Aethalometer® Model AE33

User Manual

Version 1.34

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Aerosol d.o.o., Ljubljana, Slovenia

Aethalometer® Model AE33 Manual

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1 INTRODUCTION

1.1 Description of the instrument

Figure 1. The Aethalometer® Model AE33.

Magee Scientific and Aerosol Co. are pleased to announce the ‘Next Generation’ Aethalometer®, Model AE33. This development incorporates scientific and technical advances designed to offer improved measurement performance, user features, communications and interface, and the ability to perform routine performance tests to verify correct operation. Most importantly, the instrument incorporates the patented DualSpot™ measurement method. This provides two significant advantages: elimination of the changes in response due to ‘aerosol loading’ effects; and a real-time calculation of the ‘loading compensation’ parameter which offers insights into aerosol optical properties, and has been interpreted in models of aerosol origins and aging.

The Aethalometer Model AE33 has been developed with input from the research and monitoring communities, and is designed for reliable operation under all conditions ranging from state-of-the-art research to compliance monitoring.

The leading innovations incorporated into the Model AE33 include:

1. The DualSpot™ measurement method, which solves the effects common to all filter-based real-time monitors, in which the instrumental response factor shows a dependence on the loading of material on the filter.

2. Features for automatic 'dynamic zero' testing under a flow of internally-generated clean air; 'span' testing of the response of the optical sources and detectors; calibration of the response of the internal mass flow meters, if an external standard flow calibrator is connected; and validation of the photometric response by use of a kit of 'Neutral Density' optical filters whose properties may be traced to reference standards.

3. User and communications interfaces, permitting remote monitoring of operation; data retrieval; performance of internal tests; and reporting of 'state-of-health' parameters.

4. Modular construction designed for ease of routine maintenance service.

In addition to the above features, the Aethalometer Model AE33 offers real-time aerosol absorption analysis at up to ten optical wavelengths, with rapid time resolution to 1 second even in 10-wavelength mode. This permits the measurement of optically-absorbing aerosols – 'Black' Carbon and 'Brown' Carbon components of particulate matter – in applications including routine monitoring of ambient air quality for regulatory purposes; measurements of the concentration of BC in urban, suburban, regional, rural and remote locations; source testing; and laboratory-based research.

‘DualSpot™’ technology

The Aethalometer Model AE33 uses the patented DualSpot™ method to compensate for the ‘spot loading effect’; and also to provide a real-time output of the ‘loading compensation’ parameter, which may provide additional information about the physical and chemical properties of the aerosol.

The ‘spot loading effect’ is a variable phenomenon which appears as a gradual reduction of instrumental response as the aerosol deposit density of the filter tape increases from zero to the predetermined limit of ‘Maximum Attenuation’ (Gundel 1984, Weingartner 2003, Arnott 2005, Virkkula 2007, Kanaya 2008, Hyvärinen 2012). When the filter tape advances to a fresh spot, the data undergoes a discontinuous jump from its previous lower value, calculated when the spot was heavily loaded; to a higher value, calculated from collection on a fresh spot at zero loading. In the Aethalometer the reduction of data at increasing loadings is well described by a linear function of attenuation, but its magnitude cannot be predicted: some aerosols in some locations in some seasons may show a small or zero ‘loading effect’; while under other conditions, the effect may be larger and noticeable. Empirically, it is found that fresher aerosols closer to their combustion sources will show a larger ‘spot loading effect’; while well-aged aerosols under atmospheric conditions of high chemical activity and oxidative processing may show an almost zero effect. The effect is revealed statistically by processing data collected over a large number of tape advances, representing many data points collected at loadings (‘ATN values’) ranging from zero to the preset maximum. The data is collected into bins according to loading (attenuation, ATN). If there is a systematic reduction of the calculated result as a function of loading, the data will show a clear negative slope, with the intercept representing the ‘zero loading’ value. Figure 2 illustrates two datasets from urban locations with loading effects either present or not.

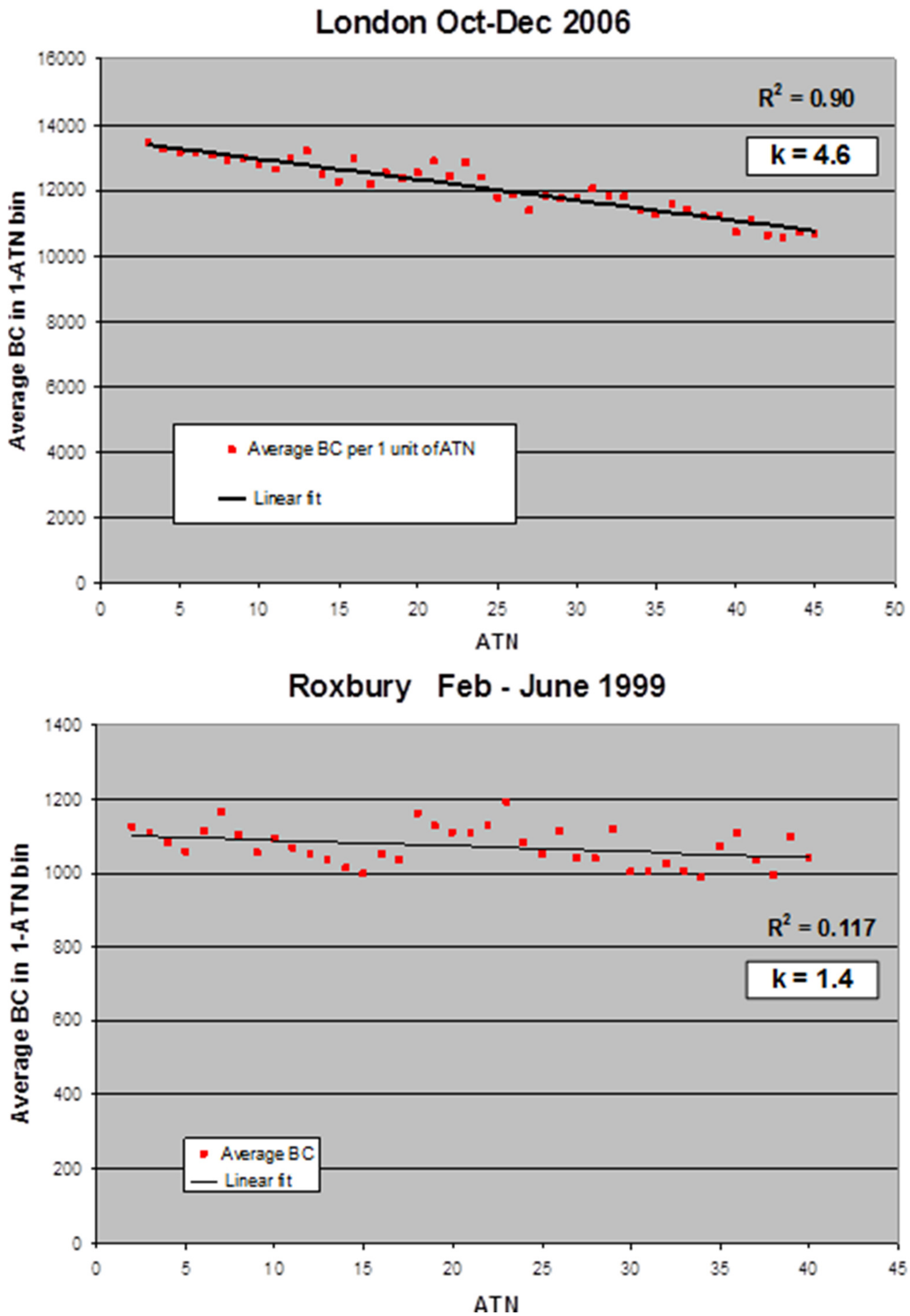

Figure 2. Aethalometer data sorted and averaged according to loading (attenuation, ATN) on spot – roadside location in London, UK (top); urban site in Boston (Roxbury), USA (bottom).

The London data show a systematic reduction at increasing loadings; while the Boston data do not. This demonstrates that any method intended to compensate for the 'spot loading effect' must be auto-adaptive and able to adjust dynamically to different situations. An instrument based on firmware with a fixed 'loading non-linearity' parameter will not operate correctly at all locations. The 'loading non-linearity' parameter must be measured.

It is clear that the effect, when present, is linear with loading ('ATN'). This can be represented as

BC (reported) = BC (zero loading) * { 1 - k • ATN }

where BC (zero loading) is the desired ambient BC value that would be obtained in the absence of any loading effect; and k is the 'loading compensation parameter' (similar to Virkkula, 2007).

The analysis of a large number of datasets from a wide variety of locations shows that this relationship is linear in all cases studied; but with different values of k. It is therefore possible to eliminate the 'loading effect' of k by making two simultaneous identical measurements BC1 and BC2 at different degrees of loading ATN1 and ATN2.

BC1 = BC * { 1 - k • ATN1 }
BC2 = BC * { 1 - k • ATN2 }

From these two linear equations we may calculate the 'loading compensation parameter' k; and the desired value of BC compensated back to zero loading.

The Aethalometer Model AE33 Aethalometer Model AE33 analyzes the Black Carbon component of aerosols on two parallel spots drawn from the same input stream, but collected at different rates of accumulation, i.e. at different values of ATN. By combining the data according to the above equations, the AE33 yields the value of BC extrapolated back to 'zero loading'; as well as a real-time output of the 'loading compensation parameter' k which provides insights into the aerosol nature and composition. This process is performed in real time for all wavelengths: examination of the 'k' values as a function of wavelength provides further information about the aerosol composition. An example of this is shown for extreme concentrations of black carbon (Figure 3).

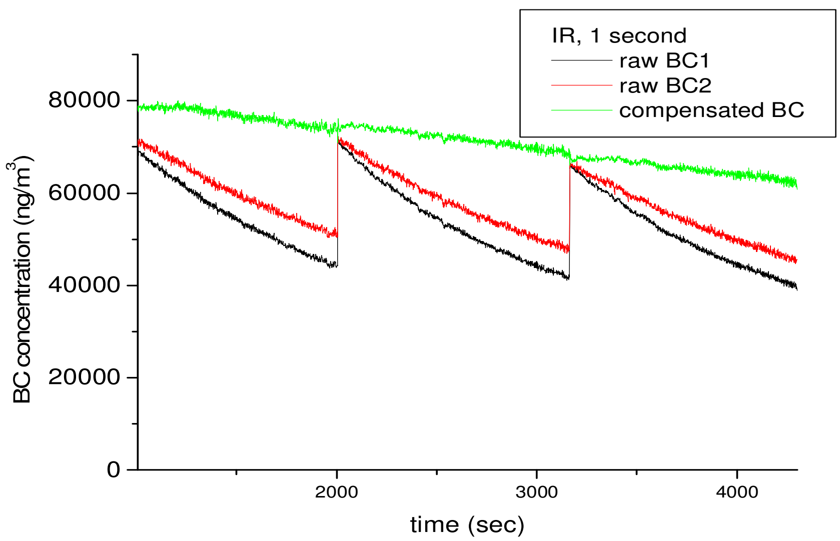

Figure 3. The time-series of AE33 raw and compensated BC concentrations with 1 second timebase – note the extreme concentrations and loading effects.

Automatic Zero and Span

The Aethalometer Model AE33 offers the capability for automatically checking the 'zero-air' response of the instrument under dynamical operating conditions. This test is implemented by back-flushing the inlet connection with an excess flow of internally-filtered air and circulating the filtered air in the instrument. The data reported during this period are analyzed for the mean value and the point-to-point variation. The mean value should be close to zero under ideal conditions; any positive value greater than zero represents the leakage of BC-containing room air into the instrument's analytical zone. The point-to-point variation represents the instrument's measurement noise level under actual operating conditions of actual flow – i.e., a 'dynamic' test. The point-to-point variation for the wavelength 370 nm at the time-base set to one second is about 125 ng/m3, which translates to a couple of ng/m3 at 1 minute time resolution (Figure 4).

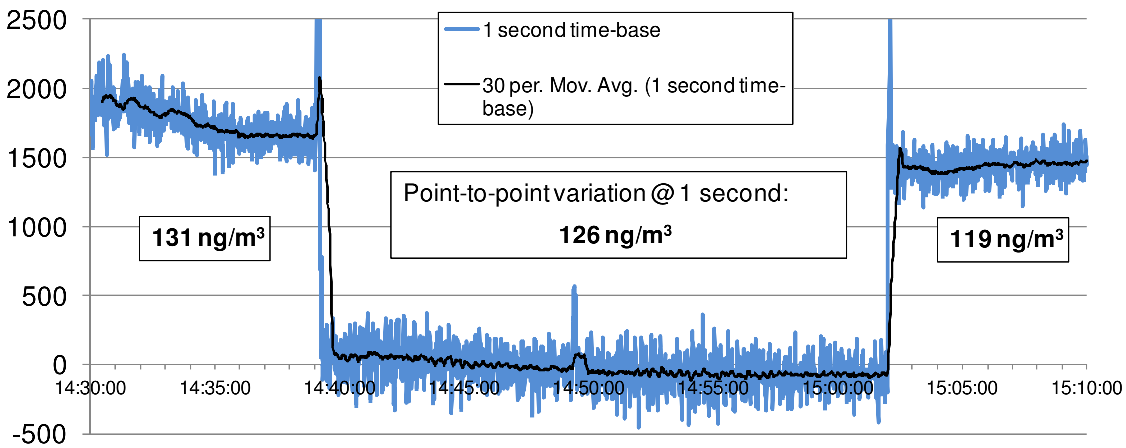

Figure 4. 'Zero-air' check – the Aethalometer Model AE33 switches form sampling ambient air to filtered air – 1 second time resolution point-to-point variation is very stable.

The response of the optical detectors of the Aethalometer Model AE33 may be verified by use of a standard kit of Neutral Density optical filters. These are glass elements with a range of known and stable optical absorptions, from light to dark, which are traceable from manufacturing records back to primary standards. When these are inserted into the AE33 Aethalometer, its photodetectors will give a certain output signal. The stability and reproducibility of the relationship between optical signal and ND Filter density from one validation test to another; and the comparison with the original factory values; is a measure of the consistency of performance of the instrument's optics.

User and Communications Interfaces

The Aethalometer Model AE33 incorporates the following user, data and communications features:

- 21-cm color graphics touch-screen for data display and local user interface;
- USB ports for insertion of a memory stick for local data download;

- USB ports for connection of a keyboard, if necessary for initial setup of parameters, such as station identification;
- RS-232 COM ports for data transmission from auxiliary instruments or to the digital datalogger;
- Ethernet port for full network access and control, including

i. Remote data acquisition, either batch or streaming

ii. Remote retrieval of instrument status and state-of-health

iii. Remote control of instrument operating parameters

Modular Construction

The Aethalometer Model AE33 is constructed with a modular design, so that sub-units may be easily serviced. The only item requiring attention in routine use is cleaning of the optical insert to remove accumulated dust or other contamination which may be brought in with the sample air stream. The optical chamber is attached with a bayonet fitting for quick removal; easy cleaning; and reliable re-assembly. The entire instrument is hermetically sealed to reduce the entry of dust.

References

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1.2 Technical specification

Operation: • Supply voltage: 100-240 V~, 50/60 Hz • Max power consumption: 90W • Measurement wavelengths: 370, 470, 525, 590, 660, 880 and 940 nm • Air flow: adjustable 2, 3, 4 and 5 LPM
Environmental operating conditions: • Indoor use • Altitude: up to 3000 m with internal pump, other configurations possible • Temperature range: 10 – 40 degrees Celsius (instrument) • Relative humidity range: non-condensing
Mechanical specification: • Chassis material: sheet metal • Front plate material: plastic • Dimensions: standard 19"/6U, rack mount • Weight: approx. 20 kg
Connectors: • Sampling air: inlet / outlet type – ¼" NTPF • Communication: 3x USB type A, 3x COM, 1x Ethernet
User interface: • 8.4" SVGA display with LED backlight • Basic control: touch-screen • Optional control: standard PC keyboard and mouse • Red, Yellow, Red status LEDs

1.3 Functional description of the instrument

The AE33 features modular design and is composed of several subsystems which are so interconnected that most simple and safe handling of the instrument is possible.

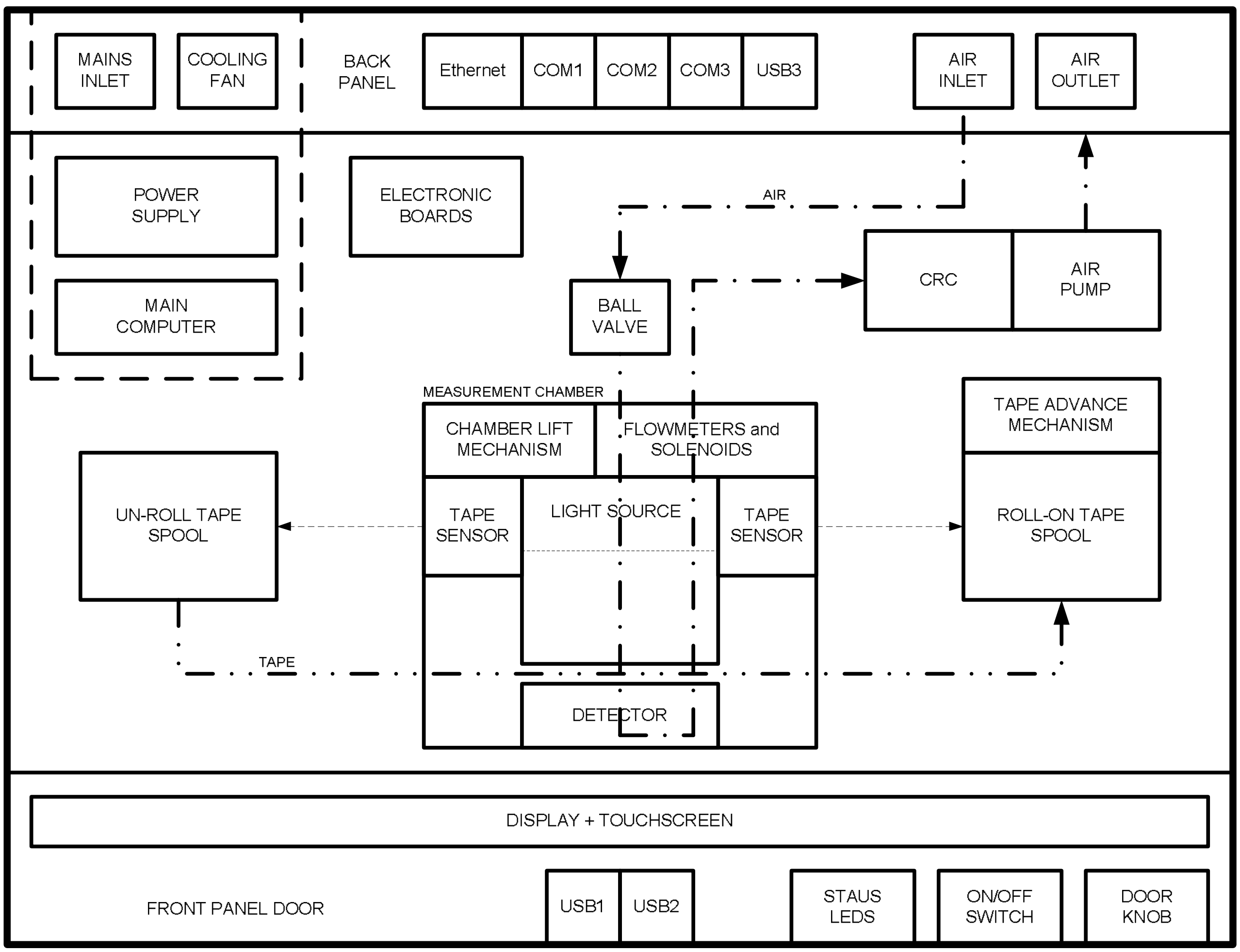


Figure 5. AE33 functional block diagram

ENCLOSURE

The AE33 enclosure is very robust and made from sheet metal. The enclosure mechanically protects the delicate inner measurement parts. The dimensions of the enclosure meet the rack mount standard for the instrumentation.

POWER SUPPLY

The power supply module is composed of the mains inlet, the power supply electronics and the cooling fan. Since the power supply electronics heats up, it is mechanically integrated in a separated and thermally sealed area.

MAINS INLET

The mains inlet accepts standard EU, US or UK supply cords. It is composed of the inlet itself, the EMC filter, the main fuse and the primary ON/OFF switch. The switch is a part of the power supply module.

COOLING FAN

The cooling fan is also a part of the power supply module. The control electronics measures the temperature of the power supply area and switches on and off the cooling fan.

MAIN COMPUTER

The main computer processor also generates quite a lot of heat. It is integrated in the power supply area so it can be cooled down together with the power supply electronics. The highest level control software and the user interface are implemented on the main, PC based computer.

ELECTRONIC BOARDS

The system features modular design so the electronics is composed of various electronics boards which mechanically fit together with other mechanical modules. The low level control firmware is implemented with microcontrollers, which are located on separate electronic boards so parallel real time data processing is possible.

ETHERNET CONNECTOR

The Ethernet connector allows the connection of the AE33 measurement system to Ethernet based communication networks.

COM1, COM2, COM3 CONNECTORS

The COM connectors allow the connection of the system to RS232 based devices, like external sensors or dataloggers.

USB CONNECTOR

The USB connector allows the connection of the system to USB based devices, like external sensors or data processing units.

AIR INLET and OUTLET CONNECTORS

The air inlet and outlet connector allows the connection of the instrument to external airflow system. The measured air enters the instrument through the inlet connector and leaves the instrument through the outlet connector.

BALL VALVE

The ball valve is an electrically actuated valve which is connected directly to the inlet connector and connects or separates the instrument from the external air system.

MUFFLER

The muffler (CRC filter) is used to decrease the noise in the airflow which is created by mechanical rotation of the pump.

AIR PUMP

The air pump pumps the measured air through the inlet connector, directly to the measurement chamber. It is one of the main components in the system.

FLOWMETERS

Two flow-meters measure the airflow in different points in the system. One of them is used also in the air flow regulation loop.

SOLENOID VALVES

Three solenoid valves are used to switch the airflow trough different airflow paths when the instrument is set in different operating modes like measure, tape advance or similar.

CHAMBER LIFT MECHANISM

The chamber lift mechanism allows the measurement chamber to be lifted manually or electromechanically. During tape advance the automated chamber lift procedure is invoked. During tape replacement the manual chamber lift procedure can be engaged. The manual chamber lift mechanism features also a special locking mechanism which simplifies the tape replacement or chamber cleaning procedure. The main electronic components of the chamber lift mechanism are the stepper motor and the chamber lift position sensor.

TAPE ADVANCE MECHANISM

The advance mechanism allows the instrument to perform automatic tape advances during measurements. The main electronic parts of the tape advance mechanism are a stepper motor and the two tape sensors.

ROLL-ON and UN-ROLL TAPE SPOOLS

The roll-on and the un-roll tape spools hold the measurement tape. During automated tape advance the tape unrolls from the un-roll spool and rolls on the roll-on spool. If the un-roll spool is empty, the event is detected automatically thanks to the tape sensors. The tape replacement procedure must be performed manually by the operator. The measurement tape is one of the main parts of the system.

TAPE SENSORS

The two tape sensors are used by the instrument software to detect the amount of tape on the un-roll and roll-on spools.

LIGHT SOURCE

The light source integrates groups of LEDs of different light wavelengths. It is one of the main parts of the system.

DETECTOR

The detector detects what amount of light passes through the measurement tape. A special algorithm is used to calculate the black carbon concentration using the information from the detector and the flow-meter.

FRONT PANEL DOOR

The front panel door can be opened which allows the access to the instrument for tape replacement or chamber cleaning.

DISPLAY and TOUCH-SCREEN

The display and the touch-screen are the main user interfaces of the instrument. Using this interface the operator can perform all necessary operations for proper functioning of the instrument.

USB CONNECTORS

The two USB ports on the front panel door can be used to connect a keyboard, mouse or a USB key for data download or data upload.

STATUS LEDS

The red, yellow and green status LEDs show the correct or incorrect operation of the instrument. This status is replicated on the screen with the status flag (see, 5.2 Instrument Status).

DOOR KNOB

The door knob is used to open the front panel door.

ON/OFF SWITCH

The secondary ON/OFF switch is located behind the front door. It is electrically connected in series with the primary ON/OFF switch, which is located at the back of the instrument, next to the mains inlet.

2 SAFETY NOTES and LABELS

CAUTION!

READ THIS CHAPTER VERY CAREFULLY BEFORE OPERATING THE INSTRUMENT.

Instrument operation

Read this User's manual BEFORE operating the instrument. INCORRECT instrument operation can be DANGEROUS for the operator.

Unauthorised instrument access and operation

The instrument must be protected against unqualified use. UNAUTHORISED instrument access and operation can be dangerous. The instrument can only be operated by persons who can ensure proper handling due to their qualification, technical skills and practical experience.

Electric shock

CHECK the mains power supply cord ANNUALLY. If the supply cable is DAMAGED, stop using the equipment and contact your authorized representative.

Fire and explosion

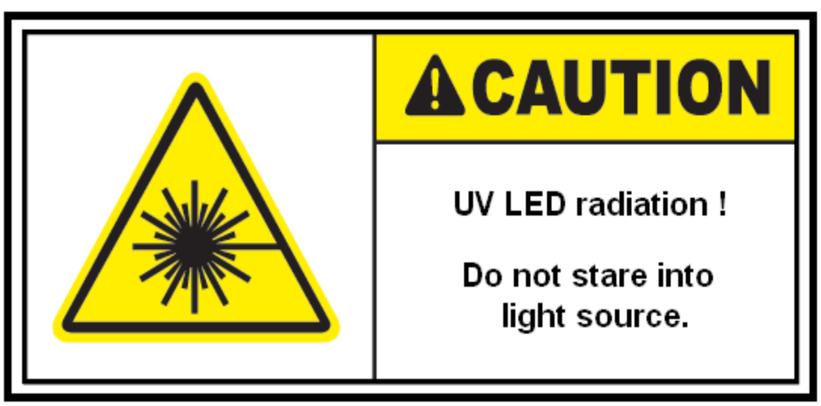
NEVER install the instrument in explosion-risk areas and never use the equipment near flammable substances.

Instrument overheating

ALWAYS assure the instrument operates under proper operating ambient conditions. NEVER install the instrument in spaces with limited air circulation.

UV radiation

AE33 light source contains an ultraviolet (UV) light emitting diode (LED). The LED radiates UV and visible light during operation. Precautions must be taken to prevent looking directly at the UV light with unaided eyes. NEVER touch or look directly into the AE33 light source!



Instrument service and repair

UNAUTHORISED instrument service and repair procedures are NOT ALLOWED. The instrument can only be serviced, repaired or modified by authorized persons. Please contact your authorized representative if you have any problems with the instrument. Please make sure to have the equipment checked regularly for technical safety.

Moving parts

During AUTOMATIC tape advance procedure, the measurement chamber is lifted by a motorized chamber lift mechanism. To prevent any injuries to your fingers, NEVER squeeze your hands or fingers into ANY mechanical apertures, DURING automated tape advance procedure.

During MANUAL chamber lift procedure ALWAYS use the chamber lift locking mechanism. To prevent any injuries to your hands or fingers, NEVER squeeze your hands or fingers into ANY mechanical apertures, BEFORE manually lifting the chamber.

During filter tape replacement procedure, precaution must be taken, to prevent unintentional injuries to your hands or fingers.

3 IDENTIFICATION and MARKINGS

3.1 Instrument identification label

Magee Scientific Aethalometer®

Model AE33 with DualSpot™ technology

Manufactured in Slovenia by Aerosol d.o.o.

S/N: AE33-S00-00025

CE

3.2 Front panel markings

3.3 Back panel markings

4. INSTRUMENT INSTALLATION

4.1 Unpacking the system

Take the instrument out of the box and place it on an even surface. Keep the back of the instrument accessible.

Remember to remove protective caps on the inlet and exhaust ports before operation!

Figure 6. Remove protective caps on the rear panel of the instrument before switching it on!

4.2 The sampling line

The instrument is supplied with several meters of black conductive sample line tubing designed to minimize electrostatic particle losses in the sampling system. Keep the sampling line as short as possible. Do not attempt to substitute the sampling tubing with tubing from a different material. If substituting the supplied tubing with tubing from other material, please consult the instrument supplier for details.

When installing the sample line, try to avoid sharp bends or long horizontal runs with the sample tubing as either of these conditions can promote particle losses in the sample tube.

Insulate the sample lines inside the instrument shelter and avoid exposing them to direct exhaust from the HVAC unit – this can lead to condensation inside the sample line tubing and can damage the instruments and interfere with the measurement.

Thread the supplied fitting onto the Sample Inlet port on the rear panel of the Aethalometer (Figure 7, top). Use Teflon tape on the thread. Fit the supplied barbed connector to the end of the black conductive sample tubing and insert the connector into the fitting on the rear panel of the instrument.

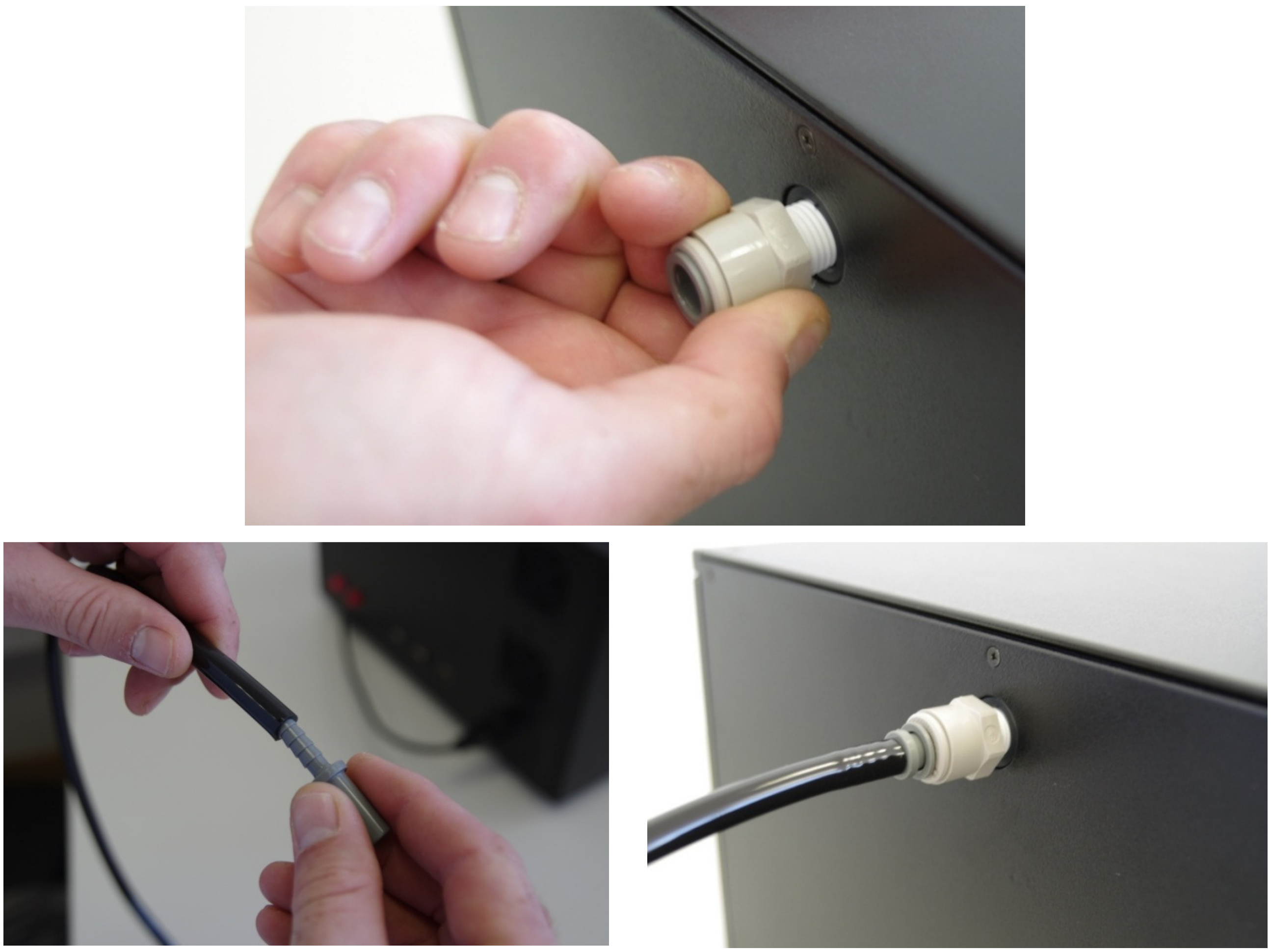


Figure 7. Fit the inlet connector on the rear panel of the Aethalometer and connect the sampling line tubing to it.

Connect the other end of the sample line tubing to the sampling manifold or to the inlet on the outside of the measurement station. Make sure that any openings in the station walls or ceiling is leak-proof. If not using a size selective inlet, please make sure to keep the end of the tubing inverted so rain cannot enter. A funnel on the sampling end of the inverted sample line tubing with the opening covered by a mesh screen is recommended. Alternatively, the optional insect screen can be installed near the sampling end of the tubing. The inlet should be unobstructed, securely fixed and placed at an appropriate distance from the roof or walls of the station. Please consult the appropriate national and international technical standards for particulate matter sampling and analysis for details.

4.3 Switching the Aethalometer on

Connect instrument to AC power and turn on. The instrument has two power-on switches – one on the rear panel and another on the front inside the door on the right (Figure 8).

Figure 8. Power on switches: rear panel (top) and inside the door on the right (bottom).

Upon start-up, the instrument will proceed through an initialization period which can take up to 5 minutes (Figure 9). Various subunits are tested during this period and test results are indicated by green check boxes for each step. The instrument will automatically begin measurements if the touch screen display remains untouched for several minutes.

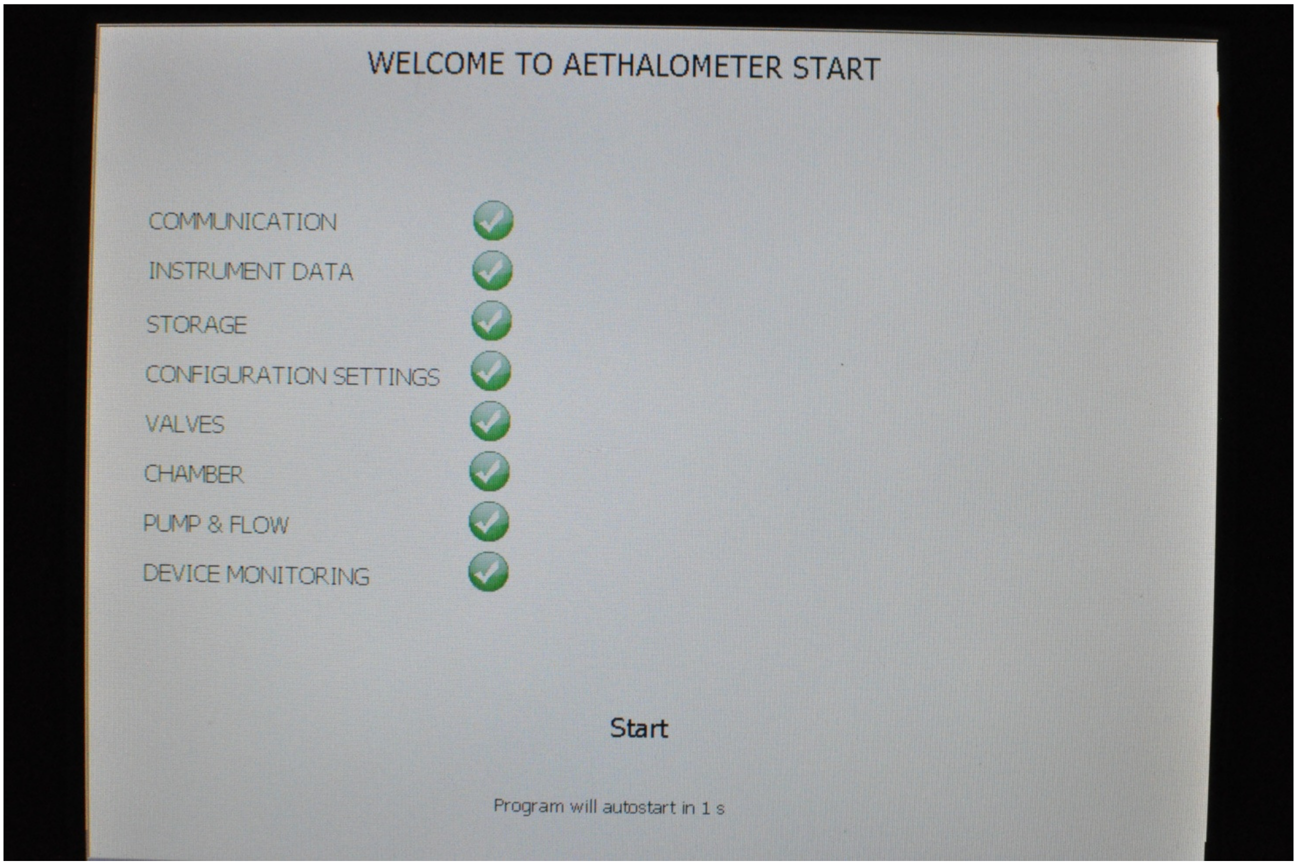


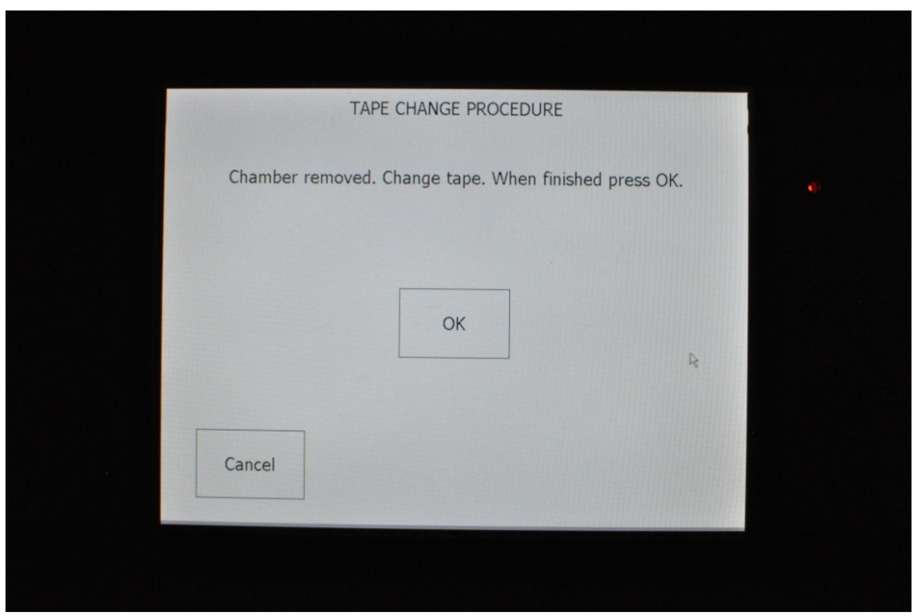
Figure 9. The initialization screen with test results.

4.4 Filter tape installation

Stop measurements and press go to the "Operation / General" menu. Press "Change Tape" and follow instructions – you will need a fresh roll of filter tape and some adhesive tape. For details, please see below.

Stop measurements and press "Change Tape" from the "Operation / General" menu

The chamber lifts.



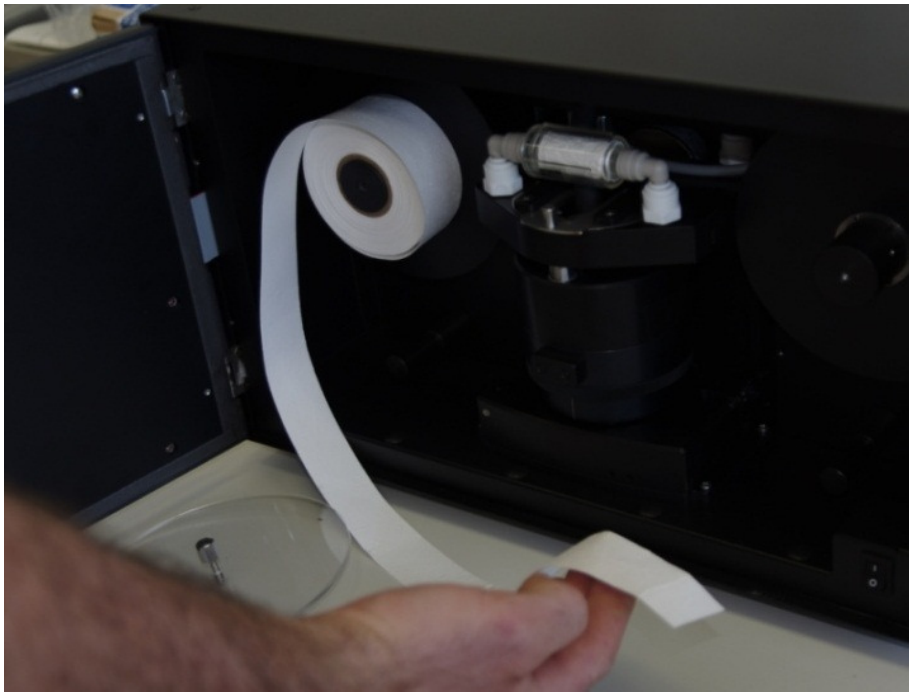
Start changing filter tape. First remove the transparent holder of the roll on the left of the chamber…

… and on the right.

Remove the tape from underneath the optical chamber.

Take both spools of tape from the Aethalometer.

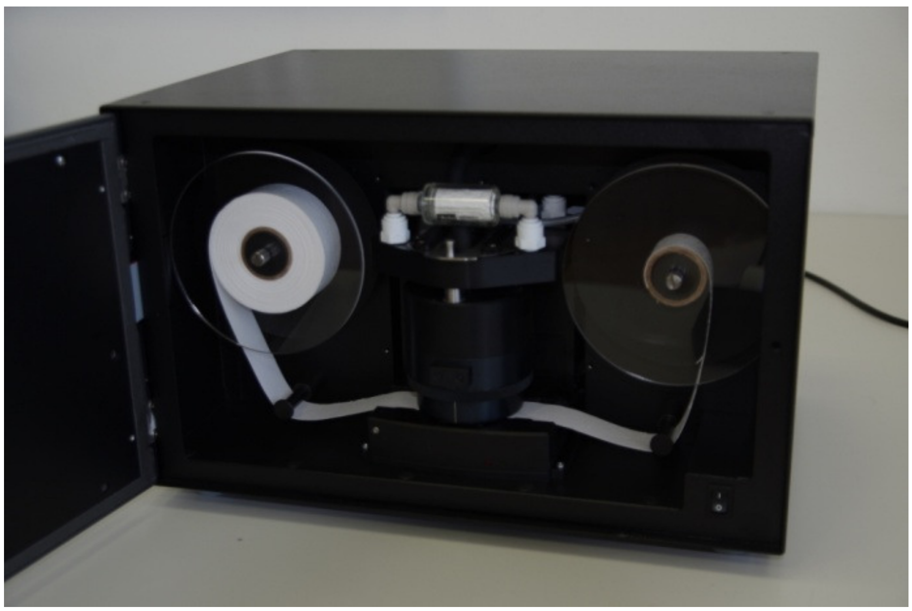
Install a fresh roll of filter tape on the left hand side of the optical chamber.



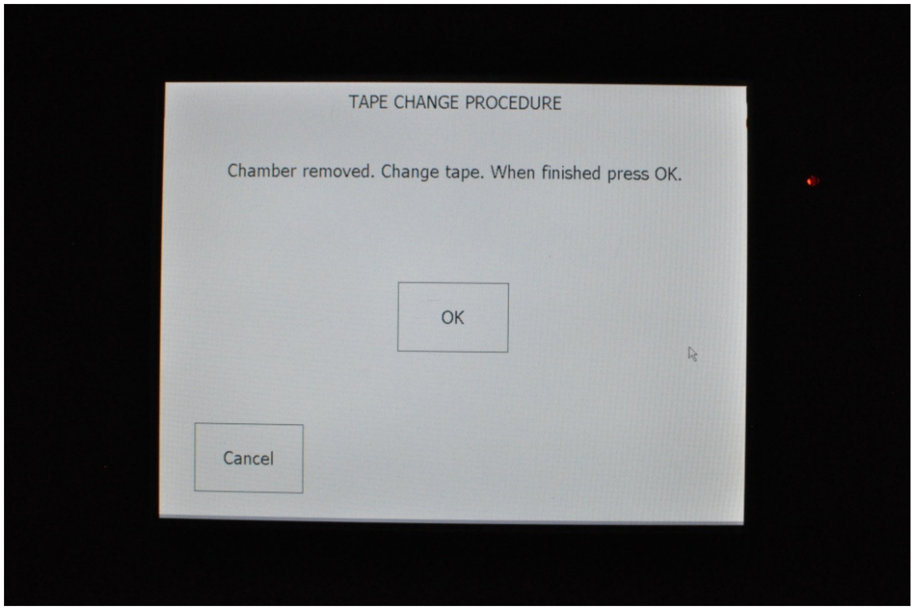
Tape the end of the tape to the cardboard spool.

Insert the tape to the right-hand side of the chamber.

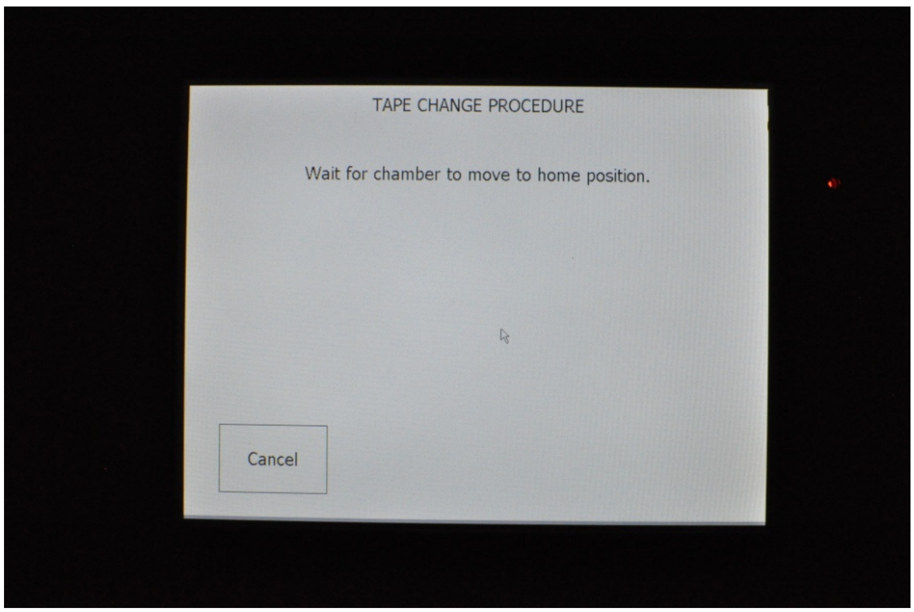
Screw back the transparent holders on the left- and right-hand side of the optical chamber.



Close the door and click OK.



Wait for the chamber to return to home position.



The tape change is finished. Click OK.

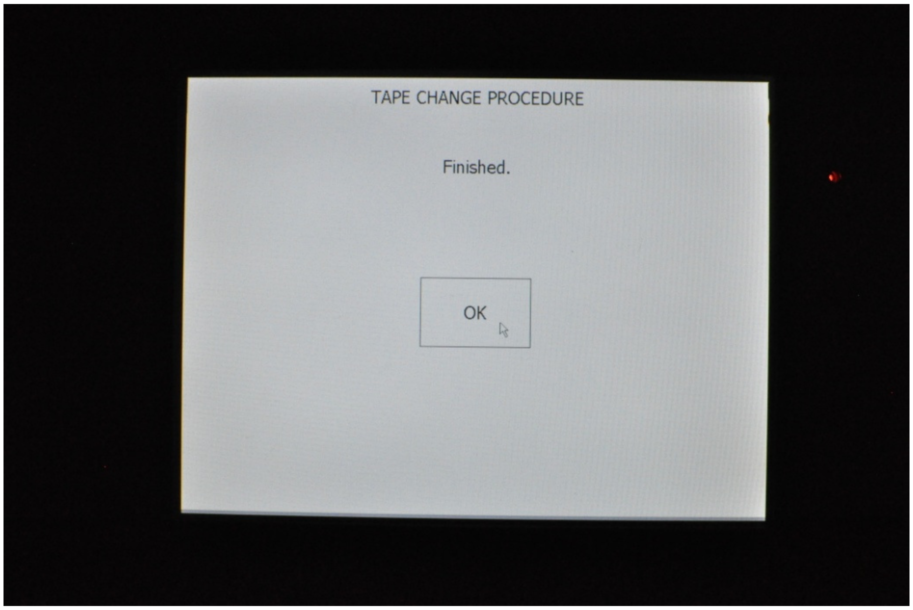


Figure 10. Changing filter tape

In case if the instrument **is turned off** during new tape installation, the chamber can be lifted manually.

ATENTION! – If the chamber is lifted while instrument is operating, it is not possible to start the measurement without cycling the instrument power.

5 USER INTERFACE, SETTINGS and OPERATION

5.1 User interface and settings

There are four 1st level menu tabs in the touch-screen user interface one can navigate through (Figure 11):

- **HOME** showing:
    - the measured values for Black Carbon (measured at 880 nm, BC) and UV particulate matter (calculated at 370 nm, UVPM),
    - measured flow,
    - timebase setting,
    - the amount of remaining tape,
    - status: green (all OK), yellow (check status), and red (stopped) with a status flag (see, 5.2 Instrument Status),
    - date and time.

    Note: The BC and UVPM values will typically be similar, but not exactly the same. If aromatic compounds are present in the sampled air (such as when sampling fresh wood-smoke, for example), the UVPM concentration will exceed the BC mass concentration value significantly, depending upon the amount and type of organic material present.

- **OPERATION** with four sub-tabs: GENERAL, ADVANCED, LOG and MANUAL.
  GENERAL where one can change the settings:
    - flow (LPM),
    - flow-reporting standard: These are the pressure and temperature which the instrument uses to report flow. By choosing to report mass flow, (101325 Pa, 21.11 C) are used to convert the measured mass flow to reported volumetric flow at these conditions (these are values used by the flow meter in the AE33). These values can be substituted for any other (pressure, Temp) values, should you want the flow to be reported at 0 C, or 25 C for example. Optionally, you can chose volumetric flow at ambient conditions to be reported. To do that you need an accessory for the (pressure, Temp) measurement. We offer this separately. This external device is connected to the COM ports, please see below (chapter: 5.6 External devices).
    - timebase (seconds),
    - maximum attenuation at which the Aethalometer advances tape – TA ATNmax or,
    - the time interval at which the Aethalometer advances tape (hours) – TA INT or,

- the time at which the Aethalometer advances tape – TA Time.

ADVANCED with all parameters which can be set in the Aethalometer.
LOG with the last operational reports of status, parameter changes, data download.
MANUAL with basic commands, to operate hardware (solenoids, pump, chamber, TA)

- **DATA** with two sub-tabs: TABLE and EXPORT.
  TABLE where raw measurement values are reported, BC concentration calculated from each individual spot (BC1, BC2), and the compensated BC concentration. All three concentrations have the unit ng/m^3.
  EXPORT with selection data to be copied to USB

- **ABOUT –** features and contact information.

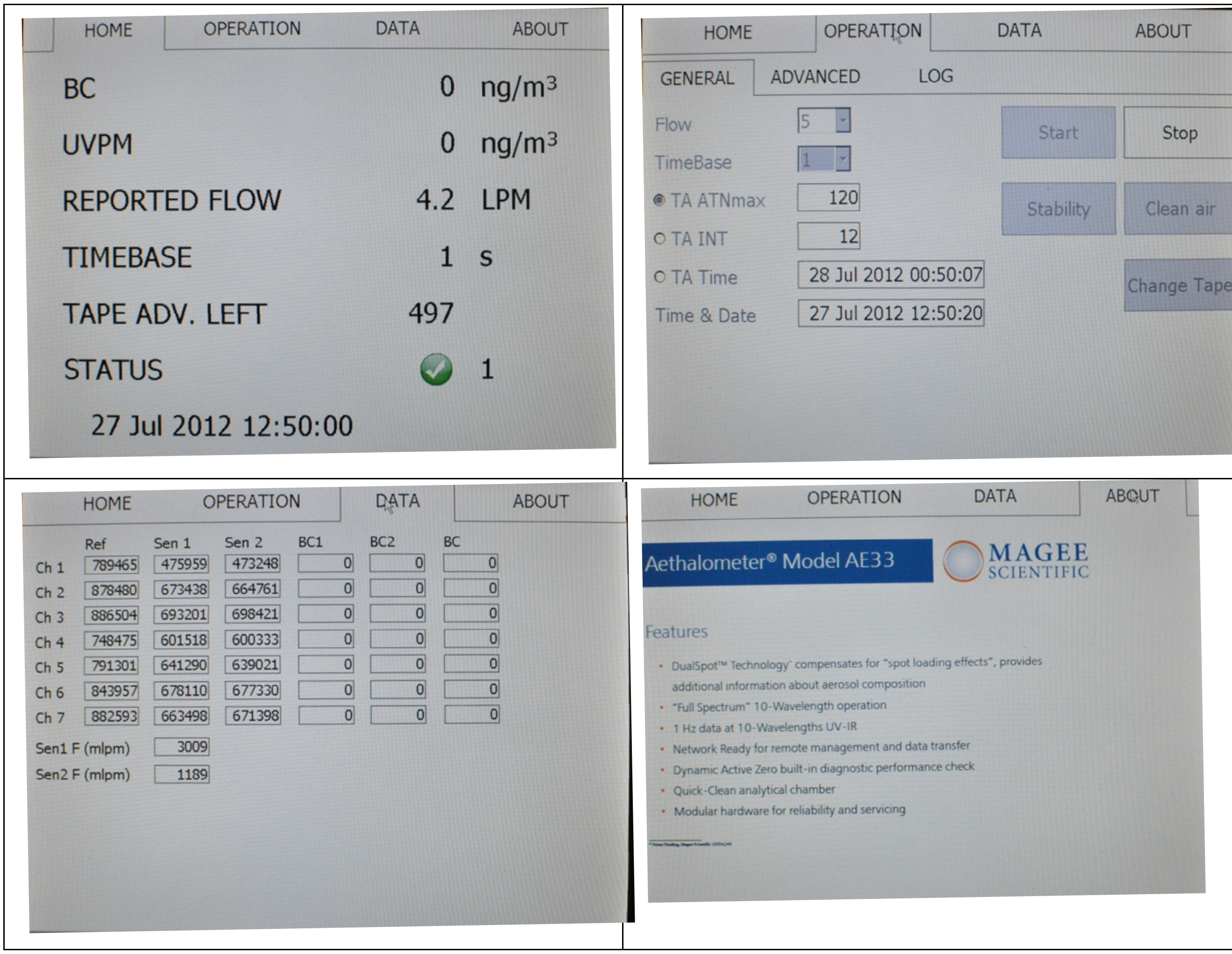


Figure 11. The Aethalometer HOME, OPERATION, DATA and ABOUT screens, clock-wise from top left.

5.2 Instrument Status

Status of the instrument is currently a status flag (16bit value) consisting of detector (bit 0,1), flow (2,3), LED (4,5), tape advance(7,8) flags, and will be later extended to chamber (6), valve (9), settings (10) , and other important status notifications.

Status relates to:	**bit position**	**status flag**		**description**
		binary	**decimal**	
detector	1 and 0	00	0	measuring
		01	1	Tape advanve (tape advance, fast calibration, warmup)
		10	2	first measurement – obtain ATN0
		11	3	Stopped
flow	3 and 2	00		flow OK
		01	4	flow low/high by more than 0.25 LPM
		10	8	Flow check status history
		11	12	Flow L/H and check status history
LED	5 and 4	00		LEDs OK
		01	16	calibrating
		10	32	calibration error (at least one channel OK)
		11	48	led error (all channels calibration error, COM error)
chamber	6	0		No chamber error
		1		Chamber error
tape advance	8 and 7	00		tape advance OK
		01	128	tape warning (less than 10 spots left)
		10	256	tape last warning (card box visible, less than 5 spots left)
		11	384	tape error (tape not moving, end of tape)
Tests	10 and 11	00		No test
		01	1024	Stability test

		10	2048	Clean air test
		11	3072	Change tape

8	7	6	5	4	3	2	1	0
0/1	0/1	0	0/1	0/1	0/1	0/1	0/1	0/1

Table 1. Status flags and explanations.

When a status flag 3 (decimal) is encountered, the Aethalometer stops. In all other statuses, it continues to operate with a warning, and the data is flagged accordingly.

The overall status is a sum of the statuses in the Table 1. These status flag add, for example:

Status = 0, all OK -> front panel LED's GREEN

0	0	0	0	0	0	0	0	0

Status = 1, all OK, tape advancing -> blinking GREEN LED

0	0	0	0	0	0	0	0	1

Status = 128, machine is running, tape advance warning flag is set -> YELLOW

0	1	0	0	0	0	0	0	0

Status = 289, 289 =256 + 32+ 1 -> machine is doing tape advance, in led calibration 1 or more channels (but not all) had errors and only 5 or less TA left

1	0	0	1	0	0	0	0	1

5.3 Downloading and Viewing Data

Please insert the USB stick in either of the front USB ports. Rear ports are intended for the mouse and keyboard only and not for data transfer (surge protection).
Go to the “Data / Export” menu and press “Export to USB”. The data will be stored in a text file with a header. The file name is:

AE33_S*ss*- *nnnnn_yyyymmdd*.dat

where *ss* is the production series number, *nnnnn* is the serial number, and *yyyymmdd* is the date, for example 20120901 means 1 Sept 2012.
Please make sure that the transfer is finished before removing the USB stick from the USB port on the Aethalometer. You can now transfer the data file to a personal computer as any other file, making note, where you saved it, and open it in your favorite data processing application.

Data file structure and description of the fields

Header:

Date(yyyy/MM/dd); Time(hh:mm:ss); Timebase; RefCh1; Sen1Ch1; Sen2Ch1; RefCh2; Sen1Ch2; Sen2Ch2; RefCh3; Sen1Ch3; Sen2Ch3; RefCh4; Sen1Ch4; Sen2Ch4; RefCh5; Sen1Ch5; Sen2Ch5; RefCh6; Sen1Ch6; Sen2Ch6; RefCh7; Sen1Ch7; Sen2Ch7; Flow1; Flow2; FlowC; Pressure (Pa); Temperature (°C); RH (%); ContTemp; SupplyTemp; Status; ContStatus; DetectStatus; LedStatus; ValveStatus; LedTemp; BC11; BC12; BC1; BC21; BC22; BC2; BC31; BC32; BC3; BC41; BC42; BC4; BC51; BC52; BC5; BC61; BC62; BC6; BC71; BC72; BC7; K1; K2; K3; K4; K5; K6; K7; TapeAdvCount; ID_com1; ID_com2; ID_com3; fields_i

Data line:

2012/09/21 00:34:00 60 890416 524323 709193 823296 573862 756304 884844 619592 789142 822391 673266 816066 792706 686925 828401 738101 718325 841075 789053 722690 833686 3325 1674 4999 101325 21.11 -1 30 40 0 0 10 10 00000 0 1150 1290 1242 1166 1248 1215 1150 1231 1190 1146 1196 1175 1214 1195 1234 1144 1114 1139 1180 1225 1174 0.00133 0.00095 0.00092 0.00080 0.00057 -0.00024 -0.00025 12 0 2 0 21.1

Data field description:

- *Date(yyyy/MM/dd)*: date.

- *Time(hh:mm:ss)*: time.

- *Timebase*: timebase – units in seconds.

- *Ref1, Sen1Ch1, Sen2Ch1…:* are the raw signal Reference (Ref), Sense 1 (Sen1) and Sense 2 (Sen2) values form which the BC concentrations are calculated for channel 1 (Ch1), that is wavelength 370 nm. BC11 is the uncompensated BC calculated from the spot 1 for channel 1. BC1 is the final results the BC calculated form measurements for channel 1 (370 nm).

- *Flow1; Flow2; FlowC:* Measured flow in ml/min. Flow 1 is flow through the spot 1, Flow_C is common (total flow) through the optical chamber, Flow_2 is the difference between these two.

- *Pressure (Pa); Temperature (°C); RH (%)*: These are the pressure and temperature which the instrument uses to report flow. By chosing to report mass flow, (101325 Pa, 21.11 C) are used to convert the measured mass flow to reported volumetric flow at these conditions (these are values used by the flow meter in the AE33). These values can be substituted for any other (pressure, Temp) values, should you want the flow to be reported at 0 C, or 25 C for example. Optionally, you can chose volumetric flow at ambient conditions to be reported. To do that you need an accessory for the (pressure, Temp) measurement. We offer this separately. This external device is connected to the COM ports, please see below.

- *ContTemp; SupplyTemp*: control and power supply board temperatures

- *Status; ContStatus; DetectStatus; LedStatus; ValveStatus; LedTemp*: status codes for the instrument, reported in the , please see manual, chapter 5.2. and the subcomponents: controller, detector LED board; valve status (each valve can be on or off); LED board temperature

These are not documented yet, but we'll add them in one of the upcoming versions of the manual.

- *BC11; BC12; BC1; BC21; BC22; BC2; BC31; BC32; BC3; BC41; BC42; BC4; BC51; BC52; BC5; BC61; BC62; BC6; BC71; BC72; BC7*: BC11 is the uncompensated BC calculated from the spot 1 for channel 1. BC1 is the final results the BC calculated form measurements for channel 1 (370 nm).

- *K1; K2; K3; K4; K5; K6; K7*: K_i are the compensation parameters for wavelengths i=1…7

- *TapeAdvCount*: TapeAdvCount – tape advances since start
- *ID_com1; ID_com2; ID_com3; fields_i:* ID_comi are the identifiers telling the Aethalometer which auxiliary device is connected to which serial port (necessary because of the different data structure). This is a 3 byte field:

0 2 0 21.1

means that the "Comet temperature probe" (instrument code 2) is connected to COM2 and nothing is connected to COM1 and COM3. The temperature is 21.1 C. (This is not true for the temperature and pressure measurements to calculate volumetric flow using AMES_TPR159 sensor!)
If we connected additionally another aux instrument to COM1 the dataline would be (ID_comi: 1 2 0):

Date(yyyy/MM/dd); Time(hh:mm:ss); Timebase; RefCh1; Sen1Ch1; Sen2Ch1; RefCh2; Sen1Ch2; Sen2Ch2; RefCh3; Sen1Ch3; Sen2Ch3; RefCh4; Sen1Ch4; Sen2Ch4; RefCh5; Sen1Ch5; Sen2Ch5; RefCh6; Sen1Ch6; Sen2Ch6; RefCh7; Sen1Ch7; Sen2Ch7; Flow1; Flow2; FlowC; Pressure (Pa); Temperature (°C); RH (%); ContTemp; SupplyTemp; Status; ContStatus; DetectStatus; LedStatus; ValveStatus; LedTemp; BC11; BC12; BC1; BC21; BC22; BC2; BC31; BC32; BC3; BC41; BC42; BC4; BC51; BC52; BC5; BC61; BC62; BC6; BC71; BC72; BC7; K1; K2; K3; K4; K5; K6; K7; TapeAdvCount; ID_com1; ID_com2; ID_com3; fields_i

2012/09/21 00:34:00 60 890416 524323 709193 823296 573862 756304 884844 619592 789142 822391 673266 816066 792706 686925 828401 738101 718325 841075 789053 722690 833686 3325 1674 4999 101325 21.11 -1 30 40 0 0 10 10 00000 0 1150 1290 1242 1166 1248 1215 1150 1231 1190 1146 1196 1175 1214 1195 1234 1144 1114 1139 1180 1225 1174 0.00133 0.00095 0.00092 0.00080 0.00057 -0.00024 -0.00025 12 1 2 0 20.0 45 1090 21.1

where the aux instrument with the code 1 is a weather station reporting temperature (20.0), RH (45%) and pressure (1090 mbar). the temperature 21.1 is reported by the "Comet temperature probe" installed at a different location.

5.4 Connecting to External Datalogger or PC

Connect with a crossover cable (or standard serial cable with null modem adapter) from the PC / Datalogger to the serial port of the instrument on the rear panel.

Establish communications using the following values:

.BaudRate = 115200

.DataBits = 8

.StopBits = IO.Ports.StopBits.One

.Parity = IO.Ports.Parity.None

.Handshake = IO.Ports.Handshake.None

.DtrEnable = True

.RtsEnable = True

5.5 Serial Commands for Communication with the Aethalometer

All commands finish with a Carriage Return.

<table>
<tr><td>$AE33:Dnnn</td><td colspan="2">nnn number of lines of data requested</td><td>Request nnn last measurements</td></tr>
<tr><td>$AE33:TyyyyMMddHHmmss</td><td>yyyy
MM
dd
HH
mm
ss</td><td>year
month
day
hour (24)
min
second</td><td>Synchronize time with the data-logger</td></tr>
</table>

Command: $AE33:D1[CR] will return one data line (i.e. 1 byte -> value = 13 so all together there should be 9 bytes)
Please note these are all capital letters.

Example 1: $AE33:D120[CR] => 11 bytes; Output will be 120 lines of data.

Example 2: If you are using Hyper Terminal just write following command $AE33:D1 and press enter (this should add CR character at end of command).

Example 3: $AE33:T20120110120000[CR] will synchronize the time on the Aethalometer to 10 Jan 2012, noon.
Note: Hyper Terminal may experience problems when sending the string more than two consecutive identical numbers (111, for example).

5.6 External devices

Several external devices are supported for data-logging using the Aethalometer. Before use the connection with the selected device should be enabled using "External device" button on the Operation/Advanced tab. Select the device connected to the certain COM port and click "Connect". Aethalometer will try to connect to the device every few seconds. When connected the status will go green.

Supported devices:

- AMES_TPR159 (ID_com = 1) – dedicated ambient temperature + relative humidity + pressure sensor used for flow reporting at ambient conditions
- Comet_T0310 (ID_com = 2) – temperature sensor
- Vaisala_GMP343 (ID_com = 3) – CO2 sensor
- TSI_4100 (ID_com = 4) – mass flowmeter
- Remote_Access (ID_com = 5) – the selected port is waiting for communication with the data-logger

5.7 Software upgrade

1. Take a high quality USB key (Kingston, for example) and copy the selected files in the root directory:
 - NK.bin - application software,
 - ae33co502.hex, ae33de502.hex, ae33le502.hex, the three hex files (firmware).

2. Switch on the AE33 and stop measurement.

3. Insert the USB key into the front USB slot. Wait 10 seconds.

4. Go to "Operation/Advanced" menu and press the "Update" button.

5. Choose "Software" upgrade.

6. Wait until the Aethalometer finishes the upgrade.

7. Take the USB key out of the Aethalometer.

8. Restart the Aethalometer.

9. Switch on the AE33 and stop measurement.

11. Insert the USB key into the front USB slot. Wait 10 seconds.

12. Go to "Operation/Advanced" menu and press the "Update" button.

13. Choose "Firmware" upgrade.

14. Wait until the Aethalometer finishes the upgrade. This can take up to 10 min!

15. Take the USB key out of the Aethalometer.

16. Restart the Aethalometer.

17. Check the "Advanced" menu for the software application and firmware versions.

5.8 BC source apportionment

Source apportionment of black carbon emissions is based on the Sandradewi et al. (2008) model, with optical absorption coefficient being a sum of biomass burning and fossil fuel burning fractions. Model is based on the difference in absorption coefficient wavelength dependency assuming that absorption due to from fossil fuel and biomass emissions follow λ^{-1} and λ^{-2} spectral dependencies, respectively (Sandradewi 2008). The exponents which describe the spectral dependence are called Ångström exponents: α_{ff}=1 for fossil fuel and α_{bb}=2 biomass.

Settings

- BC Source apportionment is switched on by selecting *Home display/procBB* setting on *Operation/Advanced* tab.
- the algorithm can be fine-tuned by changing the value of Ångström exponents α_{ff} and α_{bb}, from the default values of α_{ff}=1 and α_{bb}=2.

Presentation

- BC and portion of biomass burning (%) are displayed on the *Home* tab.
- The percentage of BC created by biomass burning is stored in the field BB (%).

Reference

Sandradewi, J. et al. (2008), Using Aerosol Light Absorption Measurements for the Quantitative Determination of Wood Burning and Traffic Emission Contributions to Particulate Matter, Environ. Sci. Technol. 42, 3316–3323.

6 MAINTENANCE and SERVICE

The Aethalometer needs to be maintained regularly. We recommend the following schedule for regular maintainance.

Sample inlet flow	Once / month
Inspect the sample line tubing	Once / month
Inspect and clean the size selective inlet (if present)	Once / month
Verify time and date /if not set to update automatically)	Once / month
Inspect optical chamber, clean if necessary	Twice / year Site dependent, use educated judgement!
Check flow, calibrate if necessary	As needed. Twice / year
Install a new filter tape roll	As needed. The instrument issues a warning.
Change by-pass cartridge filter	As needed. Once / year

6.1 Automatic flow-meter calibration

For the automatic calibration a TSI4100 flow-meter, data cable and the flow calibration pad are needed.

Flow calibration procedure:

1. Go to OPERATION tab.
2. In case instrument is running, STOP the instrument under GENERAL sub-tab.
3. In ADVANCED sub-tab click ”FlowCal”.
4. Press AUTO to start automatic Flow meter calibration.
5. Wait for chamber to be lifted.
6. Remove tape and insert the flow calibration pad press OK when done.
7. Wait for chamber to move back to home position.
8. Connect the flow-meter to the inlet of the Aethalometer, note the orientation! Connect the data cable to the serial connector (COM3) on the back of the Aethalometer.
9. Wait for calibration to finish.
10. Wait for chamber to be lifted.
11. Remove the flow calibration pad, insert and tighten filter tape, then press OK.
12. Wait for chamber to move to home position.

6.2 Manual flow-meter calibration

For the manual calibration a flow-meter and the flow calibration pad are needed. Please note the units and conditions at which flow is reported. Please note whether the flow meter measures volumetric or mass flow!

Flow calibration procedure:

1. Go to OPERATION tab.
2. In case instrument is running, STOP the instrument under GENERAL sub-tab.
3. In ADVANCED sub-tab click “FlowCal”.
4. Press MANUAL to start manual Flow meter calibration.
5. Wait for chamber to be lifted.
6. Remove tape and insert the flow calibration pad, press OK when done.
7. Wait for chamber to move back to home position.
8. Connect the flow-meter to the inlet of the Aethalometer and press OK.
9. Input measured flow and flowmeter reporting conditions (pressure, temperature) and press OK (repeated for 3 different flows).
10. When the calibration is finished, wait for chamber to be lifted.
11. Remove the flow calibration pad, insert and tighten tape, then press OK.
12. Wait for chamber to move to home position.

6.3 Leakage test

Leakage (ζ) is measured during instrument operation. It is calculated from the flow in (Fin) and flow out (Fout).

$$\zeta = 1 - (Fin/Fout)$$

Average leakage is 7% at 5 LPM. It can differ slightly from spot to spot and during the spot loading.

Flow measurement using a mass-flow meter (for example TSI4100)

1. Connect the flow meter to the input of the instrument. Wait for a few seconds for the flow to stabilize and read the flow Fin. Disconnect flowmeter from the input.
2. Connect the flow meter to the output of the instrument by a long tube (10 m) to reduce the oscillations, which can influence the flow measurements. Take a Fout reading.

IMPORTANT!

If you use a volumetric flow meter take into account the difference in air pressure and temperature between the flow in and flow out (use the ideal gas law equation).

Report

Aethalometer SN	**Flowmeter**	**Date**	**Fin (LPM)**	**Fout (LPM)**	**ζ (%)**
AE33-S00-0054	TSI4100	15.1.2013	4.67	5.01	6.8

6.4 Manual stability test

Stability test is conducted without flow to determine the performance of the light source – detector pair. In the operation/General tab select the desired timebase and click "Stability" button to start the test. Stability test is marked by status 1024. During the test BC values will be calculated assuming there is 5 LPM air flow. You have to manually stop the test for the desired test duration.

Interpretation of the results:

- Average BC values should be close to zero if the Aethalometer is warmed up (was measuring for a few hours just before conducting the test).
- Point to point variation of BC (PPBC) is calculated as an average absolute difference between the consecutive BC measurements. It depends on the timebase, tested channel and spot. For example at 1 s timebase PPBC61 = approx. 400 ng/m^3.

6.5 Manual clean air test

Clean air test is conducted using the built-in filter to determine the performance of Aethalometer under the standard flow condition. In the operation/General tab select the desired timebase and flow, then click "Clean air" button to start the test. Clean air test is marked by status 2048. You have to manually stop the test for the desired test duration.

Interpretation of the results:

- Average BC values should be close to zero if the Aethalometer is warmed up (was measuring for a few hours just before conducting the test). It is possible to observe a short transient due to filter compression.
- Point to point variation of BC (PPBC) is calculated as an average absolute difference between the consecutive BC measurements. It depends on the selected timebase, flow and tested channel. For example PPBC61 = approx. 500 ng/m^3 at 5 LPM and 1 s timebase.

6.6 Automatic clean air test

Automatic clean air test is activated by checking “Auto Clean Air” option on Operation/General screen. It is run weekly/monthly on specified time.

Test runs for 20 minutes at 1 s time resolution. Data is marked with status 2048. Test results are displayed in the log file: average BC concentrations and point-to-point variations are calculated for each channel and spot.

6.7 Tape sensor calibration

Tape sensor calibration is conducted when removing the Measurement chamber from/to the Aethalometer. For calibration you need special calibration cylinders covered with the filter tape. Small cylinder has diameter of 39 mm; big cylinder has diameter of 102 mm.

For tape sensor calibration you have to stop the measurement and select “TapeSenAdj” button on the Operation/Advanced tab. Then follow the instructions on the screen. It is essential to fix calibration cylinders with the covers during calibration.

6.7 Flow verification

Flow verification routine is used to check if internal flow-meters need calibration. No instrument settings are changes during the flow verification routine.

For flow verification you need a flow calibration pad and external flow-meter, which you connect to the Aethalometer inlet.

To start flow verification select “Flow verification” button on Operation/General screen. When the procedure is finished you will get the table with measured flows, reported at the flow reporting standard selected for the instrument. If measured flows differ for more than 10 % you need to recalibrate the flow.

6.8 ND filter test

Neutral density filter test is used for monitoring changes of the sensitivity of the optical system. Test consists of measurement of optical attenuation of 4 different neutral density filters. The slope of the linear fit between of measured attenuations versus default attenuation is a measure of sensitivity: if the slope differs more than 10% from unity, the test fails.

To perform the test you need a ND filter-set: AE-33-ND-XXXX. On Operation/General screen select “ND test” and follow the instructions on screen. At the end of the test you will get the test results on screen. Measurement results and slopes are also reported in the Aethalometer log file.

7 TECHNICAL SUPPORT and CONTACT INFORMATION

Please contact the service department through our web sites (Service & Support):

www.mageescientific.com or

www.aerosol.si

Please include the serial number of the instrument and a sample of recent data in the communication. Always send the raw files.

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The distributor responsible for your country is: