DEPARTMENT OF ECOLOGY
State of Washington

PM$_{2.5}$ TAPERED ELEMENT OSCILLATING MICROBALANCE WITH FILTER DYNAMIC MEASUREMENT SYSTEM OPERATING PROCEDURE

Air Quality Program

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$PM_{2.5}$ Tapered Element Oscillating Microbalance with Filter Dynamic Measurement System Operating Procedure

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TABLE OF CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

1. INTRODUCTION

This document describes the Washington State Department of Ecology's procedures for sampling ambient air for particulate matter with aerodynamic diameter 2.5 µm or less ($PM_{2.5}$) using a Thermo Fisher Scientific Tapered Element Oscillating Microbalance with Filter Dynamic Measurement System (FDMS TEOM®). This procedure applies to all FDMS TEOMs operated as part of the Washington Ambient Air Monitoring Network (Washington Network). It covers the configuration, operation and maintenance of models 1400ab with 8500C FDMS (referred to below as "8500") and 1405-F. It is intended to be used with the model-specific information and instructions provided by the manufacturer.

The FDMS TEOM provides continuous $PM_{2.5}$ mass concentration measurements in actual conditions, accounting for the volatile component of the mass. It was designated a federal equivalent method (FEM) for measuring $PM_{2.5}$ by the U.S. Environmental Protection Agency in 2009 (74 FR 28696, EQPM-0609-181). To meet the federal requirements for FEM $PM_{2.5}$ measurement, the sampler must:

- be configured with an approved PM_{10} inlet followed by a BGI, Inc. Very Sharp Cut Cyclone (VSCC) particle size separator;
- operate at a total volumetric flow rate of 16.67 liters per minute (lpm);
- run firmware 3.20 or greater (8500) or 1.50 or greater (1405-F); and
- be operated and maintained in accordance with the manufacturer's operating manual.

Though the operating principles of the 8500 and 1405-F TEOM are the same, many of the specific steps of operation vary between the two models. This procedure includes instructions for both instruments. Where these steps diverge substantially, instructions for the 8500 TEOM can be found on the left of the page and instructions for the 1405-F TEOM on the right.

Pictures of the 8500 (left) and 1405-F (right) models are shown in Figure 1-1.

Figure 1-1. Photos of 8500 (left) and 1405-F (right) FDMS TEOM.

2. PRINCIPLES OF OPERATION

The FDMS TEOM draws ambient air at 16.67 lpm first through a PM_{10} inlet and then through a VSCC particle size separator to remove particles greater than 2.5 µm in aerodynamic diameter from the sample stream. The air stream is then split isokinetically into a main sample stream at 3.0 lpm and a bypass stream at 13.67 lpm. The main sample stream flows into the FDMS module, where it runs through the Nafion dryer to reach a set temperature and relative humidity (RH), then enters the switching valve. The position of the switching valve determines whether the sample stream becomes the base flow or the reference flow. The valve switches between the two flow paths every 6 minutes.

When the switching valve is in the base position, it directs the sample stream to the mass transducer. The mass transducer contains a hollow, tapered ceramic element fixed at one end. Its other end is free and has a filter attached. The tapered element oscillates like a tuning fork at a frequency determined by its physical characteristics and the mass contained on its free end. As particles collect on the filter, the oscillation frequency decreases proportionally to the mass added to the filter. The base mass concentration (Base MC) is calculated as the mass added to the FDMS TEOM filter, as measured by the change in frequency, divided by the volume of air sampled during the base cycle.

During the reference flow cycle, the sample stream is diverted to the reference flow path, which contains a 47-mm filter cassette with a polytetrafluoroethylene-coated borosilicate filter (the "chiller filter") maintained at 4°C. At this low temperature, volatile particles condense on the filter, resulting in a particle-free sample stream. This clean reference air then flows to the mass transducer, which measures changes in the mass on the oscillating filter during the reference cycle. The reference mass concentration (Ref MC) is calculated as the change in filter mass during the reference cycle and is negative when volatile material is present in the previously sampled particulate. The Ref MC is subtracted from the Base MC to yield the sum of volatile and non-volatile $PM_{2.5}$ concentrations in the sample stream.

The raw mass concentration (MC) output from the FDMS TEOM is equal to Base MC – Ref MC. The FEM MC is calculated from the raw MC using a proprietary exponential equation. The Base MC, Ref MC, MC and FEM MC are calculated as rolling 1-hour averages updated every 6 minutes. The official FEM 1-hour MC is updated hourly and is identical to the FEM MC channel at the top of the hour. The FEM 1-hour MC is used by Ecology to report $PM_{2.5}$ concentrations to its public website and EPA's Air Quality System (AQS).

Schematic diagrams of the full FDMS TEOM systems and the flow paths are shown for the 8500 TEOM in Figure 2-1 and Figure 2-2 and for the 1405-F TEOM in Figure 2-3 and Figure 2-4.

Note: The operating manual for the 8500 TEOM refers to the bypass flow path as the "auxiliary" flow path. This procedure uses the term "bypass" regardless of the instrument model.

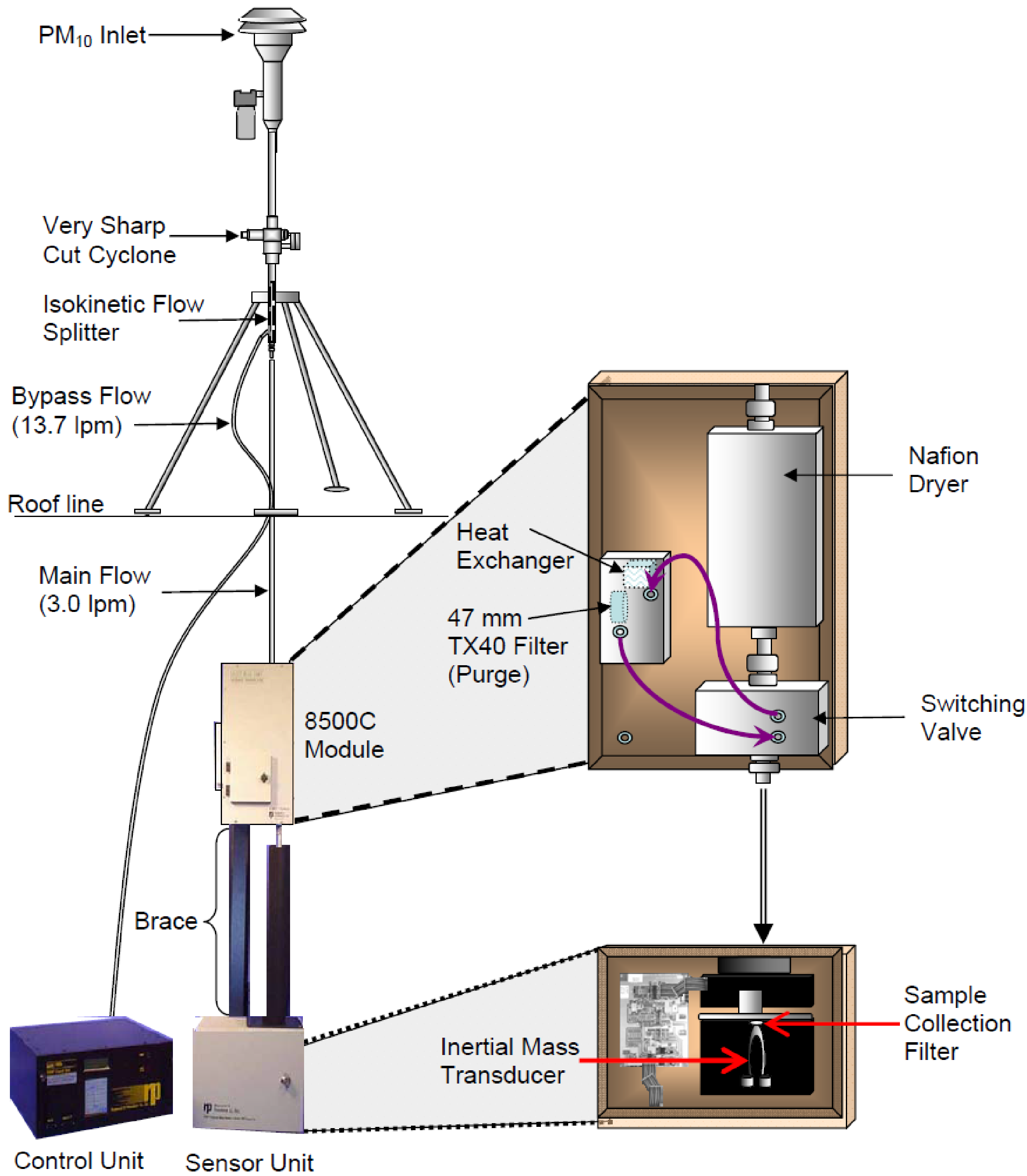

Figure 2-1. Schematic diagram of full 8500 TEOM (Vaughn and Ray, 2011).

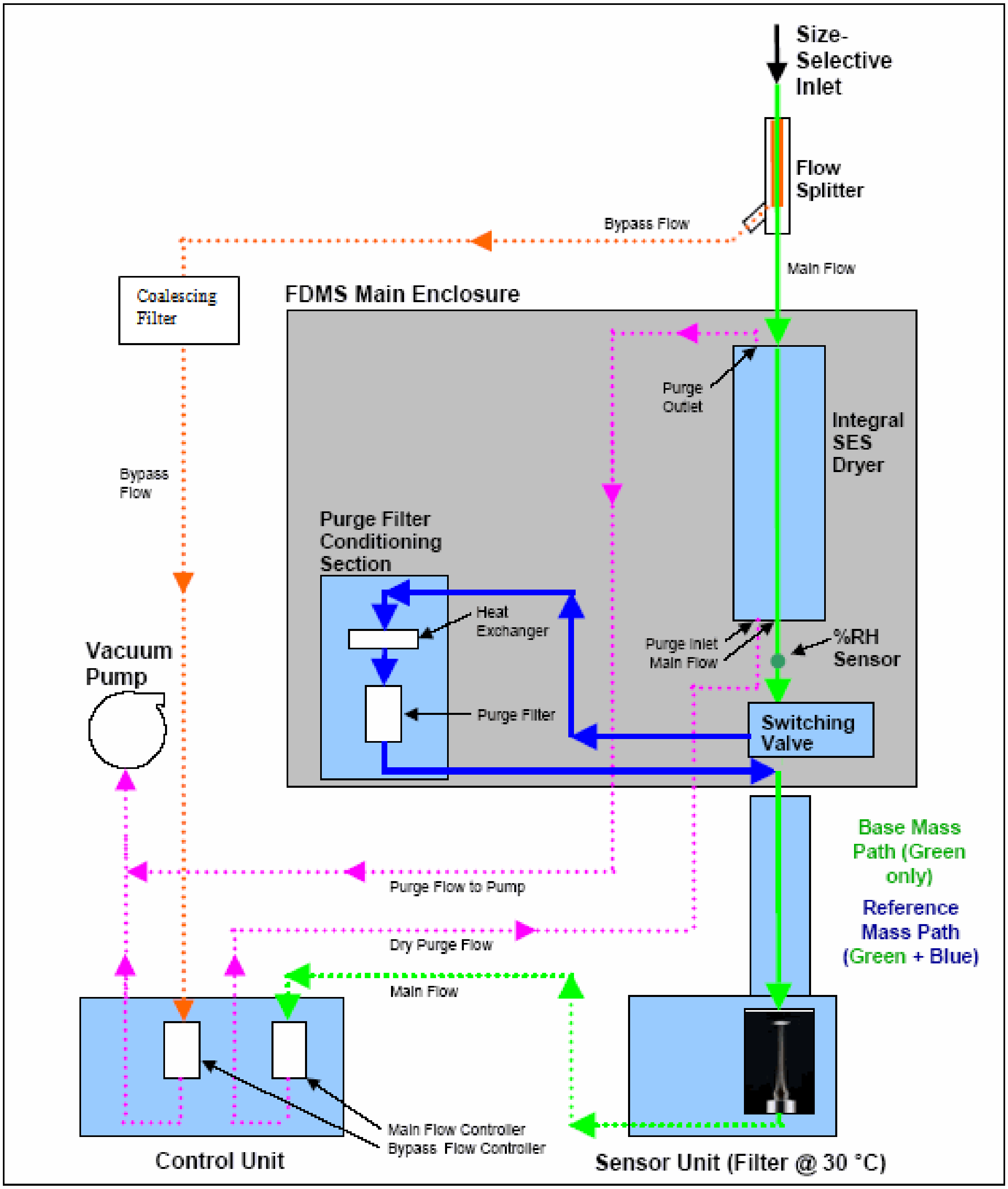

Figure 2-2. Schematic diagram of 8500 TEOM flow path (Vaughn and Ray, 2011).

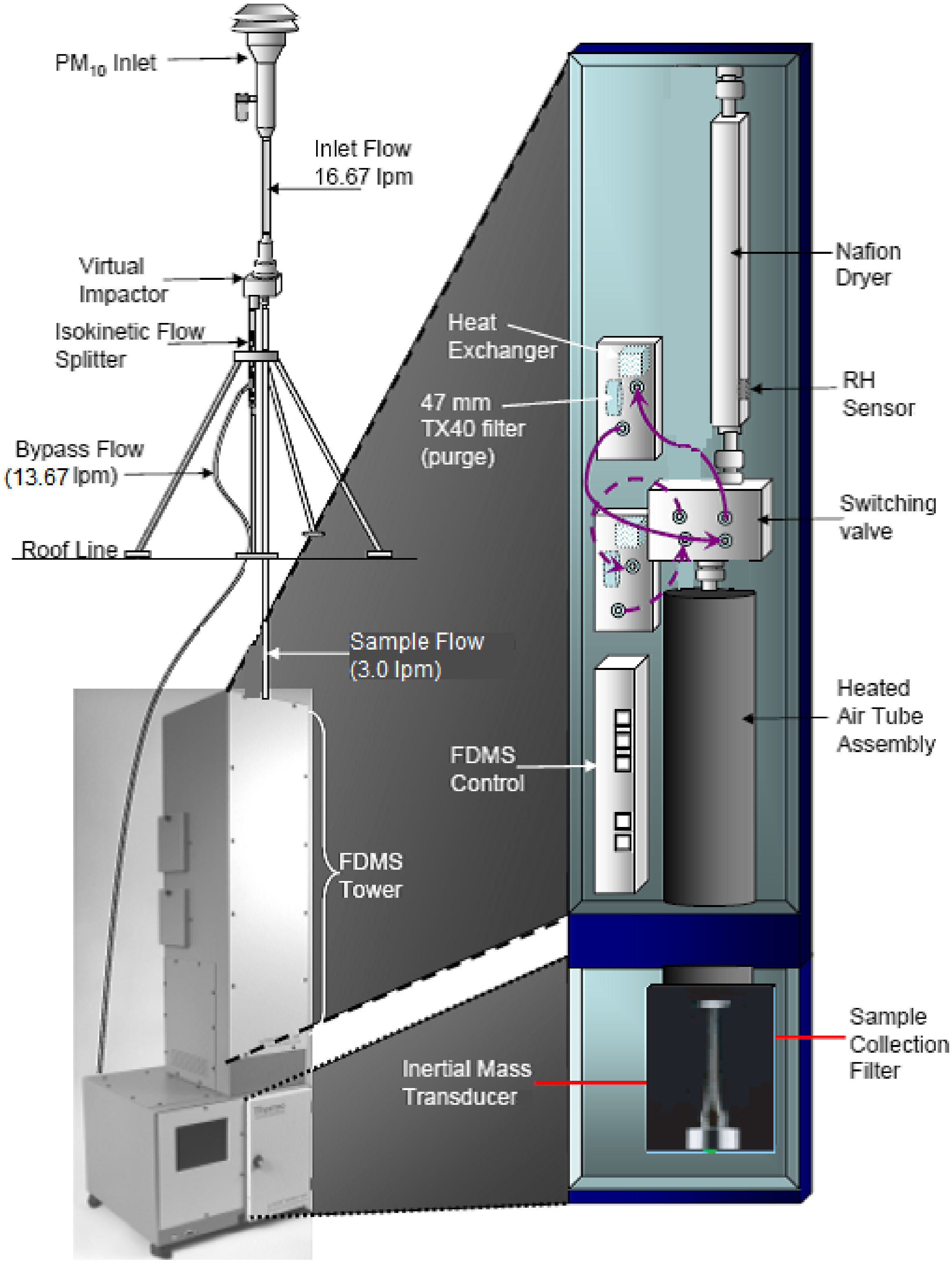

Figure 2-3. Schematic diagram of full 1405-F TEOM (Ray and Vaughn, 2009).

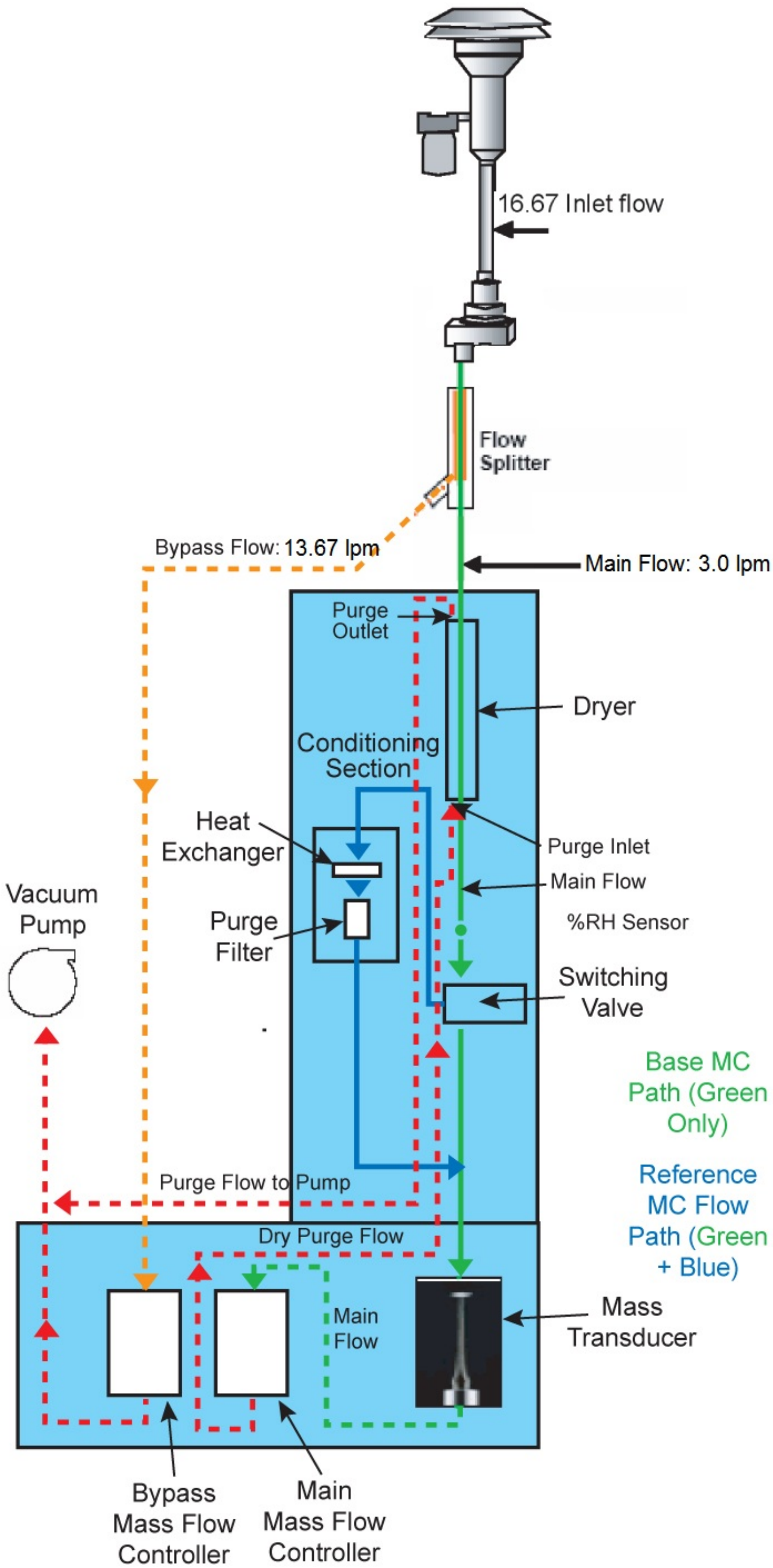

Figure 2-4. Schematic diagram of 1405-F TEOM flow path (Ray and Vaughn, 2009).

3. EQUIPMENT AND SUPPLIES

The diagnostic tools, parts and supplies necessary to operate and maintain the FDMS TEOM are summarized in Table 3-1 below.

Table 3-1. Summary of FDMS TEOM standard hardware, tools, routine parts and supplies (adapted from Ray and Vaughn, 2009).

Category	Equipment	Purchase Schedule
Diagnostic Tools	Flow standard	Once
	Flow audit adapter	Once
	NIST-traceable thermometer	Once
	Handheld barometer/altimeter	Once
	Digital multi-meter	Once
	Hand tools (tweezers, screwdrivers, wrenches, etc.)	Once
Consumables	TEOM filters	Monthly
	Chiller filters (47-mm)	Monthly
Spare Parts	Pump rebuild kit	Annually
	Nafion dryer	Annually
	In-line filter elements	As needed
	V-seals, various sizes	As needed
	O-rings, various sizes	As needed
	Valve cleaning brush (provided with instrument)	As needed
Cleaning Supplies	Ammonia-based cleaner	As needed
	Silicone grease	As needed
	Soap, alcohol solution	As needed
	Small soft-bristle brush	As needed
	Cotton swabs	As needed
	Paper towels, soft cloth	As needed
	Deionized water	As needed

4. INSTALLATION PROCEDURE

4.1 SITING

Proper siting is essential to ensure that data collected are representative of the area defined in the monitoring objective. The vast majority of $PM_{2.5}$ monitors in the Washington Network are sited to represent air quality conditions on a neighborhood scale. Siting criteria for $PM_{2.5}$ monitoring sites are described extensively in 40 CFR Part 58, Appendix E; the primary neighborhood-scale siting criteria are summarized in Table 4-1 below.

Table 4-1. Summary of $PM_{2.5}$ FDMS TEOM siting criteria (adapted from Ray and Vaughn, 2009).

Parameter	Category	Siting Requirement
Inlet height	General	2-15 m above ground
	On rooftop	2 m above roof
	Collocated samplers	Within 1 vertical m of each other
	Inlet tube length	≤ 16 ft (4.9 m)
Inlet radius clearance	General	≥ 1 m radius clearance
	Collocated samplers	1-4 m between inlets
	Near Hi-Vol	≥ 3 m between FDMS TEOM and Hi-Vol inlets
	Near small obstructions (fences, walls, etc.)	≥ 2 m
	Near large obstructions (buildings, sound walls, billboards, etc.)	Distance ≥ 2x height of obstruction
	Near overhanging trees	≥ 20 m from tree drip line
	Arc of air flow	Unrestricted 270° arc that includes prevailing direction of high concentrations
Nearby Air sources	General	As far away as possible from vents
Distance from roadways	< 3,000 vehicles per day	≥ 5 m from nearest traffic lane
	Elevated roadway (> 25 m high)	≥ 25 m away
	Unpaved roads	As far away as possible

Operators should refer to the Ecology SOP Air Monitoring Site Selection and Installation Procedures (#95-201B) for further information on site selection.

The FDMS TEOM must be installed in a dry, environmentally-controlled location. Walk-in shelters, mobile trailer, and environmentally controlled mini-enclosures are commonly used to house FDMS TEOMs in the Washington Network. The FDMS TEOM is highly sensitive to interference from environmental conditions, which should also be considered during site selection. Known types of environmental interference include:

- **Temperature:** Thermo Fisher Scientific recommends maintaining shelter temperature below 25°C, but FDMS TEOM operators in Washington State have experienced bias and instability in FDMS TEOM data even below this threshold. Based on this experience, Washington Network FDMS TEOM shelter temperatures must be maintained between 15° and 22°C. Fluctuations in shelter temperature can also cause excessive noise in FDMS TEOM data and bias in both directions. FDMS TEOM shelters should be equipped with both a heater and air conditioner programmed to run at set points approximately 2°C apart. For example, a shelter with a target temperature of 18°C should have a heater set to run below 17°C and an air conditioner set to run above 19°C. Air conditioners with a 12-minute run cycle should be avoided.

- **Vibration**: External vibration can interfere with the oscillation of the mass transducer and cause inaccurate readings of the oscillation frequency. Placing the FDMS TEOM on a separate bench will isolate the unit from vibration from other equipment within the shelter. FDMS TEOM pumps can cause substantial vibration and should be placed as far as possible from the instrument, ideally outdoors in a separate pump enclosure.

Figure 4-1. Photo of outdoor pump enclosure (PSCAA).

4.2 INSTALLATION

It is recommended that operators follow the detailed instructions found in the Operating Guides for the 8500 and 1405-F TEOM when installing a new instrument. In addition to the manufacturer's instructions, the following special precautions should be taken before installing the FDMS TEOM:

- **Make sure there is enough room to access the rear of the instrument and the FDMS module** for filter changes, quality control checks and maintenance.
- **Align the downtube in a straight, vertical line above the inlet of the** FDMS TEOM**.** Drill a 1 ¾" diameter hole for the downtube centered directly above the TEOM inlet. If the alignment is not perfectly perpendicular, transverse stress on the inlet connections can cause leaks.
- **Ensure that there is sufficient clearance on the roof for the tripod** before cutting the downtube to length.
- **Use a tubing cutter to cut the downtube to length.** Make sure that both ends are cut perpendicular to the tube. Do not allow tube fragments to fall into the TEOM inlet.
- **Secure the downtube to the roof** with a roof flange or other method so that the PM_{10} head can be removed without disturbing the instrument.
- **Support the roof during installation.** Once the downtube is installed, flexing of the shelter roof under the weight of an operator can stress the downtube connection and disturb the mass transducer. A roof platform can absorb the shock of this movement if it is necessary to walk on the roof during installation.
- **Provide proper electrical grounding.** Check that the resistance of the inlet tube to earth ground (the round pin on the power plug) is <3 ohms.
- **Install the ambient temperature/humidity sensor before operating the instrument.** Without the sensor, the mass flow controller will operate as if the ambient temperature were absolute zero.

After installing the instrument, conduct the following steps to begin operation:

1. Power on the instrument and the pump.
2. Review the configuration parameters by following the menu selections italicized in Table 4-2 below.
3. Complete the routine quality control and maintenance procedures that are necessary upon installation. These procedures and their references are summarized in Table 4-3 and described in detail in Section 5.

Table 4-2. FDMS TEOM configuration parameters to review upon installation.

Setting	8500 TEOM	1405-F TEOM
Flows	*Step Screen > Set Temps/Flows > Enter*	*Main Menu > Instrument Conditions > Flows > Flow Control*
	Main flow: 3.0 lpm Bypass flow: 13.67 lpm	Make sure the “Active” and “Actual” buttons are selected in blue
	Select left and right *T-A/S* values and set to 99.00	*Main Menu > Instrument Conditions > Flows > Flow Rates*
	Select left and right *P-A/S* values and set to 9.000	Main flow: 3.0 lpm Bypass flow: 13.67 lpm
Temperatures	*Step Screen > Set Temps/Flows > Enter*	*Main Menu > Instrument Conditions > Instrument Temperatures*
	T-Case: 30.00°C T-Air: 30.00°C T-Cap: 30.00°C	Cap temperature: 30.00°C Case temperature: 30.00°C Air tube temperature: 30.00°C
	Step Screen > Set Hardware	*Main Menu > Instrument Conditions > FDMS Module*
	PurgeF T: 4.00°C	Cooler temperature: 4.00°C
Mass Calculations	*Step Screen > Set Hardware*	*Main Menu > Settings > Advanced > Mass Calculation Variables*
	Wait Time: 1800 Gate Time: 10 XX-Hr MC: 8 Soft Rate: 0.00 Hard Rate: 0.00 Mass Ave: 360 Freq Wait: 90	System wait time: 1800 seconds XX-Hour value: 8 hours Frequency wait time: 60 seconds Equivalent Designation (v1.71+): EPA
Data Storage	*Main Menu >* Store key *> Step Screen > Set Storage*	*Main Menu > Settings > Data Storage*
	Select the variables listed in Table 6-2	Select the variables listed in Table 6-3 Storage interval: 180 seconds

Table 4-3. Summary of post-installation quality control and maintenance steps.

Procedure	Section
Ambient temperature check	5.1.2
Ambient pressure check	5.1.2
Flow check	0
Leak check	5.1.4
Pump vacuum check	5.1.5
Clock verification	5.1.6
Install TEOM filter	5.2.1
Install chiller filter	5.2.1.2
Clean PM10 inlet	5.2.1.3
Clean VSCC	5.2.1.4
Install in-line filters	5.2.1.5

5. QUALITY CONTROL AND MAINTENANCE PROCEDURE

The schedule for routine quality control and maintenance is summarized in Table 5-1.

Table 5-1. Summary of quality control and maintenance procedures (adapted from Vaughn and Ray, 2011).

Category	Procedure	Frequency			Section
		Upon installation	Once every 30 days	Once every 12 months	
Quality Control	Ambient temperature check	✓	✓		5.1.2
	Ambient pressure check	✓	✓		5.1.2
	Flow check	✓	✓		0
	Leak check	✓	✓		5.1.4
	Pump vacuum check	✓	✓		5.1.5
	Clock verification	✓	✓		5.1.6
Maintenance	Replace the TEOM filter	✓	✓ (or as needed)		5.2.1.1
	Replace the chiller filter	✓	✓ (or as needed)		5.2.1.2
	Clean the PM_{10} inlet	✓	✓		5.2.1.3
	Clean the VSCC	✓	✓		5.2.1.4
	Check the in-line filters	✓	✓		5.2.1.5
	Rebuild the pump	✓		✓	5.2.2.1
	Replace/refurbish the dryer	✓		✓	5.2.2.2
	Check the calibration constant (K_0)			✓	5.2.2.3
	Clean the heated air inlet system			✓	5.2.2.3
	Clean the chiller			✓	5.2.2.3
	Clean the switching valve			✓	5.2.2.3
	Full system leak check			✓	5.2.2.3.1

5.1 QUALITY CONTROL

At a minimum, operators are required to perform a quality control (QC) check every 30 days. The monthly QC procedure consists of:

- **5.1.1** Preparation
- **5.1.2** Ambient temperature and pressure check
- **5.1.3** Flow Check
- **5.1.4** Leak Check
- **5.1.5** Pump vacuum check
- **5.1.6** Clock verification
- **5.1.7** Temperature, pressure and/or flow calibration (as needed)

All operators of Washington Network FDMS TEOMs are required to record the results of monthly QC checks on the Washington State Department of Ecology FEM $PM_{2.5}$ TEOM Quality Control Check Results form (see Appendix 9.1). All quality control check results must be sent to the Quality Assurance Coordinator by the 10th of the month following the end of the month of data collection.

During the course of the QC check, if any parameters are found to be outside of the stated acceptance limits, operators must refrain from making any calibrations or adjustments until after the QC check is complete. After calibration, operators must repeat the QC check process and submit two separate "as found" and "as left" QC check forms.

5.1.1 Preparation

1. Disable data logging by putting all FDMS TEOM channels in offscan mode in Envidas.
2. Create a log book entry documenting the time you took channels offscan, the instruments you intend to service, any unusual site or air quality conditions, any instrument alarms, and the names of people onsite.
3. Suspend data collection on the FDMS TEOM:

8500 TEOM	1405-F TEOM
Press <*Data Stop*>	Enter Setup mode *Main Menu > Service > Instrument Control > Setup*

5.1.2 Ambient temperature and pressure check

1. Record the FDMS TEOM's indicated ambient temperature and pressure:

8500 TEOM	1405-F TEOM
Main Menu > Step Screen > Set Temps/Flows	*Main Menu > Instrument Conditions > Ambient Conditions*

2. Measure and record the actual ambient temperature at the FDMS TEOM's temperature probe (either the horizontal white PVC tube near the inlet or the radiation shield) using a certified, NIST-traceable thermometer.
3. Measure and record the actual ambient pressure at the FDMS TEOM inlet using a certified handheld barometer.

5.1.3 Flow Check

Note: The 1405-F TEOM is equipped with a Flow Check Wizard, which adds a number of unnecessary steps to the flow check process. The following steps are applicable to both models and are recommended in lieu of following the 1405-F wizard.

1. Make sure that the flow audit adapter valve is in the open position, then remove the PM_{10} head and replace it with a flow audit adapter. Record the monitor's indicated flows on the QC form. These can be found at the bottom of the main screen on the 8500 and in the *Instrument Conditions > Flows > Flow Rates* menu on the 1405-F. Confirm that these are within 2% of their setpoints (3.0 lpm main flow and 13.67 lpm bypass flow).
2. Use tubing to connect the flow audit adapter to an approved flow transfer standard. Read the transfer standard's total flow and record it in ambient conditions on the QC check form.
3. Disconnect the bypass flow line where it connects to the flow splitter. Plug the bypass flow port with a 3/8" Swagelok plug.
4. Note the position of the switching valve:
   8500 TEOMs: *Step Screen > Mass Concentration > Enter*
   1405-F TEOMs: *Main Menu > Instrument Conditions > FDMS Module > Current valve position*
5. Read the main flow on the flow standard and record it on the QC check form.
6. (Recommended) Wait for the switching valve to switch positions, then repeat step 5 and record the reference flow.
7. Disconnect the tubing from the flow audit adapter and connect it to the bypass line. Read the bypass flow on the flow standard and record it on the QC check form.
8. Remove the Swagelok plug and replace the bypass flow line.

5.1.4 Leak Check

Leak check instructions:

8500 TEOMs	1405-F TEOMs
1. Turn off the power to the FDMS module. Leave the control unit powered on. 2. Slowly close the valve of the flow audit adapter. 3. Navigate to the bottom of the main screen on the control unit and record the main and bypass flow rates. 4. Unplug the pump and record the main and bypass flow rates. The flows reported by the TEOM in the absence of pump pressure are the “non-linearity offset values” (NOVs). Subtract the NOVs from the flows measured in step 3 and record the final leak flow rates. 5. Leak flow rates above 0.15 lpm on the main flow and 0.60 lpm on the bypass flow indicate leaks. 6. Slowly open the valve on the flow audit adapter, restore power to the FDMS module, wait for the switching block to switch to the other flow path, and repeat steps 2-5. 7. If a leak check fails, check the hose fittings and other connections in the flow path and repeat the leak check. If a leak check fails again, complete the remainder of the QC check and then contact the Calibration and Repair Lab for assistance.	1. Navigate to the Leak Check Wizard: *Main Menu > Service > Verification > Leak Check* 2. Select *<Next>* 3. The wizard will display the current valve position. Select *<Next>*. 4. Follow the wizard’s instructions to complete the leak check. Repeat with the second valve position. 5. The “Complete Leak Check Wizard” screen will display the leak check results. Record the main and bypass leak flows in both the base and reference positions on the QC check form. Flow rates above 0.15 lpm on the main flow and 0.60 lpm on the bypass flow indicate leaks. 6. If a leak check fails, check the hose fittings and other connections in the flow path and repeat steps 1-5. If a leak check fails again, contact the Calibration and Repair Lab for assistance.

5.1.5 Pump vacuum check

Record the vacuum pressure on the pump's vacuum gauge. If it shows less than 18 inches Hg of vacuum pressure, rebuild or replace the pump.

5.1.6 Clock verification

Verify that the FDMS TEOM clock is set 2-6 minutes ahead of the data logger clock as described in Section 6.2.3. If the FDMS TEOM clock is less than 2 minutes ahead of the data logger clock, adjust the FDMS TEOM clock:

8500 TEOM	1405-F TEOM
Main Menu > TIME/DATE key > Edit Set 2-3 minutes ahead of data logger.	*Main Menu > Settings > System > Set Time* Set 6 minutes ahead of data logger.

As 8500 TEOM clocks are relatively stable, these can be set 2-3 minutes ahead of the datalogger and are unlikely to drift. Since clocks on 1405-F TEOMs routinely run slow, they should be set 6 minutes ahead and monitored closely. Once they drift within 2 minutes of the data logger clock, they should be reset 6 minutes ahead.

5.1.7 Temperature, pressure and/or flow calibration (as needed)

If the ambient temperature or pressure differences (actual - indicated) exceed the acceptance limits (±2°C and ±10 mm Hg, respectively), calibrate the indicated conditions:

8500 TEOM	1405-F TEOM
Main Menu > Step Screen > Set Temps/Flows	*Main Menu > Service > Calibration > Ambient Conditions*

If the results of the flow check are outside or near the 4% flow acceptance limits and/or 5% design flow acceptance limits, calibrate the flows:

8500 TEOM	1405-F TEOM
Flow calibration instructions can be found in the 8500 service manual or in the operating manual for the 1400ab base unit. Contact the Calibration and Repair Laboratory for assistance calibrating flows.	1. Navigate to the Flow Calibration Wizard: *Main Menu > Service > Calibration > Flow Calibration.* 2. Select <*Next*>. 3. To use a flowmeter that reports flows in lpm, select “Direct Flow Device” and select <*Next*>. To use an Airmetrics/Chinook device, select “FTS System” and input the device’s slope and intercept. 4. Follow the wizard’s instructions to complete the flow calibration.

If any ambient temperature, ambient pressure and/or flow parameters were calibrated, repeat sections 5.1.2 - 5.1.4 and record the results on a separate QC check form labeled “As Left.” Label the form containing the results of the pre-calibration QC “As Found.”

5.2 REQUIRED MAINTENANCE

Operators should refer to the detailed maintenance instructions in the model-specific operating guide. Required routine maintenance consists of the following steps:

Every 30 days:

5.2.1.1 Replace the TEOM filter (monthly or as needed)
5.2.1.2 Replace the chiller filter (monthly or as needed)
5.2.1.3 Clean the PM_{10} inlet
5.2.1.4 Clean the VSCC
5.2.1.5 Check the in-line filters

Every 12 months:

5.2.2.1 Rebuild the pump
5.2.2.2 Replace/refurbish the Nafion dryer
5.2.2.3 Check the calibration constant (K_0)
5.2.2.3 Clean the heated air inlet system
5.2.2.3 Clean the chiller
5.2.2.3 Clean the switching valve
5.2.2.3.1 Full system leak check

5.2.1 Monthly maintenance steps

5.2.1.1 Replace the TEOM filter (monthly or as needed)

Please note the following precautions for handling the TEOM filter:

- Keep the door of the TEOM filter housing closed as much as possible to minimize temperature changes to the mass transducer.
- Make sure that the filter exchange tool is clean before you begin.
- Only touch the filter with the filter exchange tool to avoid contaminating the filter.
- Only move the filter straight up and down on the tapered element, as any lateral movement can cause damage.
- Only install filters that have already been equilibrated on the sensor platform.
- Set a new filter onto the sensor platform to equilibrate each time you replace the filter.
- Store the box with new filters inside the sensor housing.
- Ensure that the oscillating frequency is stable before leaving the unit unattended, as improperly seated filters commonly cause data errors.

Instructions for replacing the TEOM filter:

8500 TEOM	1405-F TEOM
1. Press <*Data Stop*>. 2. Open the sensor block. 3. Remove the used filter using a clean filter exchange tool as shown in Figure 5-1. 4. Inspect the tapered element and remove any debris with a cotton swab. 5. Pick up a new conditioned filter from the storage pins, place it on the tapered element and gently press down with the tool. 6. Close the sensor block housing and the latch. 7. Press <*Run*> or <*F1*>. 8. Inspect the oscillating frequency on the FDMS TEOM data screen. If more than the last two digits fluctuate, the filter is likely not seated securely. 9. Set a new filter on the storage pin to equilibrate before the next filter change.	1. Navigate to the Filter Replacement Wizard *Main Menu > Service > Maintenance > Replace TEOM Filter(s).* 2. Follow the wizard’s instructions to replace the filter. 3. Place a new TEOM filter on the filter holder in the mass transducer compartment to equilibrate before the next filter change.

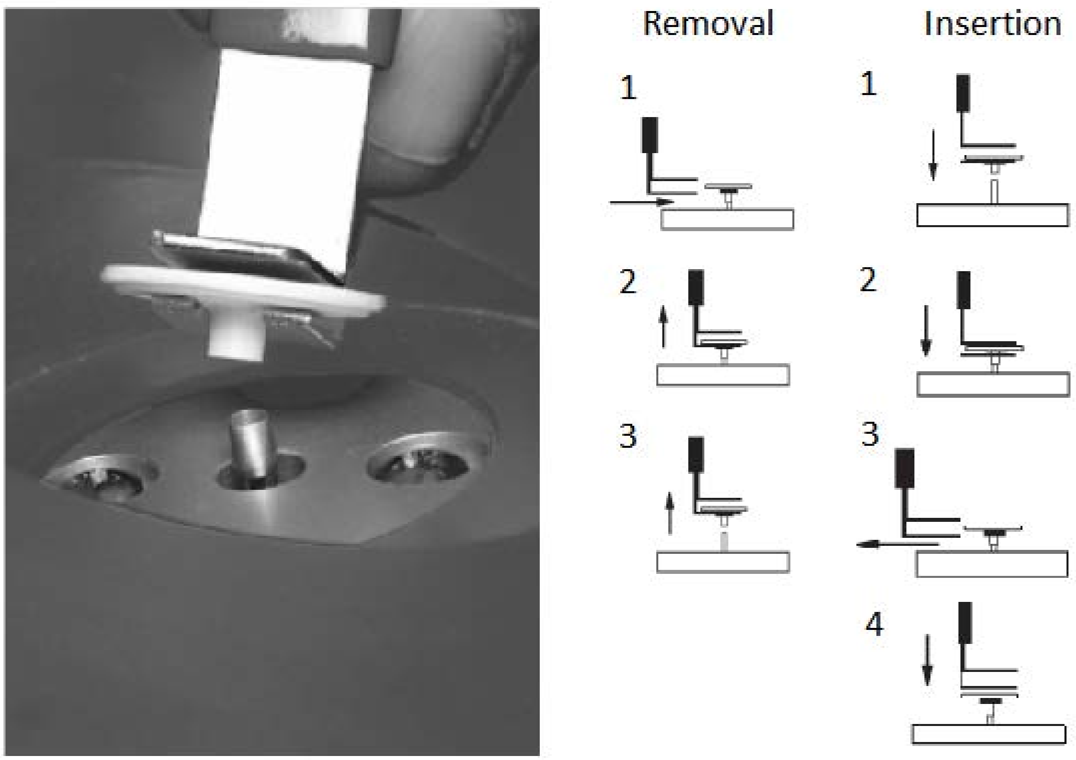

Figure 5-1. Diagram of filter insertion and removal process (adapted from Thermo Fisher Scientific, 2009).

5.2.1.2 Replace the chiller filter

Please note the following precautions for handling the chiller filter:

- Always use tweezers to handle the chiller filter.
- Prepare the new filter in the filter cartridge before opening the chiller door and removing the old filter.
- Wipe condensation off any surfaces in the chiller.

Instructions for replacing the chiller filter:

8500 TEOM	1405-F TEOM
1. Before opening the chiller door, prepare the new chiller filter. Insert the filter into the blue cassette with the textured side facing the top of the cassette as shown in Figure 5-2 and Figure 5-3. The smooth side of the filter should face the screen. 2. Press the <*Data Stop*> key with the FDMS TEOM in *base* mode. Do not change the chiller filter in *reference* mode. 3. Turn off the power to the FDMS module. 4. Open the filter door on the left side of the FDMS module. 5. Turn the grey seal counter-clockwise to remove it. 6. Remove the blue filter cartridge and replace it with the new prepared one. 7. Wipe away any moisture in and around the filter chamber. 8. Check for any damage to the V-seal and replace as necessary. 9. Replace the gray seal cap and turn it clockwise to lock. 10. Close the filter door and tighten the thumbscrew. 11. Turn on the FDMS module.	1. Place the FDMS TEOM in *Setup* mode to suspend data collection. *Main Menu > Service > Instrument Control > Setup* 2. Open the small filter door on the left side of the FDMS TEOM unit. 3. Turn the filter holder counterclockwise until the notches line up with the locking disk, then pull outward to remove the filter holder. 4. Open the blue cassette and remove the used chiller filter. 5. Insert a new chiller filter into the cassette with the textured side facing the top of the cassette as shown in Figure 5-2 and Figure 5-3. The smooth side of the filter should face the screen. 6. Close the filter cassette and install into the filter holder with the top of the cassette facing out. 7. Line up the notches with the locking disk and insert the filter holder, then turn clockwise to lock into place. 8. Close the filter door.

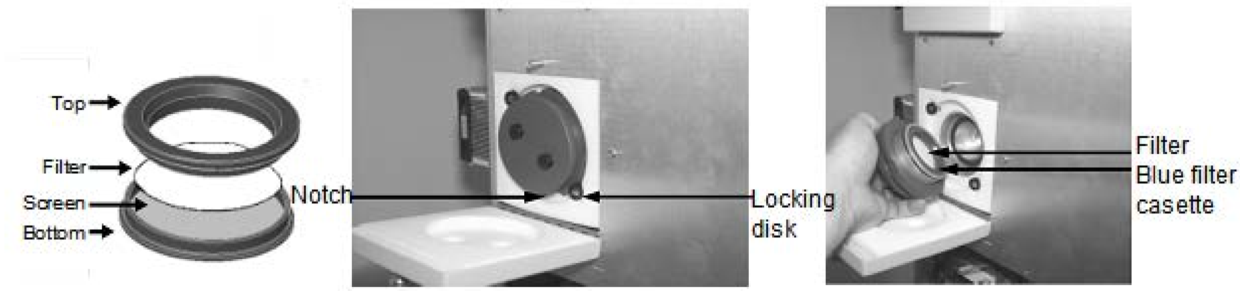

Figure 5-2. Diagram of chiller filter components (Vaughn and Ray, 2011).

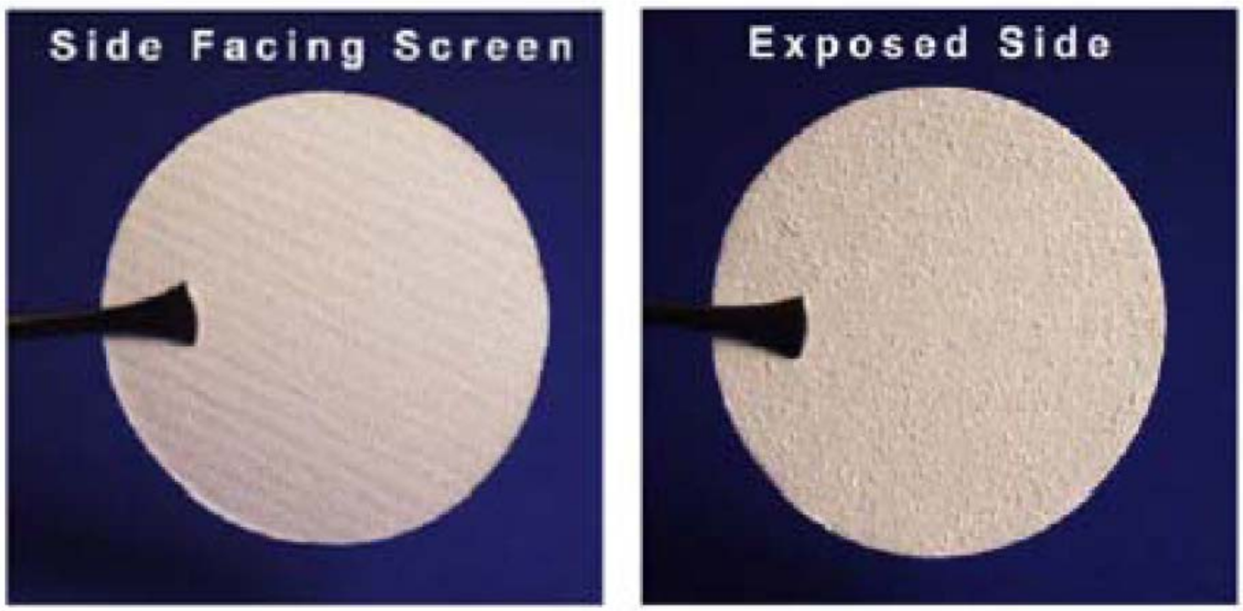

Figure 5-3. Photographs of the two sides of the chiller filter (Vaughn and Ray, 2011).

5.2.1.3 Clean the PM_{10} inlet

1. Remove the condensation jar.
2. Unscrew the collector assembly from the acceleration assembly as shown in Figure 5-4.
3. Remove the four screws on the underside of the top plate of the acceleration assembly and separate the top plates from the insect screen and assembly body.
4. Clean using brushes, a lint-free cloth, and/or compressed air. It is possible to clean the parts with water as long as they are thoroughly dry before reassembly.
5. Using a brush, lint-free cloth and/or cotton swabs, clean the collector plate and the walls around the three vent tubes. Run a wet cloth through the three vent tubes.
6. Wipe out the bottom of the collector assembly where the O-rings are located.
7. Grease the O-rings with silicone grease (never use other types of grease) and inspect for damage. Replace if necessary.
8. Wipe out the condensation jar and lid. Grease the seal inside the lid.

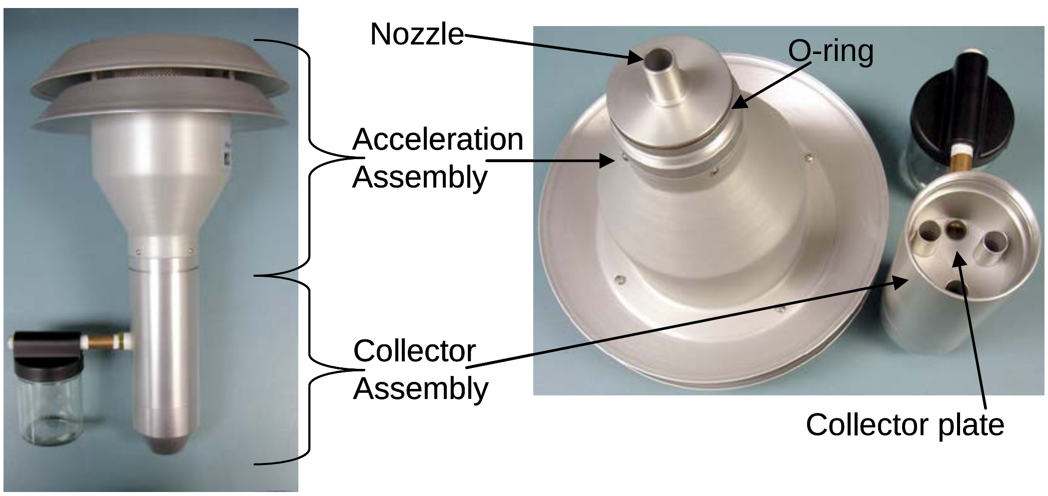

Figure 5-4. Diagram of PM_{10} head inlet components (Vaughn and Ray, 2011).

5.2.1.4 Clean the VSCC

1. Remove the top cap and the emptying cup as shown in Figure 5-5.
2. Use a damp lint-free wipe to remove visible crud, paying special attention to the emptying cup and the cone inside the top cap.
3. Grease the O-rings and inspect for damage. Replace if necessary.

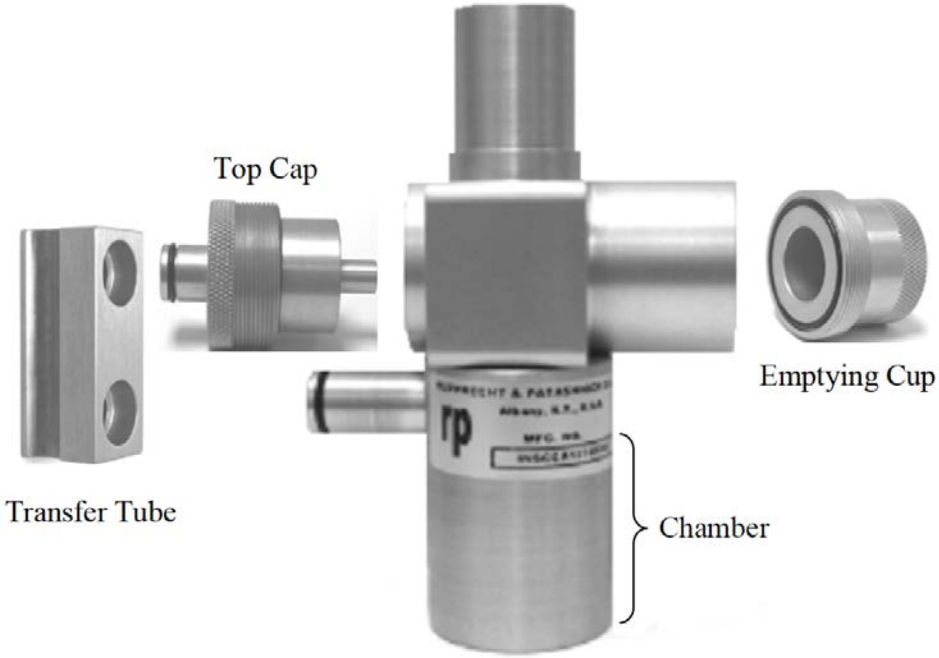

Figure 5-5. Exploded view of VSCC components (Vaughn and Ray, 2011).

5.2.1.5 Check the in-line filters

Inspect the large in-line filters each month and replace if the filters are noticeably dirty. Install these filters with the arrows pointing against the flow and away from the control unit. This allows the operator to see the amount of contamination collected on the filter.

The coalescing filter in the bypass flow line that serves as a water trap cannot be positioned against the direction of the flow. Inspect this filter monthly and replace if water is present.

5.2.2 Annual maintenance steps

5.2.2.1 Rebuild the pump

The pump should be rebuilt every 12-18 months. Follow the detailed instructions contained in the pump rebuild kit (Thermo Fisher Scientific part number 32-008672).

5.2.2.2 Replace/refurbish the Nafion dryer

The performance of the dryer should be evaluated quarterly using the diagnostic data collected. The following are indications of poor dryer performance:

- The sample dew point routinely reads > -8°C
- The sample dew point and ambient dew point appear very similar.
- The Ref MC consistently reads below -5 µg/m^3 during a zero test.
- The sample dew point fluctuates widely.
- The FEM MC data do not match results from collocated instruments.

Refurbish the dryer annually or sooner if any of the above indications of poor dryer performance appear. To use Thermo Fisher Scientific's dryer exchange program, purchase a refurbished dryer, install it and return the old dryer for account credit. See the "Thermo Scientific Particulate Dryer/FDMS Maintenance Program" bulletin (Appendix 9.2) for more information.

5.2.2.3 Other annual maintenance steps

The following maintenance steps should be completed once a year by the Calibration and Repair Laboratory. Operators who wish to perform these steps independently should check with the Calibration and Repair Laboratory to ensure that their maintenance equipment and protocols are up-to-date.

Annual maintenance steps:

- Check the calibration constant (K_0)
- Clean the heated air inlet system
- Clean the chiller
- Clean the switching valve
- Full system leak check

5.2.2.3.1 Full system leak check instructions

A full system leak check should be performed after the other annual maintenance steps to ensure that the full TEOM system is leak-free before it returns to sampling mode. The Calibration and Repair Laboratory staff will conduct this check once every 12 months, though instructions are included here for operators who wish to complete their annual maintenance independently.

The standard leak check described in the instrument operating manuals tests only the sample path between the flow splitter and the flow sensors on the main and bypass flow paths. The full system leak check recommended in this procedure also tests for leaks in the purge path. It requires three additional pieces of hardware: a vacuum gauge, a manual valve and a T fitting. Contact the Calibration and Repair Laboratory to obtain this hardware. This hardware can be left on the pump year-round or can be removed after the full-system leak check.

Figure 5-6. Additional hardware needed for full system leak check (Vaughn and Ray, 2011).

To modify the pump assembly (Figure 5-7):

1. Apply Teflon tape to the threads on the gauge, valve and T fitting (panel B).
2. Remove the tubing and muffler from the pump (panels C and D).
3. Attach the valve to the pump inlet (panel E).
4. Attach the T fitting to the valve (panel E).
5. Attach the gauge to the T fitting (panel E).
6. Attach the tubing to the T fitting (panel F).
7. Replace the muffler (panel F).

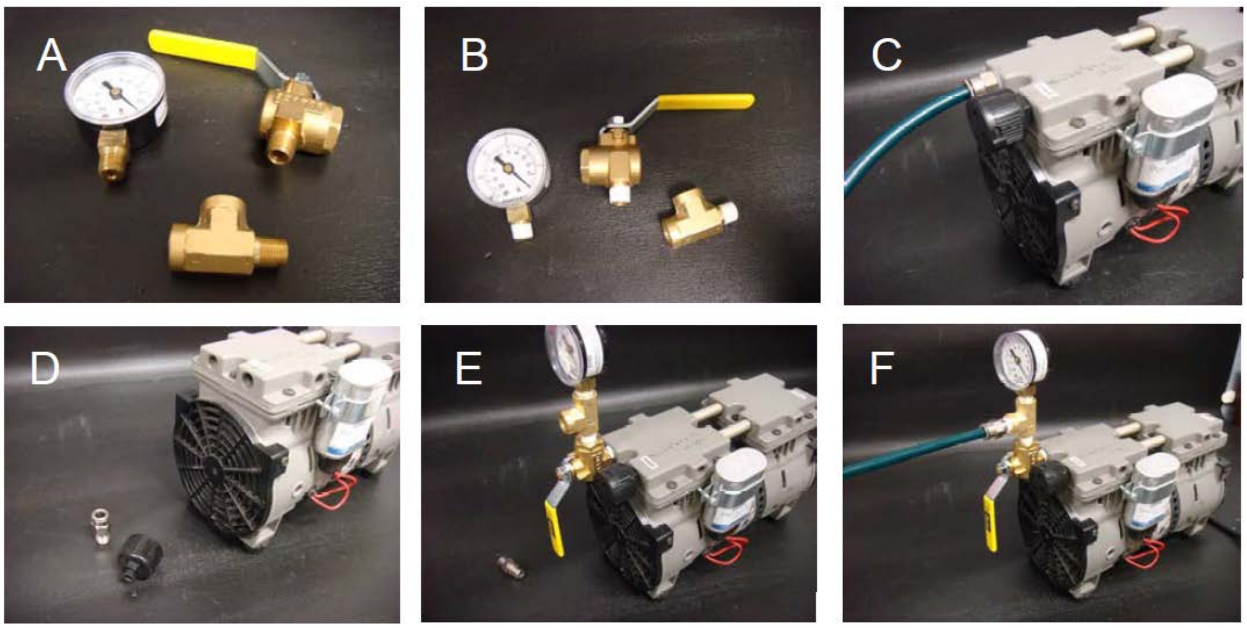

Figure 5-7. Illustration of pump modification for full system leak check (Vaughn and Ray, 2011).

Full system leak check instructions:

8500 TEOM	1405-F TEOM
1. Remove the TEOM filter from the mass transducer as described in Section 5.2.1. Do not remove the chiller filter. 2. Remove the PM_{10} head and install the flow audit adapter in its place. 3. Slowly close the valve on the flow audit adapter. 4. Note the position of the switching valve: *Step Screen > Mass Concentration > Enter* 5. Turn off the power to the FDMS module. Leave the control unit powered on. 6. Close the valve between the pump and the pump vacuum gauge to create a closed loop between the flow audit adapter and the pump. 7. Turn the pump off. 8. Watch the vacuum gauge for 1 full minute and note the change in pressure. A total loss of ≤ 1 inch Hg is a passing result. A result > 1 inch Hg indicates a leak. 9. Open the valves on the pump and the flow audit adapter, restart the pump, and turn on the power to the FDMS module. 10. Wait for the switching block to switch to the other flow path. 11. Turn off the power to the FDMS module, close the pump valve, close the flow audit adapter valve, and turn off power to the pump. 12. Repeat step 8 in the second switching valve position. 13. Slowly open the pump valve and the flow audit adapter valve, turn on the pump, and restore power to the FDMS module. 14. If a leak check fails, contact the Calibration and Repair Laboratory for assistance.	1. Enter Setup mode. *Main Menu > Service > Instrument Control > Setup* 2. Remove the TEOM filter from the mass transducer as described in Section 5.2.1. Do not remove the chiller filter. 3. Remove the PM_{10} head and install the flow audit adapter in its place. 4. Note the position of the switching valve. *Main Menu > Instrument Conditions > FDMS Module > Current valve position* 5. Slowly close the valve on the flow audit adapter. 6. Wait for the pump vacuum gauge to stabilize, then close the valve between the pump and the pump vacuum gauge to create a closed loop between the flow audit adapter and the pump. 7. Watch the vacuum gauge for 1 full minute and note the change in pressure. A total loss of ≤ 1 inch Hg is a passing result. A result > 1 inch Hg indicates a leak. 8. Open the valves on the pump and the flow audit adapter. 9. Force the switching mode into the alternate position *Main Menu > Service > Advanced > Test FDMS Valve > Test* 10. Repeat steps 5-8 in the second switching valve position. 11. Slowly open the pump valve and the flow audit adapter valve. 12. If a leak check fails, contact the Calibration and Repair Laboratory for assistance.

6. DATA COLLECTION AND STORAGE

6.1 COMMUNICATION SOFTWARE SETUP

8500 TEOM	1405-F TEOM
RPComm is a software program that allows users to control the 8500 TEOM and retrieve diagnostic data via remote interface over a serial connection. Contact IT staff for assistance installing and configuring RPComm. RPComm can only be used when Envidas polling is stopped.	ePort is a software program that allows users to control the 1405-F TEOM and retrieve diagnostic data via a remote interface over an Ethernet connection. ePort can be installed using the installation CD shipped with the instrument or from an executable downloaded from the Thermo Fisher Scientific Online Library.

6.2 ENVIDAS DATA LOGGER CHANNEL CONFIGURATION

There are three important steps to configuring Envidas channels correctly and ensuring accurate data collection.

6.2.1 Select the correct PRCs
6.2.2 Set type for all channels to “Last Sample”
6.2.3 Set the FDMS TEOM clock to 2-6 minutes ahead of the data logger clock.

6.2.1 Select the correct PRCs

The correct PRCs corresponding to each FDMS TEOM channel are listed in Table 6-1.

Table 6-1. PRCs for data collection in Envidas.

Parameter Name	PRC (8500)	PRC (1405-F)
FdmsRef	104	290
FdmsBase	102	289
FEM_TPM25	24	395

6.2.2 Set type for all channels to "Last Sample"

Though Envidas collects concentration data from the FDMS TEOM each minute, all data reported by FDMS TEOM are 1-hour averages. The reference, base and mass concentrations are rolling 1-hour averages updated every 6 minutes, and the FEM 1-hr MC is a 1-hour average updated at the top of each hour. The "type" setting for all four FDMS TEOM channels should be set to "Last Sample" instead of "Average." The Envidas type "Last Sample" refers to the value reported at :59 past the hour on the data logger's clock. This 1-hour average best corresponds to the hour :00-:59, which is the interval that 1-hour data should represent. Channels set to type "Average" will take an average of the 60 rolling 1-hour averages collected during each hour, which is not an accurate 1-hour average and does not meet the criteria necessary for compiling 24-hour Federal Equivalent Method $PM_{2.5}$ data.

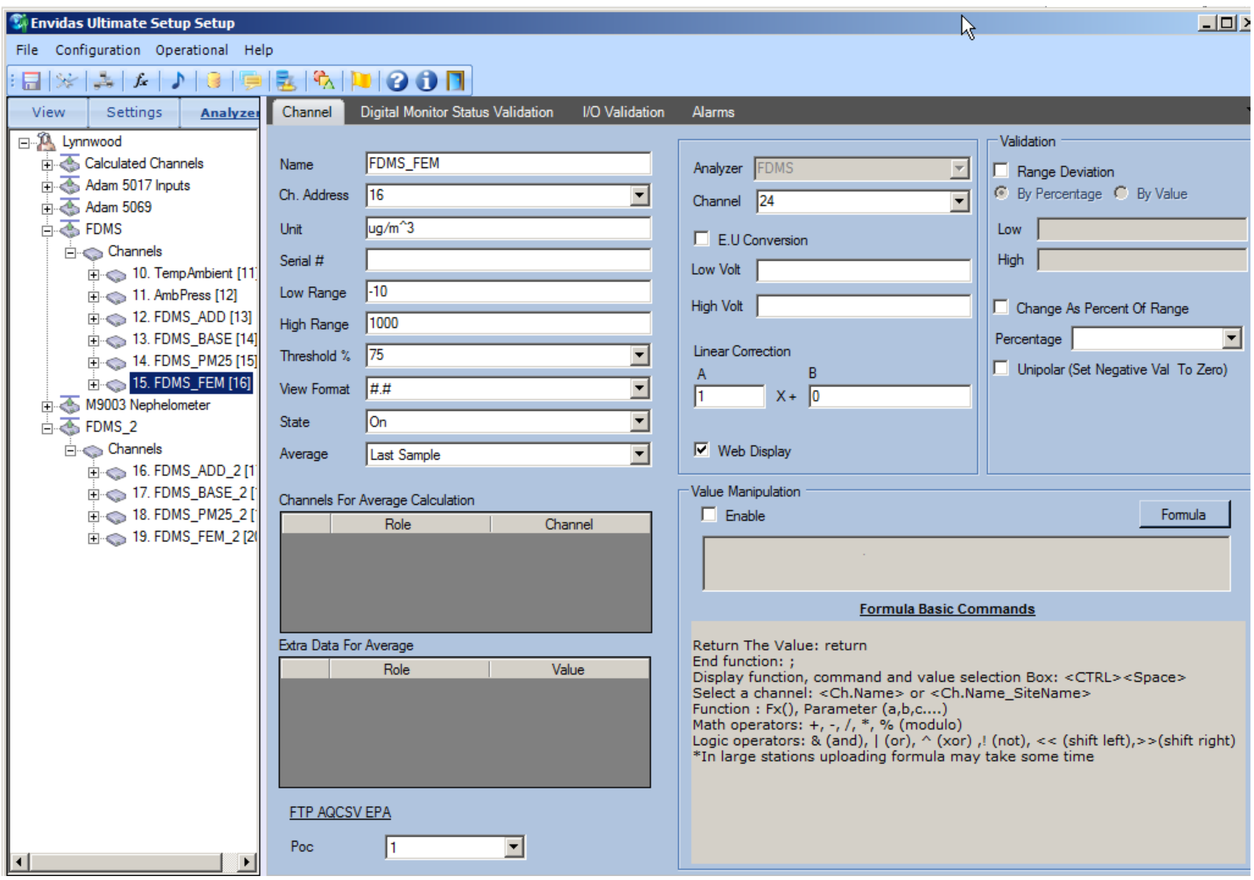

Figure 6-1. Screenshot of FEM_TPM25 Channel in Envidas Ultimate.

6.2.3 Set the FDMS TEOM clock to 2-6 minutes ahead of the data logger clock.

At the end of each hour, the FDMS TEOM's internal averaging function calculates the FEM 1-hr MC from the previous hour. The FDMS TEOM needs to be set at least 2 minutes ahead of the data logger so that its hourly update is completed before Envidas polls the hourly data. For example, if the data logger clock reads 1:00, the FDMS TEOM's clock should read 1:02 or later.

Verify that the FDMS TEOM's clock is at least 2 minutes ahead of the data logger during each monthly QC and adjust as necessary. FDMS TEOM clocks can be set as many as 6 minutes ahead of the data logger clock. FDMS TEOM clocks, particularly in 1405-F models, routinely run slow. An FDMS TEOM clock set 6 minutes ahead of the data logger will typically drift to only 2 minutes ahead within the span of only a few months. Operators of 1405-F TEOMs should therefore set the FDMS TEOM clock 6 minutes ahead of the data logger when making a clock adjustment. Once the FDMS TEOM clock drifts less than 2 minutes ahead of the data logger clock, it should once again be set 6 minutes ahead.

6.3 DIAGNOSTIC DATA STORAGE

The FDMS TEOM collects a number of parameters related to environmental and instrument conditions that may affect operation. These parameters can be useful in diagnosing instrument problems and identifying invalid data. These data can be accessed in two ways: through the FDMS TEOM's internal data storage and through Envidas' diagnostic report.

The 8500 TEOM can internally store up to 8 diagnostic parameters, while the 1405-F TEOM can store up to 20. There is no limit to the number of diagnostic parameters that can be collected by Envidas, though an excessive number of parameters can slow data polling. The standard parameters to collect on the internal FDMS TEOM storage are summarized in Table 6-2 and Table 6-3. PRCs listed as “--“ are not available on the selected instrument.

Refer to Table 4-2 for instructions on selecting parameters for storage.

Operators may elect to collect different variables in the internal FDMS TEOM storage if necessary to diagnose site-specific problems. In this case, operators should add the eliminated parameters from the tables below to the diagnostic parameters polled by Envidas.

Table 6-2. Diagnostic parameters for 8500 TEOM internal storage.

Parameter Name	Units	PRC (8500)	Comments
Status	--	41	See Section 7.1
FEM MC	µg/m^3	20	
Ref MC	µg/m^3	104	
Base MC	µg/m^3	102	
Noise	Hz-Hz	13	<0.05
Filter Loading	%	35	Change filter >80%
Sample dew point	°C	99	Should be less than ambient dew point
Ambient dew point	°C	114	

Table 6-3. Diagnostic parameters for 1405-F TEOM internal storage.

Parameter Name	Units	PRC (1405-F)	Comment
Status	--	008	See section 7.1
FEM MC	µg/m^3	393	
Ref MC	µg/m^3	290	
Base MC	µg/m^3	289	
Noise	hz-hz	258	<0.05
Main Flow	lpm	226	≈3 lpm
Bypass Flow	lpm		≈16.67 lpm
Filter Loading	%	242	Change filter if >80%
Total Mass	µg	243	
Vacuum Pump Pressure	atm	096	Rebuild pump if >0.4 atm
Ambient Temperature	°C	061	
Ambient Dew Point	°C	064	
Ambient Humidity	%	063	
Ambient Pressure	atm	066	
Dryer Temperature	°C	271	
Dryer Dew Point	°C	272	
Dryer Humidity	%	273	
Cooler Temperature	°C	287	

The diagnostic parameters to collect through the Envidas diagnostic reporting function are summarized in Table 6-4. The diagnostic collection schedule should be set to once every 30 minutes.

Table 6-4. Diagnostic parameters to collect in Envidas.

Parameter Name	Units	PRC (8500)	PRC (1405F)	Comment
Status	--	041	008	See section 7.1
Noise	hz-hz	013	258	<0.05
Filter Loading	%	035	242	Change filter >80%
Frequency	hz	012	257	
Total Mass	ug	009	243	
Main Flow	lpm	039	225	
Bypass Flow	lpm	040	090	
Ambient Temperature	°C	026	061	
Dryer Temperature	°C	--	271	>shelter temp and <30°C
Cooler Temperature	°C	--	287	
Case Temperature	°C	025	047	
Cap Temperature	°C	027	058	
Enclosure Temperature	°C	028	068	<60°C
Ambient Dew Point	°C	114	064	
Sample Dew Point	°C	099	--	
Dryer Dew Point	°C	--	272	
Ambient Humidity	%	100	063	
Dryer Humidity	%	--	273	
Ambient Pressure	atm	124	066	
Vacuum Pump Pressure	atm	--	096	Rebuild pump if >0.4 atm

7. DATA VALIDATION AND QUALITY ASSURANCE

All operator quality control check results must be sent to the Quality Assurance Coordinator by the 10^{th} of the month following the end of the month of data collection.

The Quality Assurance unit is responsible for final data validation. Data validity is evaluated using a number of criteria, including but not limited to the results of quality control checks and performance audits and the diagnostic parameters in Table 6-2 and Table 6-3. Table 7-1 summarizes the acceptance limits for critical and operational criteria. Criteria that trigger invalidation outside of acceptance limits are marked with a ✓; the validity of data outside of the remaining limits is evaluated using a weight-of-evidence approach. The full table of critical and operational criteria can be found in EPA's Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II.

Table 7-1. Summary of critical and operational criteria used to determine data validity.

Criteria	Frequency	Acceptance limits	Invalid
Flow check	Monthly QC; semi-annual audit	± 4%	✓
Leak check	Monthly QC	Main <0.15 lpm; Bypass <0.6 lpm (after subtracting NOV)	✓
Temperature verification	Monthly QC; semi-annual audit	± 2C	Weight-of-evidence
Pressure verification	Monthly QC; semi-annual audit	± 10 mm Hg	Weight-of-evidence
Clock verification	Monthly QC; semi-annual audit	2-6 minutes ahead	✓
Status	Hourly	Significant malfunction codes	See Table 7-2 Table 7-3

7.1 STATUS CODES

The FDMS TEOM reports status codes as hexadecimal numbers. If multiple status codes are applicable, the FDMS TEOM adds their decimal codes and reports the sum. Status codes can be deciphered by matching the reported decimal code(s) to Table 7-2 and Table 7-3 or by converting the decimal code to a hexadecimal number and matching the result to the "Hexadecimal" column. The 8500 TEOM also reports status codes as letters in the upper left hand corner of the screen on the control unit. Statuses that automatically trigger invalidation are marked with a ✓; the validity of data with the remaining status codes is evaluated using a weight-of-evidence approach.

Table 7-2. 8500 TEOM Status Codes (adapted from Thermo Fisher Scientific, 2008).

Warning	Hexadecimal	Decimal	Letter Code	Invalid	Explanation
Status OK	0	0	OK		Valid
Frequency signal failure	1	1	M		Transducer is not providing a frequency signal
Temperature(s) outside of bounds	2	2	T		Temperatures ± 0.5°C from set point
Flow(s) outside of bounds	4	4	F	✓	Main flow ± 0.1 lpm, bypass flow ± 0.4 lpm
Exchange filter	8	8	X		
Voltage low	10	16	V	✓	AC < 105 volts
Cooler status	20	32	C	✓	Cooler ± 1.0°C from 4.0°C
Valve position	40	64	P	✓	Valve not positioned correctly
Drier status	80	128	D	✓	Downstream dew point >2.0°C
Inlet humidity high	100	256	T		Dryer or temperature sensor malfunction

Table 7-3. 1405-F TEOM Status Codes (adapted from Thermo Fisher Scientific, 2009).

Hexadecimal	Decimal	Warning	Invalid	Explanation
0x40000000	1,073,741,824	%RH High		>= 98%
0x20000000	536,870,912	Dryer		>2
0x10000000	268,435,456	Cooler		>0.5°C deviation
0x08000000	134,217,728	Exchange Filter		>90
0x04000000	67,108,864	Flow	✓	>10% deviation
0x02000000	33,554,432	Heaters		>2% deviation
0x01000000	16,777,216	Mass Transducer	✓	frequency <10 Hz
0x00004000	16,384	User I/O Device		
0x00002000	8,192	FDMS Device		
0x00001000	4,096	Head 1		
0x00000800	2,048	Head 0		
0x00000400	1,024	MFC 1 Device		
0x00000200	512	MFC 0 Device		
0x00000100	256	System Bus		
0x00000080	128	Vacuum Pressure	✓	(Ambient - Vac) <0.1 atm
0x00000040	64	Case or Cap Heater	✓	>2% deviation
0x00000020	32	FDMS Valve	✓	
0x00000010	16	Bypass Flow	✓	>10% deviation
0x00000008	8	Ambient %RH & Temp Sensor		Ambient %RH and temp sensor disconnected
0x00000004	4	Database		Unable to log to database
0x00000002	2	Enclosure Temp		>60°C
0x00000001	1	Power Failure	✓	
0x00000000	0	Valid		All conditions normal

7.2 NEGATIVE CONCENTRATIONS

As with any filter-based $PM_{2.5}$ sampling method, filter dynamics occur constantly during the FDMS TEOM's operation. Particles collected on the sample filter interact with airborne gases, other particles in the sample stream, and filter media. As a result of these filter dynamics, the precision of hourly $PM_{2.5}$ data from FDMS TEOM is estimated to be ± 2.5 µg/m^3. At low concentrations (0-5 µg/m^3), the FDMS TEOM will routinely report valid negative concentrations as a result of both filter dynamics and normal instrument noise. These routine negative concentrations should be reported and included in 24-hour averages. In order to retain these negative concentrations, the "Unipolar" setting should remain unchecked on all FDMS TEOM channels in Envidas.

FDMS TEOMs operating in Washington State have reported occasional hourly concentrations as low as -15 µg/m^3 in the course of normal, valid operation. If concentrations are not regularly below -10 µg/m^3, these occasional values should be considered valid. However, hourly mass concentrations that routinely drop below -10 µg/m^3 can be a symptom of a number of different problems, including pump failure, chiller failure, or an improperly seated TEOM filter. Contact the Calibration and Repair Laboratory for assistance if hourly concentrations drop below -10 µg/m^3 more frequently than a few times per month.

Negative concentrations frequently occur when the Ref MC value is greater than 0 µg/m^3. The Ref MC should typically be a negative concentration, though occasional positive hourly Ref MC values are normal. Though Thermo Fisher Scientific advises that Ref MC values greater than 4 µg/m^3 indicate invalid data, field experience with the FDMS TEOM in Washington State has shown that this threshold can occasionally be exceeded with no indication of instrument malfunctions. Data should be considered valid if the hourly Ref MC value is $\leq$ 6 µg/m^3 and no status codes or other signs of abnormal instrument performance are present. If Ref MC values routinely reach above 6 µg/m^3, contact the Calibration and Repair Laboratory for assistance.

8. REFERENCES

"Notice of the designation of four new equivalent methods for monitoring ambient air quality." *Federal Register* 74:115 (17 June 2009) pp. 28696-28698.

"Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring." *Code of Federal Regulations* Title 40, Pt. 58, Appendix E, 2013 ed.

Ray, Alison E. and David L. Vaughn. *Standard Operating Procedure for the Continuous Measurement of Particulate Matter: Thermo Scientific TEOM 1405-DF Dichotomous Ambient Particulate Monitor with FDMS.* Petaluma: Sonoma Technology, 2009 (STI-905505.03-3657-SOP).

Thermo Fisher Scientific. *Operating Guide, TEOM 1405-F Ambient Particulate Monitor with FDMS Option.* Franklin, MA: Thermo Fisher Scientific, 2009 (42-010978 Revision A.000).

Thermo Fisher Scientific. *Operating Manual, Series 8500 FDMS.* Franklin, MA: Thermo Fisher Scientific, 2008 (42-010874 Revision C).

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Vaughn, David L. and Alison E. Ray. *Standard Operating Procedure for the Continuous Measurement of Particulate Matter: Thermo Scientific TEOM 1400a Ambient Particulate Monitor with 8500C FDMS.* Petaluma: Sonoma Technology, 2011 (STI-910212-4083-SOP).

9. APPENDIX

9.1 SAMPLE FDMS TEOM QC CHECK FORM

The FDMS TEOM QC Check form is shown below. All operators of $PM_{2.5}$ FDMS TEOMs in the Washington State network are required to use this form. See the Quality Assurance Unit for a copy of this form as a fillable spreadsheet.

Washington State Department of Ecology
FEM $PM_{2.5}$ TEOM Quality Control Check Results

AQS No. ____________
Location ____________
Sampler Serial No. ____________
State Tag No. ____________
Software Version ____________

Flow Std. Model ____________
Flow Std. Serial No. ____________
Flow Std. Cert. Date ____________

Date ____________
Operator ____________
QC Start Time ____________ PST
QC Stop Time ____________ PST

Temp Std. Serial No. ____________
Temp Std. Cert. Date ____________
Pressure Std. Serial No. ____________
Pressure Std. Cert. Date ____________

Temperature and Pressure QC

	Indicated	Actual	Difference
Ambient Temperature (± 2°C)			
Ambient Pressure (±10 mmHg)			

Diagnostic Checks

Pump Vacuum (inHg)	
Sample Dewpoint (°C)	
Status Codes	

Flow QC

Sampler Design Flow Rate	Indicated Flow Rate lpm	Actual Flow Rate lpm	Flow Difference (±4%)
Main 3.0 lpm			
Bypass 13.67 lpm			
Total 16.67 lpm			
Reference 3.0 lpm			
		Design Flow Difference (±5%)	

Leak Checks

	Base Flow	Reference Flow
Main (≤ .15 lpm)		
Bypass (≤ .6 lpm)		

Clock Verification

Data logger time	
As-found TEOM time	
As-left TEOM time	

Comments:

QC Result:

9.2 THERMO SCIENTIFIC PARTICULATE DRYER/FDMS MAINTENANCE PROGRAM

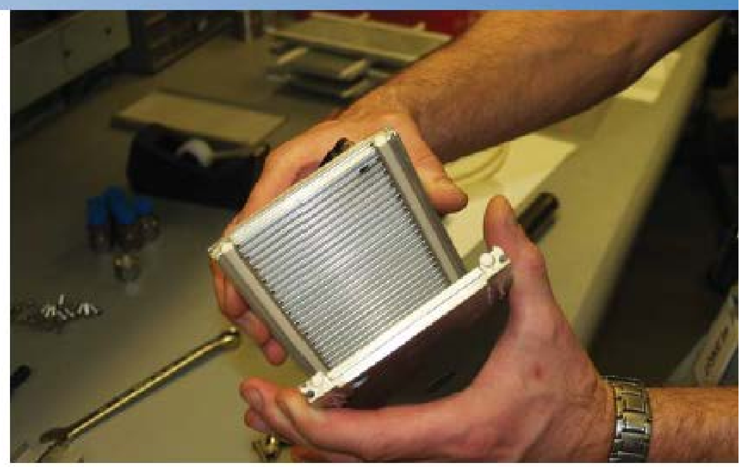
Product Specifications

Thermo Scientific Particulate Dryer/FDMS Maintenance Program

Keep your instrument running at maximum efficiency

The Thermo Scientific™ Particulate Dryer Maintenance Program provides flexible options for the maintenance of Thermo Scientific™ TEOM™ Series and Thermo Scientific™ Model 8500-C particulate dryers.

- Reduce the risks of particulate overload
- Ensure peak-performance of your instrument
- Three high quality replacement options
- Flexible choices to suit your needs



The Thermo Scientific Particulate Dryer Maintenance Program helps to protect your instrument from particulate overload. To ensure peak-performance of the Thermo Scientific TEOM 1405-F, TEOM 1405-DF and the Model 8500-C, it is recommended that the dryer be serviced every 12 months or as often as required.

Proper dryer maintenance will reduce the risks of data errors, inaccurate measurements, and increased particulate loading. To assist you in managing these risks, our Particulate Dryer Maintenance Program provides three options of replacement for you to choose from:

- Purchase New
- Dryer Exchange
- Dryer Maintenance & Instrument Repair

Purchase New
The particulate dryer is available for purchase as a new unit. You can install a new dryer on-site for immediate replacement.

Dryer Exchange
Purchase a refurbished dryer as a convenient low-cost maintenance option. Once you have installed the dryer, send us the used dryer and you will receive a credit.

Dryer Maintenance & Instrument Repair
If your instrument requires annual maintenance, repair or performance checks we will restore your instrument to the original condition. This includes a new dryer replacement, complete cleaning of the instrument, and a full function system check.

Thermo
SCIENTIFIC

Thermo Scientific Particulate Dryer Maintenance Program

Product Specifications

Replacement Options

Purchase New
Simply place your order with our customer service department and you can keep the old dryer unit in your inventory as a back-up replacement.

Dryer Exchange
Place the order with customer service and you will be sent a refurbished replacement unit. Once you have installed the dryer, return your used one for a credit towards your account.

Dryer Maintenance & Instrument Repair
Contact our customer service team for a return authorization and specify dryer maintenance and repair. This service comes with a 90 day warranty.

Ordering Information		
Dryer Refurbishment Options for the Thermo Scientific TEOM Series Monitors: TEOM 1405-F & TEOM 1405-DF Monitor		
56-009872 TEOM 1405 Monitor NAFION Dryer - New		
56-009872-EXCH TEOM 1405 Monitor NAFION Dryer Exchange Program - Refurbished		
Dyer Refurbishment Options for the Thermo Scientific 8500-C Filter Dynamic Measurement System (FDMS)		
56-010719 8500-C FDMS System NAFION Dryer - New		
56-010719-EXCH 8500-C FDMS NAFION Dryer Exchange Program - Refurbished		
This service is available world-wide. If you would like to exchange your dyer, refurbish your current dyer or purchase new please contact our Customer Service Team in your respective region.		
North & South America	**Europe / Middle East / Africa**	**China & Asia Pacific**
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To maintain optimal product performance, you need immediate access to experts worldwide, as well as priority status when your air quality equipment needs repair or replacement. We offer comprehensive, flexible support solutions for all phases of the product life cycle. Through predictable, fixed-cost pricing, our services help protect the return on investment and total cost of ownership of your Thermo Scientific air quality products.

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This product is manufactured in a plant whose quality management system is ISO 9001 certified.

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