality Assurance Unit and found to satisfy the requirements of this procedure and the criteria defined in the Alaska State Department of Environmental Conservation Air Monitoring Quality Assurance Plan will be certified as valid.

7.2 Data Reporting

After the data are logged, edited, and validated the Data Management Unit will prepare quarterly and annual summary reports and transmit the data to EPA.

Table 7-1 Monthly Average Report

Table 7-2 TEOM/FRM 2.5 Regression Analysis

Alaska Department of Environmental Conservation
2.5 TEOM/FRM Regression Analysis

AIRS SITE ID #

	3	0	6	3	0	0	4	7

DEC SITE ID #

3	2	7	8	0	4	6	A

QUARTER/MONTH:3/2009

TEOM STATE TAG #:

E	1	2	9	9	9	2	3

OPERATOR:_Hannahs______________________

LOCATION: ERO

DATE						TEOM CONC (x)			FRM CONC (y)			COMMENTS
MM		DD		YY								
0	4	0	3	9	9		1	1		1	0	
0	4	0	6	9	9		1	0		7.	4	
0	4	1	2	9	9		1	5		3.	7	
0	4	2	7	9	9		1	5		1.	9	
0	5	2	1	9	9		1	2		1.	2	
0	5	2	4	9	9		1	0		7.	5	
0	5	3	0	9	9		1	2		9.	2	
0	6	0	2	9	9		1	1		8.	6	
0	6	0	8	9	9			9		8.	7	
0	6	1	7	9	9			7		6.	9	

QUARTERLY SLOPE 0.789
QUARTERLY INTERCEPT 0.670
QUARTERLY CORRELATION COEFFICIENT 0.894

7.3 Final Data Validation

Data that has been reviewed by the Quality Assurance Unit and found to satisfy the requirements of this procedure and the criteria defined in the Alaska State Department of Environmental Conservation Air Monitoring Quality Assurance Plan will be certified as valid.

7.4 Data Reporting

After the data is edited the Data Management Unit will prepare quarterly and annual summary reports and transmit the data to EPA.

8 DATA FORMS

Blank data forms are provided on the following pages for the convenience of the manual user.

Table 8-1 Calibration And Verification Check Intervals

	Frequency	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Acceptance Criteria
Flow Rate Verification Main Flow Auxiliary Flow	Once a month													± 10% of the Transfer Standard
Flow Controller Calibration (Software)	Twice a year													
Temperature Verification	Once in 30 days													± 4 °C of Standard
Pressure Verification	Once in 30 days													± 10 mm Hg.
Clock/timer Verification	Once in 30 days													1 min/month
Mass transducer calibration verification	Once a year													
Leak Check	Once in 30 days													0.15 L/min

Table 8-2 TEOM PM 2.5 Calibration Sheet

AIRS Station # ____________________ Date: ____________________

Location: ____________________ Time: ____________________

Monitor # ____________________

Operator Name and Initials: ____________________

Flow Calibration

Total Actual________L/min Indicated________L/min % Difference ________%

Main Actual________L/min Indicated________L/min % Difference ________%

Aux. Actual________L/min Indicated________L/min % Difference ________%

$$\textbf{QC \% Difference} = \left[\frac{\textbf{Ind} - \textbf{Act}}{\textbf{Act}}\right] \times \textbf{100}$$

Mass Flow Controller Calibration (Software) ____________________

Ambient Temperature Sensor Calibration

Actual________°C Indicated________°C Difference________°C

Ambient Pressure Sensor Calibration

Actual________mm Hg Indicated________mm Hg Difference________mm Hg

Time Calibration

Actual Time________ Indicated________ Soft & Hard Rate________

Mail to Quality Assurance Unit

Table 8-3 TEOM PM 2.5 QC Check Data Sheet

Station # ________________________ Date: ________________________

Location: ________________________ Time: ________________________

Monitor # ________________________ Operator: ________________________

Thermometer Serial # ________________________

- Certification Date: ________________________

Barometer Field

Standard Serial #________________________

- Certification Date________________________

Flow Standard Serial #________________________

- Certification Date: ________________________

QC Check

Temperature Check

Ambient

Actual_________°C Indicated_________°C Difference_________°C

Pressure Check

Actual_________mmHg Indicated_________mmHg Difference_________mmHg

Leak Check

Main_________L/min Auxiliary_________L/min (< 0.15 L/min)

Flow Check

Main Actual_________L/min Indicated_________L/min % Difference_________%

Aux Actual_________L/min Indicated_________L/min % Difference_________%

Total Actual_________L/min Indicated_________L/min % Difference_________%

$$\textbf{QC \% Difference} = \left[\frac{\textbf{Ind} - \textbf{Act}}{\textbf{Act}}\right] * \textbf{100}$$

$$\textbf{Design \% Difference} = \left[\frac{\textbf{Actual} - \textbf{16.67}}{\textbf{16.67}}\right] * \textbf{100}$$

Mail to Quality Assurance Unit

Table 8-4 TEOM/FRM 2.5 Regression Analysis

Alaska Department of Environmental Conservation
2.5 TEOM/FRM Regression Analysis

AIRS SITE ID # | | | | | | | | | |

DEC SITE ID # | | | | | | | | | QUARTER/MONTH:__________

TEOM STATE TAG #: | | | | | | | | |

OPERATOR:______________________

LOCATION:_______________________

DATE						TEOM CONC (x)			FRM CONC (y)			COMMENTS
MM		DD		YY								

QUARTERLY SLOPE ______
QUARTERLY INTERCEPT ______
QUARTERLY CORRELATION COEFFICIENT ______