



Aethalometer Model AE-33 (T633) Operating Procedure

For the

Air Quality Program

Washington State Department of Ecology
Olympia, Washington

April 2024, Publication 24-02-019

Publication Information

This document is available on the Department of Ecology's website at:

<https://apps.ecology.wa.gov/publications/summarypages/2402019.html>

Contact Information

Air Quality Program

P.O. Box 47600

Olympia, WA 98504-7600

Phone: 360-407-6800

Website¹: [Washington State Department of Ecology](http://www.ecology.wa.gov)

ADA Accessibility

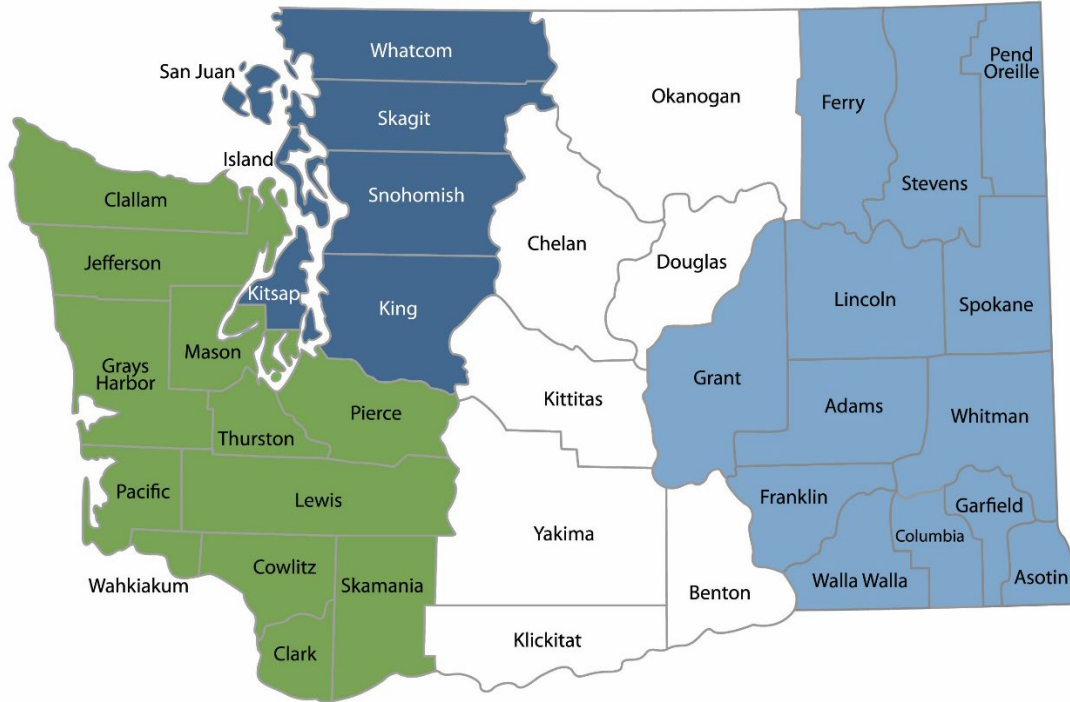
The Department of Ecology is committed to providing people with disabilities access to information and services by meeting or exceeding the requirements of the Americans with Disabilities Act (ADA), Section 504 and 508 of the Rehabilitation Act, and Washington State Policy #188.

To request an ADA accommodation, contact Ecology by phone at 360-407-6800 or email at melanie.forster@ecy.wa.gov. For Washington Relay Service or TTY call 711 or 877-833-6341. Visit Ecology's website for more information.

¹ www.ecology.wa.gov/contact

Department of Ecology's Regional Offices

Map of Counties Served



Southwest Region 360-407-6300	Northwest Region 206-594-0000	Central Region 509-575-2490	Eastern Region 509-329-3400
---	---	---------------------------------------	---------------------------------------

Region	Counties served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
Headquarters	Across Washington	PO Box 46700 Olympia, WA 98504	360-407-6000

Aethalometer Model AE-33 (T633) Operating Procedure

Air Quality Program
Washington State Department of Ecology
Olympia, WA

April 2024 | Publication 24-02-019



DEPARTMENT OF
ECOLOGY
State of Washington

Approved by:

Signature: _____ Date: _____
Arati Kaza, Ecology Quality Assurance Officer

Signature: _____ Date: _____
Rob Dengel, Air Quality Deputy Program Manager

Signature: _____ Date: _____
Sean Lundblad, Technical Services Section Manager

Signature: _____ Date: _____
Jill Schulte, Air Monitoring Coordinator

Signature: _____ Date: _____
Scott Dubble, NWRO/SWRO & Air Quality Operations Unit Supervisor

Signature: _____ Date: _____
Christopher Atherly, Air Quality Program Quality Assurance Coordinator

Signatures are not available on the Internet version.

Table of Contents

Revision History.....	6
List of Figures and Tables.....	4
Figures.....	4
Tables.....	4
1. Introduction.....	6
2. Principles of Operation	7
3. Equipment and Supplies	9
4. Installation.....	10
4.1 Siting.....	10
4.2 Sample Line Setup	11
4.3 Analyzer Setup & Operation.....	13
4.4 Datalogger communication and channel configuration.....	15
5. Quality Control Checks and Maintenance	18
5.1 Quality Control Check Schedule	18
5.2 Clean Air Check.....	19
5.3 Stability Check	19
5.4 Leak Check.....	19
5.7 Flow Check	21
5.8 Flow Calibration	21
5.9 Inlet Leak Check.....	22
5.10 Spot Spacing Check.....	22
5.11 Maintenance Schedule	22
5.12 Clean cyclone	23
5.13 Replacing filter tape.....	23
5.14 Clean optical window	24
5.13 Changing the clean air filter.....	25
6. Data Validation, Data Completeness, and Quality Assurance	25

List of Figures and Tables

Figures

Figure 1-1: Aethalometer (AE-33) Front & Back view.....	6
Figure 2-1: Flow schematics.....	7
Figure 2-2: Dual spot collection on the Aethalometer filter tape.....	8
Figure 4-1: AE-33 sample train design.....	12
Figure 4-2: A) Attach flexible tubing to SST inside the shelter; B) In-line bug & water trap	12
Figure 4-3: General operation tab - stop or start sample collection and initiate quality control checks.	14
Figure 4-4: Envidas Ultimate Port configuration for the AE-33	15
Figure 4-5: Setting up communications on the AE-33 touchscreen.....	16
Figure 4-6: Envidas Ultimate channel set up for BC	16
Figure 5-1: Spare line for easier leak and flow checks.....	18
Figure 5-2: A) Tape removal and flow calibration pad placement; B) Flow calibration pad	20
Figure 5-3: Inlet PM _{2.5} cyclone	23
Figure 5-4: Lifting the optical chamber and locking mechanism	23
Figure 5-5: Optical chamber release	24

Tables

Table 3-1: Summary of Aethalometer equipment and supplies.....	9
Table 4-1: Summary of AE-33 Aethalometer neighborhood scale siting criteria.....	10
Table 5-1: Quality Checks: Frequency, Acceptance, and Action levels	18
Table 5-2: Maintenance schedule	22

Acronyms and Abbreviations

λ	Wavelength
AAC	Absorption Angstrom Component
AD	Aerodynamic diameter
AQP	Air Quality Program
AQS	Air Quality System
BC	Black Carbon
Ecology	Washington State Department of Ecology
Envista ARM	Envista Air Resources Manager
EPA	Environmental Protection Agency
LAC	Light Absorbing Organic Carbon
LPM	Liters per minute
MAC	Mass Absorption Cross-Section
OD	Outer Diameter
PM	Particulate Matter
PM _{2.5}	PM with an aerodynamic diameter 2.5 μm or less
QA	Quality Assurance
QAP	Quality Assurance Plan
QAPP	Quality Assurance Project Plan
QC	Quality Control
SOP	Standard operating procedure
SST	Stainless Steel Tubing
$\mu\text{g}/\text{m}^3$	Micrograms per cubic meter
User's Manual	BAM 1022 Particulate Monitor Operation Manual
Washington Network	Washington State Ambient Air Monitoring Network

1. Introduction

This document describes Ecology’s procedures for sampling black carbon particulate (BC) in ambient air using the Magee Scientific Aethalometer Model AE-33 (Figure 1-1). It also applies to the Teledyne T633 analyzers, which are no longer produced but are still in field service. This SOP does not replace the user or service manuals. The manufacturer provided user manual should be used for non-standard repairs and troubleshooting. Any AE-33 or T633 operating within the Washington Network must be operated in accordance with this SOP.



Figure 1-1: Aethalometer (AE-33) Front & Back view

2. Principles of Operation

PM mass concentration can be calculated from measurements of light attenuation through the atmosphere using the Beer-Lambert law. This law states that the rate of decrease in the intensity of light per change in space is proportional to the concentration of the absorbing substance. Many types of chemical analyses using mass spectroscopy are based on this principal. The Aethalometer AE-33 measures the light absorbed by BC particles collected on a quartz fiber filter rather than in a fluid like air or water. Using a version of the Beer-Lambert law, the AE-33 converts the measured light absorption into an equivalent BC mass concentration using a prescribed BC mass absorption cross-section (MAC) at different wavelengths (see AE33 User's Manual, page 20 for calculations and page 21 for MAC values at each wavelength). Wavelength will hereafter be denoted as λ .

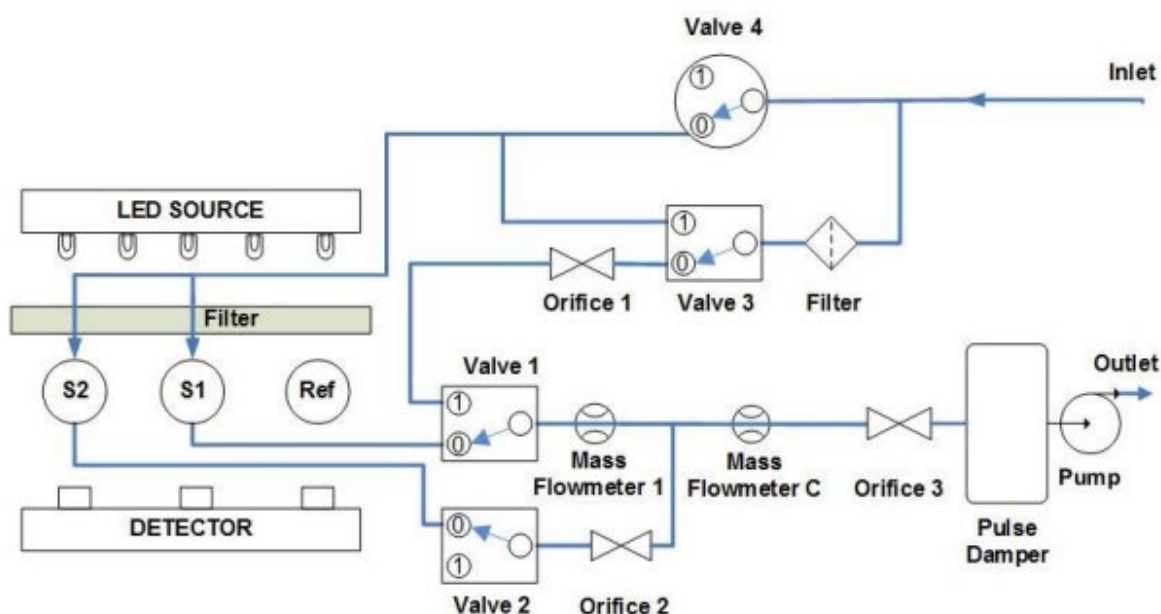


Figure 2-1: Flow schematics

Figure 2-1 is a schematic of aethalometer sample flow and collection. During standard operation, the AE-33 continuously pulls air through a PM_{2.5} size cut cyclone (inlet), through the sample train and into the analyzer where a quartz fiber filter traps particles in two spots (S1 & S2). A third spot is kept clean and used as a reference blank. A detector continuously monitors light transmitted through both the sample filter spots and the reference at seven discrete wavelengths: 370 nm, 470 nm, 520 nm, 590 nm, 660 nm, 880 nm, and 950 nm. As light absorbing particles accumulate on the filter, light transmission through the filter decreases and reduces the signal seen by the detector. Light transmission through the clean reference filter remains the same.

The fibers in the filter create a multiple scattering medium. This means the fibers scatter each incoming photon many times in random directions before the detector sees it. This is important for two reasons: 1) non-light absorbing particles, like ammonium sulfate, scatter the light

similarly to the fibers and therefore do not significantly change the light transmission through the filter and 2) Since the photon is scattered many times by the filter media, there is a greater chance of it interacting with and being absorbed by light absorbing particles in the filter. This increases the sensitivity of the absorption measurement.

Continuous BC measurements are based on the rate light is attenuated ($dATTN/dt$). To account for the decrease in the BC MAC as the filter becomes progressively laden with BC particles, and therefore less transparent, the AE-33 has a second spot (S2) that collects particles from the sample stream at half the flow rate of S1 (Figure 2-2). There are two separate flow sensors: one controls total flow (Flowmeter C) and the other controls the flow to S1 (Flowmeter 1). Measurements from both these spots are mathematically combined to produce a BC concentration free from filter loading errors (User's manual, page 49).



Figure 2-2: Dual spot collection on the Aethalometer filter tape

Channel BC6 corresponds to the light absorption measurements at $\lambda = 880$ nm. This is the measurement used to calculate BC concentration. Channel BC1 corresponds to light absorption at $\lambda = 370$ nm and may be used to estimate the percentage of light absorption from other light absorbing organic carbon (LAC), sometimes called brown carbon or UV carbon in AQS. BC light absorption as a function of λ follows the equation form $Abs_{BC} = K \lambda^{-1}$. Where Abs is the amount of light absorbed, K is a constant, and 1 is the absorption angstrom exponent (AAE). LAC AAE values are much higher and more variable, but generally greater than 2 depending on the amount and type of organic carbon present. When BC1 is reporting BC concentrations over twice that of BC6, a lot of organics are present, indicating woodsmoke as the source of black carbon. When BC1 and BC6 are nearly equal, the light absorbing carbon is very black and indicates oil or diesel combustion.

3. Equipment and Supplies

Table 3-1: Summary of Aethalometer equipment and supplies

	Equipment	Purchase Schedule
Hardware	AE-33 Aethalometer	Once
	Serial crossover communication cable (RS232)	Included w/ initial purchase
	Insect screen / Water trap	Included w/ initial purchase
	PM _{2.5} size cut cyclone and rain protection hat	Included w/ initial purchase
	Power cable	Included w/ initial purchase
	Mounting Hardware	Once
	PC data logger and communications equipment	Once
	1/2" OD stainless steel tubing, 3 meters	As needed
	3/8" OD flexible sample inlet tubing, 3 meters, (static dissipative / conductive)	Included w/ initial purchase, cleaning or change frequency depends on site air quality
Diagnostic & maintenance supplies	Flow calibration pad	Included w/ initial purchase
	Lubrication grease	As needed
	Ethanol (technical grade)	As needed
	Cotton Swabs	As needed
	Separate flow and leak check line	Once (made by operator)
	Quick-release connector tool	Included with initial purchase
	Flowmeter (1 to 5 LPM)	Once, if not already in agency possession
Spare parts	Filter tape roll	As needed-4 rolls included w/ initial purchase
	Tubing and associated fittings	As needed (An assortment included with initial purchase)
	Bypass cartridge filter	As needed

4. Installation

Upon receipt of the AE-33, visually inspect it for signs of damage. Verify all components listed in Table 3-1 as “included with initial purchase” are included in the package. If receiving the instrument from Ecology, notify the Calibration & Repair Lab if any equipment is missing or damaged, otherwise contact your sales representative, the distribution company, or the manufacturer.

4.1 Siting

The BC measured by aethalometers is a component of PM_{2.5}. Therefore, they are subject to the same siting criteria as the WA state nephelometers, which measure PM_{2.5}. The following section, including Table 4-1, is taken from the M904 Nephelometer Operating Procedure and applied to the Aethalometer AE-33. “Proper siting is essential to ensure that data collected are representative at the appropriate scale. The majority of PM_{2.5} monitoring within the Washington Network is conducted at the neighborhood scale (0.5 – 4 km), in order to better understand air pollution across a fairly large area with relatively consistent geography and land use. Siting criteria for neighborhood-scale PM_{2.5} monitoring sites are described extensively in 40 CFR Part 58, Appendices D and E; the primary considerations are summarized in Table 4-1 below. Operators of sites at other monitoring scales (e.g., microscale, regional scale, etc.) should consult Appendices D and E for siting requirements.”

Table 4-1: Summary of AE-33 Aethalometer neighborhood scale siting criteria

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 Radius Clearance	General	≥ 1 m radius clearance
	Near small obstructions (fences, walls, etc.)	≥ 2 m with a minimum of 180 degrees of open sample pathway
	Near large obstructions (buildings, sound walls, billboards, etc.)	Distance ≥ 2x height of obstruction
	Near overhanging trees	≥ 10 m from tree drip line
Nearby Air Sources	Arc of air flow	Unrestricted 270° arc that includes prevailing direction of high concentrations
	General	As far away as possible from vents
Distance from Roadways	Near any residential/commercial wood burning device	≥ 100 m away
	< 1,000 vehicles per day*	≥ 10 m from nearest traffic lane
	Elevated roadway (> 25 m high)	≥ 25 m away
	Unpaved roads	As far away as possible

* Average daily traffic counts for most roadways in Washington can be found at <http://www.wsdot.wa.gov/mapsdata/travel/annualtrafficreport.htm>.

Other factors to consider when considering installation sites:

- Operator safety: the operator may need to access the site during times of inclement weather.
- Power and telemetry connection (cell modem reception, DSL, or other wired internet connection) or telephone line must be available.
- The AE-33 must be installed in a dry, environmentally controlled location. Walk-in shelters, mobile trailers, and environmentally controlled mini-enclosures are all suitable homes for the AE-33.
- Site security: the enclosure should be locked and safe from tampering.

Refer to [Ecology's Air Monitoring Site Selection and Installation](#) Procedure for further information on site selection.

4.2 Sample Line Setup

Proper installation of the sample line is very important. After meeting site installation criteria specified in Table 4-1, the site operator should install the inlet so water cannot enter the sample train. **DO NOT LET WATER GET IN THE INLET!** Water in the lines will ruin the mass flow sensors and they will need to be replaced. This is not covered under the warranty. There are two ways to install the inlet using ½" OD stainless-steel tubing (SST) ():

1. The SST is installed vertically and extends 2-meters above the roofline. Mount the rain cap on the PM_{2.5} size cut cyclone and press fit the cyclone directly down onto the end of the tubing.
2. Where wind and rain can be extreme, bending the SST over into a candy cane shape such that the inlet is facing down may be more protective. The PM_{2.5} cyclone inlet can be press fit to the end of the tubing with the rain cap left off. The curve radius of the bend should be a minimum of 1 foot (') to avoid losses of BC to the walls. It will be more challenging to stabilize this inlet design.

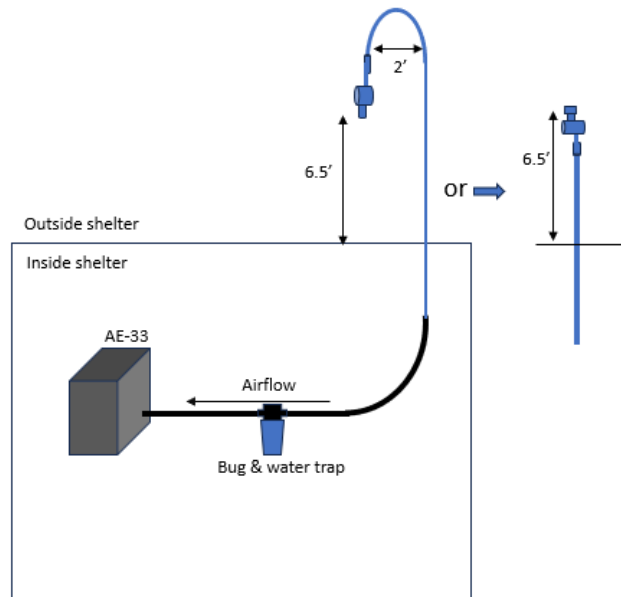


Figure 4-1: AE-33 sample train design

In either of these configurations, the SST must be secured to a railing, tripod, or some other structurally sound frame that does not obstruct the inlet. Ideally the SST will reach into the shelter where it can be connected to the aethalometer using the black flexible conductive tubing included with the purchase (Figure 4-2 A). If necessary, the flexible tubing can extend out of the shelter to meet the SST on the outside. Exposure to the elements may cause it to fail more quickly.

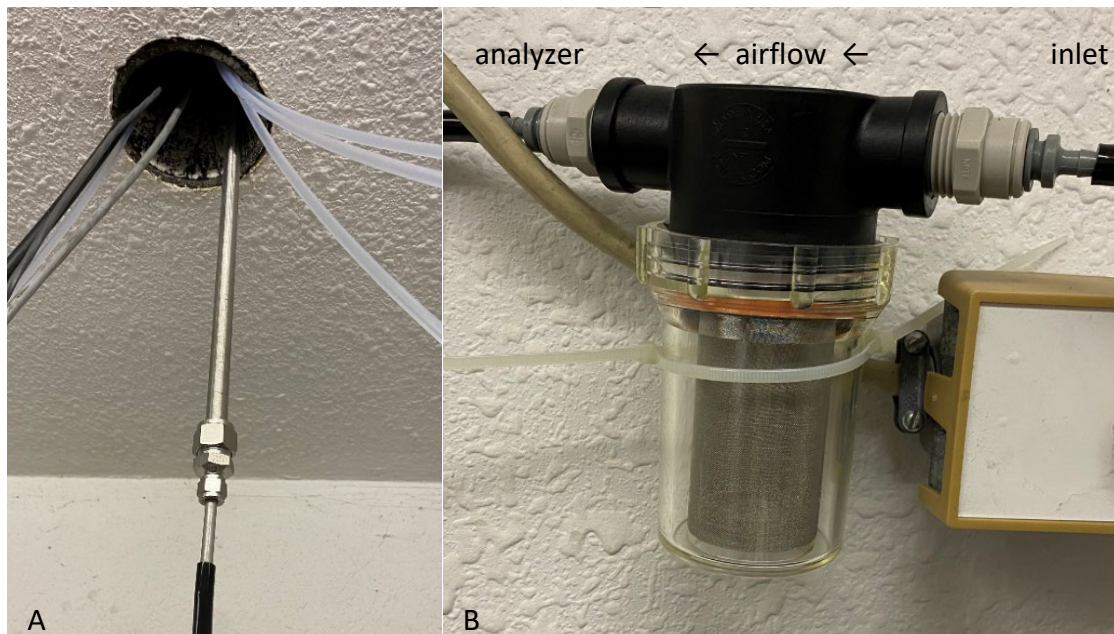


Figure 4-2: A) Attach flexible tubing to SST inside the shelter; B) In-line bug & water trap

The AE-33 should be placed in a dry, environmentally controlled shelter, as near to the inlet port as possible. This will minimize horizontal flow through the sample line and reduce particle loss to the sample line walls. It will also need to be within a few feet of a power outlet or power strip and near enough the datalogger serial port that the serial cable will reach. Several barbed, quick-release connectors are included with the purchase and are an easy way to connect the flexible sample line to the instrument and the bug/water trap (Figure 4-2 B).

- The bug & water trap should be installed in-line between where the flexible tube connects to the SST and the aethalometer (& Figure 4-2 B). Make sure the trap is pointing downward as shown in Figure 4-2 B.
- Minimize bends in the flexible sample line and when a bend is unavoidable, maximize the curve radius.
- Check the water trap after rainstorms. If you see more than a teaspoon of water in the bottom, you may need to adjust your inlet configuration to be more protective and prevent water from entering the sample line. The water trap is the first line of defense, but it is not infallible.

4.3 Analyzer Setup & Operation

Start-up of the aethalometer is simple. There is a power button on the back near the power receptacle that must be turned on and a second power switch on the front inside the door that must also be turned on. Turn on the back power button and open the front door of the unit by pushing the silver button to release the handle and then pull the door open using the now available knob.

The aethalometer comes with sample tape already installed. Visually inspect the tape to ensure there are no tears or contamination. If there are tears in the tape, change the tape according to the procedure in section 5.13. Make sure the optical chamber is seated firmly on the tape.

If everything looks good, push the second power button to turn the unit on. The front screen is a touch screen, allowing the operator to easily navigate through the different tabs for performing quality control checks, setting up communications, and verifying analyzer functionality. The door does not have to be closed to use the touch screen, or for the unit to operate. **The door should always be kept firmly closed, except during maintenance or quality control checks, to ensure the tape does not get contaminated.** To close the door, push it firmly shut and push the silver nob back into place, so it is flush with the front panel.

HOME	OPERATION	DATA	ABOUT
GENERAL ADVANCED LOG MANUAL			
TimeBase	60 s	Start	Stop
Flow	5 LPM		
Flow Rep. Std.	AMCA	Stability	Clean air
P: 101325 Pa T: 21.11 °C			
● TA ATNmax	120	Verify flow	ND test
○ TAIN T	12 h	Leakage test	Inlet leakage
○ TATime	02 Nov 2016 02:02:08		
Time and Date	21 Jun 2017 00:58:38		
Time zone	(GMT-08:00) Pacific Time (US & Can:)		<input checked="" type="checkbox"/> DST
<input type="checkbox"/> Auto Clean Air	<input type="radio"/> Weekly <input type="radio"/> Monthly <input checked="" type="radio"/> None <input type="radio"/> NTP		
	MON 09:48:00 <input type="radio"/> GPS		Shut down

Figure 4-3: General operation tab - stop or start sample collection and initiate quality control checks.

Once the unit is powered on, select the general operations tab (Figure 4-3). Set the TimeBase to 60 seconds to reduce data noise. Set the flow to 5 LPM. Flow Rep Std allows the operator to choose the pressure and temperature used by the instrument to determine flow rate. If the external mass flow meter used to verify flows and check for leaks includes temperature and pressure readings that have been certified and match that reported by the aethalometer, select AMCA (ambient temperature and pressure). If the external flow meter does not include temperature and pressure readings, select EPA. This ensures both the flow meter and aethalometer are using standard temperature and pressure, 25°C and 1013mb respectively.

Set TA ATNmax to 120. This is the attenuation value (spot 1) that will trigger the filter tape to advance to a clean spot. Tape advance may also be controlled by selecting TAIN T and choosing a set number of hours between advances or choosing a single specific time and date to advance to a new spot. For standard operation, choose TA ATNmax and set it to 120. Using attenuation to trigger a tape advance conserves the filter when the air is clean and will not allow the filter to become overloaded during periods of heavy smoke or other light absorbing pollution. If the attenuation exceeds 120, the dual spot technology may not accurately correct the loading error.

Make sure the analyzer date & time are the same as shown on the datalogger. This is important as the data on the CF card may be used to replace lost data if there are communication problems between the analyzer and the datalogger. Choose <none> for scheduling auto clean air checks. These checks will be triggered manually on-site during quarterly site visits.

4.4 Datalogger communication and channel configuration

Envidas Ultimate data loggers are used exclusively throughout the Washington Network. This section explains the installation and configuration of the Aethalometer AE-33 with the Envidas Ultimate logger.

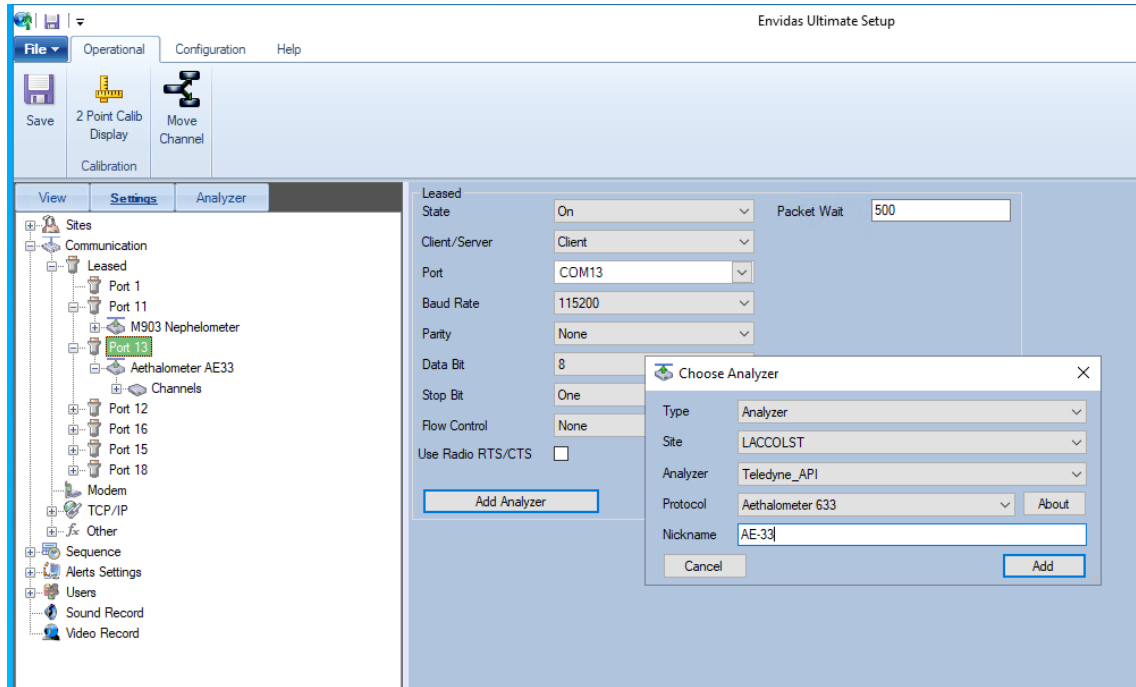


Figure 4-4: Envidas Ultimate Port configuration for the AE-33

The information and screen shots below reflect the correct logger and communication settings. First, establish serial communications between the AE-33 and the data logger. Use the cross-over serial cable shipped with the AE-33 to ensure the correct cable is used. Plug one end into serial port com1 on the back of the aethalometer. Plug the other to the serial connection on the datalogger. Make sure to identify the correct datalogger serial com port number associated with the connection. In the Envidas settings tab, choose the com port connected to the AE-33 under settings>Communication>Leased and select the port settings as shown above in Figure 4-4.

On the aethalometer front touch screen, under the advanced operation tab select “external device” (Figure 4-5 A). A window will pop up with 3 COM device options. On the COM1 device, choose <Datalogger_AE33_protocol> as shown in Figure 4-5 B. If a green check mark appears next to COM1, there is communication between the datalogger and the AE-33.

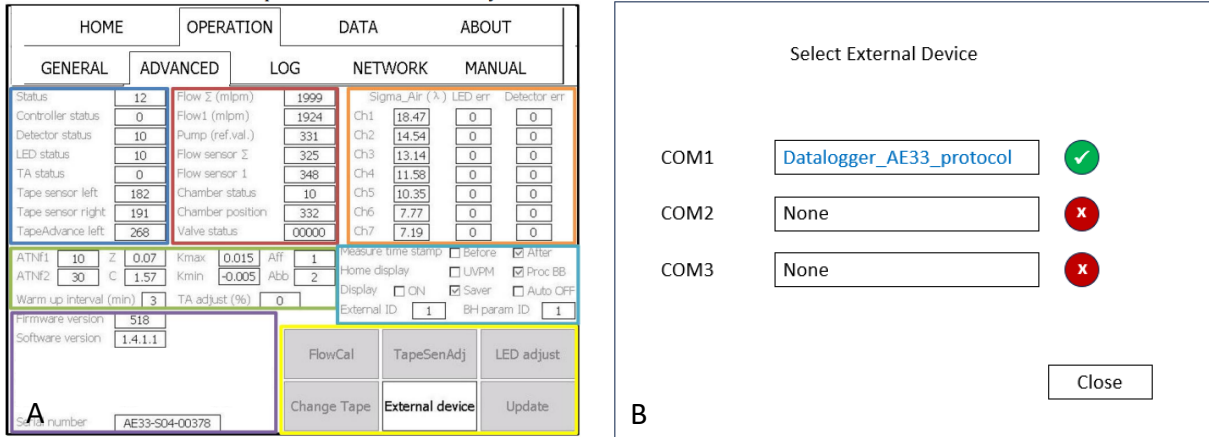


Figure 4-5: Setting up communications on the AE-33 touchscreen

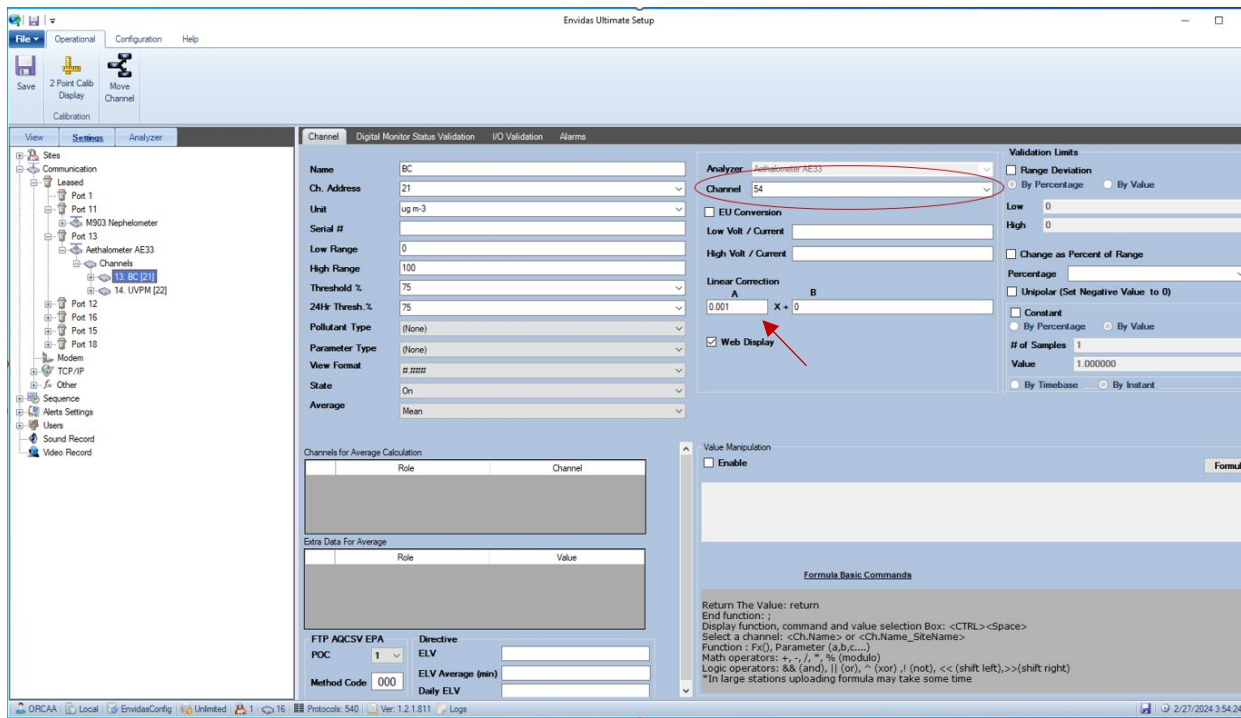


Figure 4-6: Envidas Ultimate channel set up for BC

Return to the Envidas Port Set up screen on the datalogger and click the <add analyzer> button. Under 'Analyzer', choose Teledyne_API, even though they are no longer the manufacturers of the AE_33, and choose Aethalometer 633 under 'Protocol' as shown in Figure 4-4. This protocol works with the AE_33. The Analyzer: Andersen_Magee, protocol: Aethalometer AE33 will not work.

Set up two channels for the Aethalometer, BC and UVPM. Add channel for black carbon or BC and set up as shown in Figure 4-5. Select channel 54, which is the AE-33 channel corresponding to BC6 or black carbon (circled in red on Figure 4-6). The UVPM channel, which is used to identify relative amounts of organic or brown carbon is channel 39 on the AE-33. All other

settings are the same as the BC channel. Units are $\mu\text{g m}^{-3}$, view format should be #.###, state should be on, and average set to mean.

The AE-33 reports BC as ng m^{-3} and AQS reports BC as $\mu\text{g m}^{-3}$, so a linear correction needs to be applied to both the BC and UVPM channels. In the Linear Correction box under channel set-up (Figure 4-6, red arrow) type 0.001 to convert ng to μg .

Once the AE-33 is connected to sample lines and properly configured to communicate with Envidas, press the <start> button on the general operations tab. Allow it to complete the start-up procedures and ensure all criteria have green check marks. This can take up to 5 minutes. The AE-33 will start collecting data automatically. Open Envidas Ultimate view and verify BC and UVPM show up under their respective channels and that Envidas is recording values under Raw Val. that match what is shown on the AE-33 home screen. Confirm Envidas values under the 'instant' column are 0.001 times the raw value and units are $\mu\text{g m}^{-3}$.

The final step to setting up the AE-33 is to perform the following quality control (QC) checks: inlet leak, internal leak, flow, clean air, and stability. Procedures for all QC checks are described in section 5. If all checks pass, press the <start> button on the general operations screen and begin sampling valid data.

5. Quality Control Checks and Maintenance

Monthly and quarterly site visits are required to perform quality control (QC) checks. The AE-33 does not accept commands from Envidas so a QC check cannot be triggered remotely or set-up to run automatically. All QC checks must be manually initiated on-site by the operator.

There are four required checks: 1) flow verification, 2) leak check, 3) stability, and 4) a zero, or clean-air, verification. The site operator should use a spare quick-connect/barbed hose attachment and about 4' of flexible tubing, both included with the initial purchase (Figure 5-1), to make a separate line for conducting flow and leak checks. This line can be easily swapped for the sample line on the back of the aethalometer using a quick-connect fitting. A certified, external flow meter, technical grade ethanol, cotton swabs, and compressed air (dust-off) are needed to complete all the quality control checks.



Figure 5-1: Spare line for easier leak and flow checks

5.1 Quality Control Check Schedule

The clean air check and stability check are required quarterly, and each take 30 minutes to complete. The leak and flow checks are required monthly. Each takes about 10 to 15 minutes to complete. The operator should allow 1.5 to 2 hours to complete all checks during the quarterly site visit and 30 minutes during a monthly check.

Table 5-1: Quality Checks: Frequency, Acceptance, and Action levels

Check	Frequency	Acceptance Criteria	Action Level
Clean Air check	Biannual (6 months)	500 ng m ⁻³	300 ng m ⁻³
Stability check	Biannual (6 months)	450 ng m ⁻³	200 ng m ⁻³
Leak check	Monthly	<10%	> 7%
Flow check	Monthly	+/- 10%	+/- 7%
Spot Spacing Check	Monthly	No overlap	<1 mm
Inlet Leak Check	Biannual (6 months) When cleaning, replacing, or installing new sample lines	<10%	>7%

While on site and before beginning the monthly aethalometer QC checks:

1. Set the aethalometer data flags to mode “maintain” in Envidas

2. Press <stop> on the aethalometer front touch screen panel under the General Operations tab (Figure 4-3). This stops data collection on the analyzer and sets channel outputs to zero. All quality checks are initiated from this screen.

If performing a quarterly check on the analyzer, begin with the Clean Air and Stability checks below. If running a monthly check, skip to the leak and flow check procedure.

5.2 Clean Air Check

During the clean air check the analyzer routes all air through the filter housed above the optical chamber so the air passing through the measurement spot on the filter is perfectly clean and the AE-33 should read zero or close to zero for both black carbon and UV carbon.

The clean air check takes about 30 minutes and other than initiation requires no other action on the part of the operator. If there are other tasks around the site that need finishing, this is a good time to do them. If the analyzer is in sampling mode press <stop> on the general operations screen (Figure 4-3). If already in stop mode from earlier checks, press the <clean air> button on the same screen, then press <OK>.

Note: Do not check the 'continue after test' box. Doing so will automatically return the analyzer to sample mode when the test concludes and there may be additional checks or maintenance to conduct following this check.

The analyzer will complete a 4-minute warm up before starting the 20-minute test. During this time, visually verify that 1-minute averages are within $\pm 0.2 \mu\text{g m}^{-3}$ in Envidas. Operators may choose to flag data during this check as 'zero' on the Envidas datalogger. The analyzer will display the results of the test on the screen and save the report to the CF card. Record the results of the test in the appropriate space on the QC form.

5.3 Stability Check

This test checks the stability of the light source and detector with no flow through the system. As there is no flow, there should be no change in light attenuation through the filter and black carbon and UV carbon readings should be within $\pm 0.1 \mu\text{g m}^{-3}$ (100 ng m^{-3} on the analyzer).

The stability check follows the same procedure as the clean air check. On the general operations screen select the <stability> button. There will be a 4-minute warm up, followed by a 20-minute stability test. During the test there is no flow through the filter. When the test is complete a report will be displayed on the screen. Record the result on the QC form.

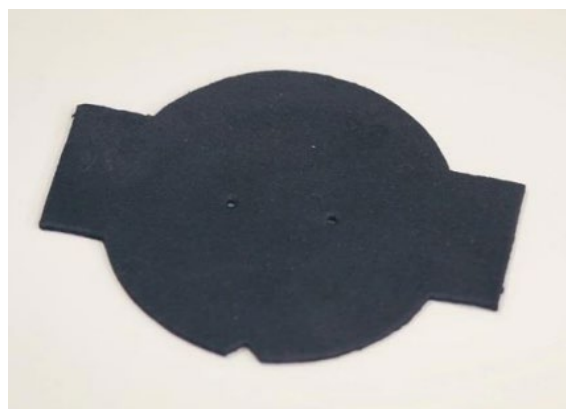
5.4 Leak Check

Swap out the sample inlet line at the back of the AE-33 with the flow and leak check line shown in Figure 5-1. Initiate the leak check on the Operation/General screen by pressing the button marked <Leakage test>. If the analyzer is sampling, press <stop>. The AE-33 screen will change to the leak check screen and prompt the operator when to take each action described below. Press <manual> to initiate the leak check. The analyzer will first measure flow through the filter tape.

1. Press <OK> and connect the mass flow meter to the line attached to the sample inlet port. Press <OK> again when done.
2. Choose 5000 ml/min when asked at what flow to conduct the test and press <OK>.
3. If the flow meter measures temperature and pressure, ensure the values on the mass flow meter are consistent with those reported by the analyzer. Record both temperature and pressure indicated by the AE-33 and the flow meter (or other external devices) on the QC form in the appropriate space under 'indicated' and 'actual' respectively.
4. Record the flow shown on the flow meter in the input box field on the analyzer screen and on the QC form next to the "Flow through tape" cell. When done, press <OK> on the analyzer screen.
5. The optical chamber will automatically lift. The screen will then prompt the operator to remove the filter tape. Gently grip the edge of the tape to the left of the optical chamber and pull down to loosen from the supply spool on the left. Slide the tape toward the front of the analyzer (Figure 5-2 A). Place the rubber flow calibration pad (Figure 5-2 B) under the optical bench with the notch facing towards the front. When the pad is properly seated, press <OK>. The optical chamber will automatically lower, and the analyzer will check the flow through the calibration pad.



A



B

Figure 5-2: A) Tape removal and flow calibration pad placement; B) Flow calibration pad

6. Record the flow from the mass flow meter on the screen, input box field and on the QC form next to the "Flow through calibration pad". Leak rate is calculated as:

$$\text{Leak} = 1 - (\text{Flow_tape} / \text{Flow_pad})$$

7. When finished, press <OK>. The optical chamber will lift. Leave the flow calibration pad in place and press <OK> again to complete the leak test, lower the optical chamber, and move on to the flow check procedure. *If opting not to do the flow check, remove the flow calibration pad when the optical chamber lifts and replace the filter tape, ensuring the tape is under both rollers on either side of the optical chamber. Press <OK> to complete the leak test and return to the general operation screen. Replace the*

calibration line with the sample line and press <start> to tighten the tape, go through start-up procedure, and commence sampling.

5.7 Flow Check

From the general operation screen (Figure 4-3) press <stop> if in sample mode. If continuing from the leak check and the flow calibration pad is already in place, press the <verify flow> button. When prompted, select <manual>. If the flow calibration pad is already in place choose <skip>, otherwise wait for the optical chamber to lift, and follow step 3 from the leak check procedure above.

1. If not already connected, connect the mass flow meter to the sample port in the back of the analyzer and press <OK>.
2. The analyzer will check flows at three different rates: ~1000 mLPM, ~3000 mLPM, and ~5000 mLPM. When prompted to do so on the analyzer touch screen, press the box marked flow and enter the flow from the flow meter. On the QC form, record the analyzer flow as 'indicated' and the flow meter flow as 'actual'. Do this when prompted for all three flows. If the difference between the flows is greater than +/- 5%, flow calibration is required. If the difference exceeds +/- 10%, the QC check fails.
3. If the flow check passes and no action is required, press <OK> to conclude the test. When the optical chamber lifts, remove the flow calibration pad and carefully replace the filter tape. Make sure the tape lies under the two rollers on either side of the optical chamber. If there are no more checks return to the general operation tab and press <start> to return to sampling. Otherwise move on to the clean air and stability checks. The analyzer will automatically tighten and advance the filter tape during start-up procedure.
4. If the flow check fails or requires action, follow the procedure below to calibrate the analyzer flows.

5.8 Flow Calibration

From the advanced operations tab (Figure 4-5 A) on the AE-33 screen, press the <FlowCal> button. Usually, the calibration is performed after a failed flow check and therefore the pad should already be in place and the operator can press the <skip> button. If this is not the case, follow step 3 under the leak check procedure to remove the tape and insert the flow calibration pad. If following the flow check, the flow meter should also still be connected to the analyzer. If it isn't, connect it to the back sample port and press <OK>. Follow the same procedure as for the flow check above. This time the analyzer will calibrate its flow to match the external flow meter readings input by the operator. Press <OK>. When the optical chamber lifts, remove the flow calibration pad and gently replace the tape. Make sure the tape runs below both rollers to either side of the optical chamber. Finally remove the flow check line from the sample port at the back of the analyzer and reconnect the primary sample line to the analyzer. This completes the monthly quality checks. Return to the general operation tab and press <start> to return to sampling. If this is not a quarterly site visit, set Envidas datalogger channel flags to OK.

5.9 Inlet Leak Check

This check should be done when initially setting up the site, after cleaning or replacing the sample lines, and during the biannual quality checks. It ensures there are minimal leaks in the sample train between the exterior inlet and the analyzer. The most likely places for leaks in the sample train are around the bug & water trap connectors and lid, the line connection at the rear of the analyzer, where the flexible tubing connects to the stainless-steel tubing, or cracks in the flexible tubing.

Make sure the analyzer is in <stop> mode. You will not be able to initiate the inlet leak check if it is not. From the general operations screen press <inlet leakage>. Insert the flow calibration pad following step 3 from the leak check procedure above. Follow the directions on the screen to measure the flow at the sample entry port on the back of the analyzer and again at the entry point for the inlet (outside and likely on the roof of the monitoring shelter) when prompted. Make sure to reconnect the sample line to the analyzer before measuring flow at the external inlet point. The sample line will need to be swapped for the flow check line when measuring at the back of the analyzer. If the leak rate is >7%, check and tighten all connections in the sample train and measure flow at the inlet again. A passing inlet leak check is <10%.

5.10 Spot Spacing Check

To the right of the optical chamber, spot pairs are visible on the filter tape where ambient air PM_{2.5} has been collected (Figure 2-2). The left spot should be roughly twice as dark as the right. There should be a blank space larger than the spot diameter between each pair. If the spots in a pair are nearly touching or overlapping, the tape sensors likely need to be adjusted or calibrated. Increasing the value of “TA adjust” on the Advanced Operation screen, will increase the separation between spots. Cleaning the tape sensors may solve the problem and should be done once a year. A tape sensor calibration requires additional accessories (User’s manual page 76).

5.11 Maintenance Schedule

Table 5-2: Maintenance schedule

Maintenance	Frequency
Inspect sample line tubing for cracks, holes, & kinks	Monthly
Inspect & clean bug/water trap	Monthly
Clean inlet cyclone	Monthly or as needed
Replace filter tape	As needed
Clean optical window	When tape is replaced
Change the clean air filter	As needed
Lubricate optical chamber sliders	As needed
Clean or replace sample line	Annually

5.12 Clean cyclone

The inlet cyclone should generally be cleaned monthly for sites located in urban areas or near roads. At remote cleaner sites, quarterly cleaning is sufficient. Remove the cyclone from the sample line. If a rain cap is installed loosen the small screw on the side and remove the cap. Wipe out dust and debris from inside the cap. Wet a cotton swab with DI water and wipe out the inside of the top and bottom tubes. Remove the end cap and clean all dust and debris.

5.13 Replacing filter tape

The number of filter tape advances left are displayed on the home screen. When the operator observes fewer than 30 advances left during a monthly site visit, the filter tape should be replaced, or the operator should plan to return with a week or two to replace the filter tape depending on ambient air quality. If the analyzer is not already in stop mode for other quality checks and maintenance items, press <stop> on the general operations window.

1. Open the front panel and loosen both thumbscrews holding the clear plastic covers over the tape spools on either side of the optical chamber; the supply (clean filter) spool on the left side and the collection (used filter) spool on the right side.
2. Using both hands, place thumbs on the top of the optical chamber and fingers around the sides and under the bottom of the optical chamber (Figure 5-4). Firmly lift the chamber up against its springs. This will take some force. When it is lifted all the way, continue holding with both hands and with one thumb, slide the metal latch (yellow arrow) toward the back of the analyzer and lock the chamber into place. It's now safe to remove your hands.
3. Remove both tape rolls from the spools and wind what is left of the supply or clean filter to the collection roll. Place the now empty cardboard tube from the old supply roll on to the collection spool.

Note: This is a good time to clean the optical window (section 5.12).
4. Take the new roll of filter tape from the box and place on the supply spool so that the tape end unrolls off the left side of the spool. Gently unroll enough tape to feed **under** the left guidepost, in the tray below the optical chamber, **under** the right guidepost and



Figure 5-3: Inlet PM_{2.5} cyclone



Figure 5-4: Lifting the optical chamber and locking mechanism

up to the right side of the collection spool. Tape the end of the tape to the right side of the cardboard tube sitting on the spool. The used filter tape will wind on the spool in a counterclockwise direction. *Only filter tape supplied by MageeScientific should be used. Other tape can damage the analyzer or lead to incorrect data.*

5. Release the locking mechanism on the optical chamber by lifting up with both hands and allow it to fall back into place. Replace the clear plastic covers over both rolls and hand tighten the thumbscrews back in place.
6. Finally, pull gently on the supply side of the filter tape to ensure free movement of the left spool. Pull gently on the right side of the tape to make sure it does not move. The collection spool should be locked in place.
7. Press <start> on the general operations tab to resume collections. Do not be concerned if the filter tape is loose. The analyzer will automatically advance and tighten the tape during start-up.

5.14 Clean optical window

Clean the optical window, whenever the filter tape is changed. A can of dust-off spray, cotton swabs, and technical-grade ethanol are needed for this procedure. The analyzer should already be in stop mode for the tape change. If it is not, place it in stop mode and open the front door.

1. If starting this procedure in the middle of the tape change, the optical chamber should already be lifted and locked in position. If not, follow step 2 of the filter tape change procedure above.
2. Find the release button on the front of the chamber (Figure 5-5, yellow arrow) and gently press upward (*not so hard the locking mechanism disengages and drops the optical chamber down*). While pressing upward on the release button, turn the optical head clockwise until it releases (Figure 5-5, white arrow) and can be removed from the main chamber.
3. The optical head is a translucent cylinder surrounded by black metal. Clean both sides with ethanol and cotton swabs. Blow loose dust and debris out of any openings with the canned air. Place a few ethanol drops in the openings and surfaces. Clean with the cotton swabs.
4. After cleaning is complete, reinstall the optical head. Align the grooved line on the front of the optical head with the left grooved line on the chamber, about 45 degrees from the front. Gently push up until the optical head slides into place and can be turned back to the right. When the grooved line on the optical head lines up with the front grooved line on the main chamber, a locking pin will click into place.
5. If this cleaning occurs during a filter tape change, resume with step 4 of the filter tape change procedure, otherwise lift up on the optical chamber to release the locking mechanism and allow it to fall into place over the filter.

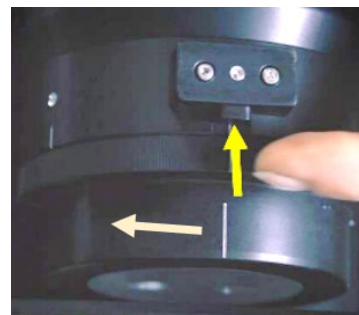


Figure 5-5: Optical chamber release

5.13 Changing the clean air filter

If the clean air filter, located above the optical housing, starts to look dirty, it should be changed. Remove it from the top of the optical chamber using the L-shaped quick release connections on both sides. The filter is also connected using quick release connections. Swap it out for a new filter and replace on the top of the optical chamber.

6. Data Validation, Data Completeness, and Quality Assurance

All Aethalometer AE-33 Quality Control Check forms must be sent to the Quality Assurance Coordinator within 10 days of the site visit.

Preliminary data validation is the operator's responsibility. Preliminary data validation includes, but is not limited to:

- Reviewing results of on-site QC Checks.
- Using the EnvistaARM to review collected data for reasonability and comparability with other area monitors.
- Sending the QA Coordinator an email identifying any invalid data so that it can be removed from the dataset during final level data validation.

The Quality Assurance unit is responsible for final data validation. Data validity is evaluated using a number of criteria, including comparability to other area monitors and results of quality control checks.

As with other measured parameters, data completeness is evaluated on a quarterly basis. For data to be considered complete, over 75% of the data during a given reporting period must be validated.