



AIR QUALITY SURVEILLANCE BRANCH

STANDARD OPERATING PROCEDURES  
FOR  
**MAGEE SCIENTIFIC AETHALOMETER**

AQSB SOP 407

First Edition

MONITORING AND LABORATORY DIVISION

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### Approval of Standard Operating Procedures (SOP)

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## TABLE OF CONTENTS

### MAGEE SCIENTIFIC AETHALOMETER

		<u>Page(s)</u>	<u>Date</u>
<b>1.0</b>	<b><u>GENERAL INFORMATION</u></b>	5-7	07/09
1.1	Introduction	5	
1.2	Principle of Operation	5-6	
1.3	Interferences/Limitations	6-7	
1.4	Safety Precautions	7	
<b>2.0</b>	<b><u>INSTALLATION PROCEDURE</u></b>	8-22	07/09
2.1	List of Tools/Supplies	8	
2.2	Physical Inspection	8	
2.3	Initial Setup	8-9	
2.4	Hardware Set-Up	9-10	
2.5	Software Set-Up	11	
2.5.1	Operate	11-12	
2.5.2	Change Settings	12-15	
2.5.3	Signals & Flow Display	15	
2.5.4	Self Test	16-17	
2.5.5	Calibrate Flow Meter	17-18	
2.5.6	Software Upload	18	
2.5.7	Optical Test Procedure	18-19	
2.5.8	Install New Role of Tape	19-21	
2.6	Datalogger Connection	22	
<b>3.0</b>	<b><u>CALIBRATION INFORMATION</u></b>	23-24	07/09
3.1	Calibration Introduction	23	
3.2	Calibration Overview	23	
3.3	Calibration Transfer Standards and Equipment	23	
3.4	Calibration Procedures	23-24	
3.5	Optical Test Strip	24	
3.6	Optical Test Strip Procedure	24	
<b>4.0</b>	<b><u>ROUTINE SERVICE CHECKS</u></b>	25-26	07/09
4.1	General Information	25	
4.2	Daily Checks	25	

4.3	Weekly Checks	25
4.4	Monthly Checks	25
4.5	Semi-Annual Checks	25
4.6	Annual Checks	26

## **FIGURES**

Figure 1	Aethalometer Front Panel	10
Figure 2	Front View Interior	21

## **APPENDICES**

Appendix A	Monthly Quality Control Maintenance Check Sheet	27
Appendix B	ARB Calibration Report	28
Appendix C	Example of a Typical Data File	29

## 1.0 GENERAL INFORMATION

### 1.1 Introduction:

The purpose of this Standard Operating Procedure (SOP) is to document the procedures used by the Air Quality Surveillance Branch (AQSB) of the California Air Resources Board (ARB) to operate the Magee Scientific Aethalometer. The goal of this SOP is twofold; first to formalize Aethalometer installation, configuration and operation procedures in order to ensure comparability among all Aethalometer data, and second to describe supplemental information and modifications to the Magee Scientific Book, The Aethalometer 2005.07, referred to as the "Aethalometer Operation Manual" necessary to successfully integrate the Aethalometer into Air Resources Board's ambient air monitoring network. The Aethalometer Operation Manual contains a significant source of information pertinent to the operation, maintenance and understanding of this instrument, and therefore staff should thoroughly review of the Aethalometer Operation Manual prior to using the instrument.

### 1.2 Principle of Operation:

The Aethalometer is an instrument that provides a real-time readout of the concentration of 'Black' or 'Elemental' carbon aerosol particles ('BC' or 'EC') in an air stream. These particles ("soot") are emitted from all types of combustion, most notably from diesel exhaust.

The Aethalometer is a self-contained instrument that provides a means to measure the rate of change of optical transmission through a spot on a filter tape. The aerosol is continuously collected and deposited on the filter as an accumulation of optically-absorbing material in the sampled air stream. The instrument measures the transmitted light intensities through the 'sensing' portion of the filter tape, on which the aerosol spot is being collected, and a 'reference' portion of the filter tape, as a check on the stability of the optical source. A mass flow meter monitors the sample air flow rate. The data from these three measurements is used in the calculations to determine the mean black carbon (BC) content of the air stream.

During the sampling process, the tape does not move. The roll of tape contains approximately 1500 spots. When the 'Filter Change At' value is set equal to zero, then the tape is automatically advanced when optical attenuation of the filter spot is reached. Maximum Attenuation value can be specified in the Change Settings menu. If the 'Filter Change At' value is greater than zero, then the tape is advanced only when the determined time period expires.

The display on the front panel shows the calculated BC concentration, and provides a keypad for interaction with the instrument's embedded computer. Connectors on the rear panel provide for power input and fuse, an analog output whose voltage may be scaled to represent the measured BC concentration, and RS-232 digital communications with an external computer.

The aerosol inlet is plumbed through a connector on the rear panel and a pump is used to provide suction at the inlet: Some models have an internally-mounted variable-speed pump. The sampling flow rate is stabilized by software control of the pump speed, based on the mass flow meter reading. Other models require an external pump connected to the quick release on the rear panel. The aerosol collecting filter tape is held in a spring-loaded optical head behind the front panel.

The Aethalometer calculates one new aerosol black carbon concentration reading every time base period. The user sets the time base for the desired data rate, usually 5 minutes, although BC data to one reading per second are possible. The data is written to diskette or solid state memory drive depending on the version, transmitted by the COM port and produced as an analog voltage.

### 1.3 Interferences/Limitations:

Temperature - Because the Aethalometer contains sensitive electronics and a processor and may have an internal pump, **AQSB Staff recommend that the instrument be operated in a temperature and humidity controlled, weather tight environment.** Large or rapid changes in ambient temperature may contribute second-order errors to the calculation of aerosol black carbon concentration. Keep the instrument clear from the direct air flow of a vent, heater or air-conditioner. Aethalometer data quality can be jeopardized if the air-conditioning thermostat has substantial hysteresis and/or the equipment is exposed to forced air whose temperature undergoes large fluctuations.

Inlet Plumbing - The sample inlet flow may be highly charged, in which case explicitly-electrically-conducting tubing should be used. Aerosol losses due to electrostatic precipitation in the inlet tubing are normally small. The Aethalometer Operation Manual, section 5.8, Installation Requirements, recommends that Teflon tubing should **not** be used for the sample inlet. **AQSB staff recommends a grounded, ¼ inch stainless steel or anodized aluminum inlet tubing not longer than fifteen (15) feet in length.**

Contaminants - It is important to protect the Aethalometer inlet from rain and insects. The quartz fiber filter will clog and rapidly change its optical properties if exposed to water or insects. AQSB staff therefore recommend that an inlet trap or other device be used to protect the sample line from the introduction of water and also recommends that an enclosing bag of mesh screen with a weave close enough to exclude insects be used.

1.4 Safety Precautions:

Only properly trained personnel should perform Aethalometer testing, installation, operation, maintenance and calibration procedures. As with all monitoring equipment, precautions should be taken when working around electricity, power tools and above ground elevations. Always operate the instrument with a ground connection (earthing).

Under no circumstances remove or open the internal ground connection. If the Instrument is turned on, the electrical connections are charged and therefore do not attempt to touch internal components when the instrument is turned on. Internal components should only be touched or removed when the monitor has been turned off. The power supply is operated at high voltage. Do not attempt to touch the power supply when the instrument is turned on. Do not touch the interior components of the instrument when it is turned on. Never operate the instrument if the cover or any other parts the instruments are removed. If you observe that the instrument has insufficient grounding or that the grounding connection is damaged, remove the instrument from operation for repair.

## 2.0 INSTALLATION PROCEDURE

### 2.1 List of Tools/Supplies:

A set of open end SAE 7/16", 1/2", 9/16" wrenches or a crescent wrench. Any tools required to install inlet tubing from Aethalometer inlet to the source inlet such as drill and bits, fasteners, etc.

A standard external flow meter capable of reading air flow rates in the range of 2 to 10 slpm, with a low resistance to flow, traceable to a primary standard such as NIST.

### 2.2 Physical Inspection:

A complete Aethalometer installation requires the following items:

- 1) The Aethalometer instrument which includes a power cord, sample inlet tubing, and a selection of fittings for sample inlet connection. AQSB staff recommends 1/4" stainless steel fittings.
- 2) A roll of Filter tape, installed in instrument.
- 3) The instrument manual.
- 4) Factory documentation: Final inspection record, CE certificate, Calibration test document.
- 5) The original program diskette for backup or solid state memory drive.
- 6) An optical test strip.
- 7) A box of 3.5" floppy diskettes, IBM-PC formatted for 1.44 MB or solid state memory drive.

### 2.3 Initial Setup:

- 1) Connect the Aethalometer to an AC power outlet, turn power switch on, and ensure that the instrument powers up.
- 2) Insert IBM-PC formatted diskette or solid state memory drive.
- 3) Remove the clear plastic filter protection strip from the optical analysis head by holding **TAPE ADVANCE** and pulling gently. Do not tear tape.

## 2.4 Hardware Set-Up:

Sample inlet flow through the Aethalometer is produced either by an internal or external pump. When an internal pump is used the flow rate is controlled by an electronic motor speed control. The external pump models flow rate is controlled by a valve connected to the pump. Since the mass flow meter monitors the actual mass flow, the average measured mass air flow is used to calculate the sample volume.

### **Internal diaphragm pump – Variable-Speed DC Motor**

The Aethalometer is most commonly supplied with a dual-diaphragm pump operated by a variable-speed brushless DC motor. The motor speed (and hence the flow rate) is controlled automatically by the Aethalometer microprocessor using feedback from the mass flow meter to achieve a desired flow rate.

### **External Pump**

The purpose of using an external pump is to provide higher sample inlet airflow through the Aethalometer. For these cases, the Aethalometer may be used with the supplied quick-disconnect suction fitting on the rear panel, and a valve to attach to the pump to adjust the flow. Minimum pump requirements are that it can provide the necessary flow at a gauge vacuum of up to  $-0.5$  atmosphere. A GAST Manufacturing Inc. pump, model DOA-V722-AA or equivalent is suitable. These can be obtained either from GAST or from distributors such as W. W. Grainger (their catalog no. 2Z866) and McMaster-Carr (Catalog no. 4176K11).

Connect the sample inlet port to the inlet line. If the instrument is configured for 'External Pump', plug in the pump, check that it is operating correctly, and connect it to the 'Vacuum Pump' suction connector on the rear panel.

Turn the instrument on to verify that it is drawing air through the Aethalometer such that suction can be felt at the end of the sample inlet tubing.

When the power to the Aethalometer is turned on, the display screen will illuminate. For the first 30 seconds the computer is performing its program loading and initialization procedure, and the screen will only show a flashing cursor block. The screen will then display the opening dialog. The instrument can begin operation automatically from this point, and will do so after 60 seconds if none of the keypad keys are pressed.

### **Sample Inlet Tubing Connectors**

The sample inlet port on the rear panel is a standard  $\frac{1}{4}$ " female pipe thread socket. It accepts any fitting that the user may wish to employ for connection to the air sampling stream. A selection of fittings is provided with each new Aethalometer, including a gray plastic 'instant' push-to-fit connector for the  $\frac{3}{8}$ " (6 mm.) OD tubing that is supplied. If using this fitting, it is **very important** that the tubing must be pushed firmly all the way into the fitting, in order to make a leak-

proof seal on the o-ring that is inside the connector. To remove the tubing from the connector, press firmly on the release collar ring closest to the tubing, while simultaneously pulling the tubing out of the fitting.

See Section 1.3 Interferences/Limitations, Inlet Plumbing

### Size Selective Inlet

Follow the manufacturer's procedures for installation and optimum sample flow rate, when using a size selective inlet.

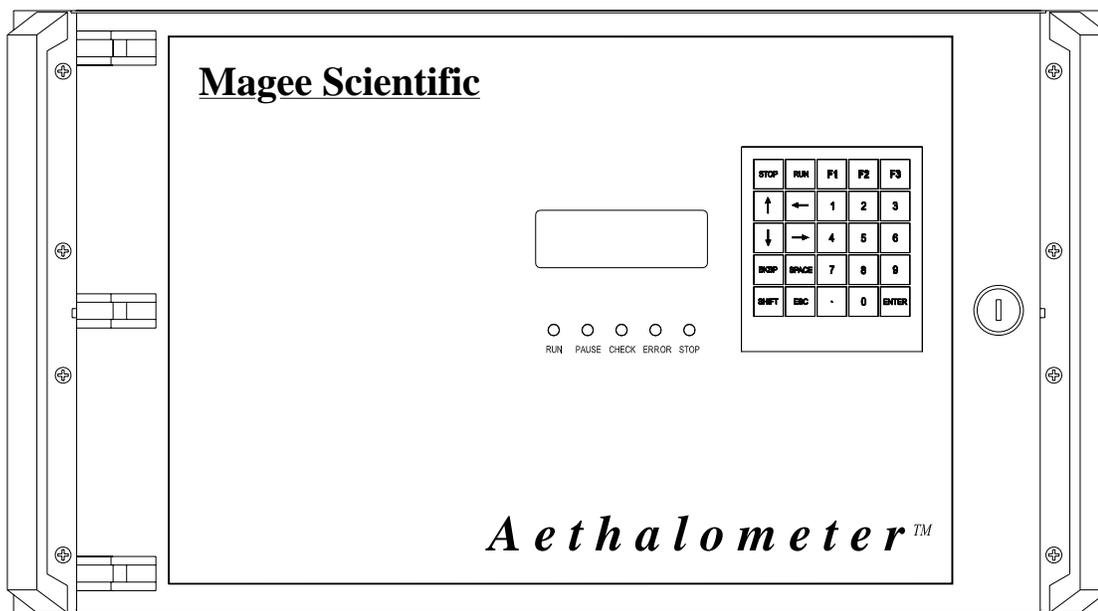


Figure 1  
Aethalometer Front Panel

## 2.5 Software Set-Up:

Main Menu Overview: The opening screen displays an opening “Aethalometer” logo; the software version number; a countdown from 60 seconds for the automatic start; and the prompt to “Press Any Key for Main Menu”.

The Main Menu offers the following selections:

- Operate
- Change Settings
- Signals + Flow
- Self Test
- Calibrate Flowmeter
- Software Upgrade
- Optical Test
- Install New Tape

- 2.5.1 Operate: This option of the Main Menu allows for automatic operation or for manual input while preparing the instrument to sample. The first screen display asks “**Go To Auto Mode?**” The default response **Y** is displayed. If **ENTER** is pressed, the instrument immediately proceeds with fully-automatic operation, and no further operator interaction is required.

If **N** is selected with the down-arrow key, and **ENTER** is pressed, the program provides the following interactions:

The program asks the user if new titles should be read (e.g. for a new study name or sampling period). These titles will appear in the ‘MF’ message files. To enter new titles, use any plain-ascii text editor to write two separate lines title1 and title2 in a text file TITLES.TXT, and insert into the floppy disk drive or the solid-state memory drive, at the prompt. These titles will be saved for future sampling periods. The program prompts the user whether the data disk or the solid-state memory drive, should be replaced, even if it is not full yet. Note that the option “**Overwrite Old Data**”, if set to **YES** in the Change Settings menu, will simply overwrite the oldest data when the disk or the solid-state memory card drive becomes full.

The screen will show a Flowrate display. This allows the operator to verify the air flow rate desired. The air flow rate is checked after a 30-second countdown that allows the flow meter to stabilize. The flow rate display provides an opportunity for the flow rate to be adjusted. If the flow rate is acceptable, press any key. Titles confirmation, “Title 1” ; “Title 2” .. “Retain Old Titles” / “Read New Titles”. This allows new titles to be uploaded.

Measurements will start automatically after the following two screen displays:  
“Advancing tape, wait”  
“Waiting for start time”.

The screen displays a countdown to start of the next integral time base period.

2.5.2 Change Settings: This menu allows the system settings to be changed according to the user's needs. The following parameters may be altered:

Time & Date: This menu allows the user to change the current time and date. If the date is changed, the time must be re-set also. Use the left-arrow and right-arrow keys to position the cursor over the item to be changed. Use the up-arrow and down-arrow keys to change the value. Note: The new time value is not written until the change menu is completely exited and saved. It is advisable to set the time to the next minute with zero seconds, exit the change menu to the point of “Write System Settings?”, and press ENTER at exactly the actual minute roll-over. **AQSB operates equipment on Pacific Standard Time (PST) year round.**

Flow Rate: Usable range 1 – 6 LPM. This allows the user to set the sample air flow rate in standard liters per minute (SLPM). On units with the internal pump, the computer and electronics automatically control the variable-speed pump to maintain the desired flow rate based on the signal from the air mass flow meter. **AQSB operates Aethalometers at 5 lpm to meet size selective inlet requirements.**

Time base: Valid values: 1 sec - 60 min. This defines the time period over which the aerosol is collected and analyzed. At the end of each time base, the data is written to disk and the display is updated. **All AQSB operated Aethalometers will use a 60 min timebase.**

Tape Saver: Selections: ‘OFF’, ‘X3’, ‘X10’ This parameter controls the flow bypass valve to prolong the lifetime of each filter tape spot, and thus to reduce the consumption of tape in locations of high BC concentration. **All AQSB operated Aethalometers will use “OFF”.**

Analog Output Port: Selections: **SIGNAL OUTPUT / ALARM**. This function allows the analog voltage output connector either to provide a data output, for connection to an analog datalogger or chart recorder, or to operate as an alarm switch.

If **SIGNAL OUTPUT** is selected:

Output Scale Factor: Valid values:

1 - 100,000 (ng BC /m<sup>3</sup>) / V, when the BC Display Unit is set to ng/m<sup>3</sup>;

1 - 1000 (µg BC /m<sup>3</sup>) / V, when the BC Display Unit is set to ug/m<sup>3</sup>.

This parameter defines the scaling factor of the analog voltage on the

output connector that represents the measured black carbon concentration in "Signal Output" mode. This output voltage is swung to the value of -5 V to indicate "No Valid Data" during periods of instrument warm-up, operator intervention and menu selection, and also during the tape advance process. The analog output voltage is scaled with its factor from 0 to +5 V to represent data when it is valid.

If **ALARM** is selected: Alarm On/Off allows the alarm function to be enabled or disabled. Valid concentration values are 0.01 - 100,000 µg/m<sup>3</sup>. **All AQSB operated Aethalometers will use "OFF"**.

Analog Out Channel: This is used only on multiple-wavelength models (AE2- and AE3-), and selects which wavelength's data will be used to control the output of the analog port.

Warm Up Wait: Selections: YES / NO

If this parameter is set to "YES", the instrument displays optical sensing and flow voltages for 30 minutes at the start or restart of the program, before proceeding with automatic operation. Note: If the electrical power is interrupted even momentarily, 30 minutes of data loss will be introduced at every power-up automatic restart. **All AQSB operated Aethalometers will use "NO"**.

Communication Parameters: COM mode, COM settings.

This menu controls the activity of RS-232 port on the rear panel of the instrument.

'OFF' disables the COM port activity.

The COM Settings sub-menu sets the communications parameters:

BAUD (9600, 4800, 2400, 1200);

DATA bits (8 or 7);

STOP bits (1 or 2);

PARITY (None, Even, Odd).

**Note!** If DATA BITS is set to **8** then PARITY **must** be set to **None**.

**All AQSB operated Aethalometers will use "9600, 8, 1, N"**.

Overwrite Old Data: Selections: YES / NO. **All AQSB operated Aethalometers will use "NO"**.

If this parameter is set to "YES", then the instrument automatically overwrites the oldest files on the data disk when the disk becomes full.

Filter Change At: Valid values: 0-30 hours. **All AQSB operated Aethalometers will use "0"**. Set value to **0** to allow automatic filter tape advancing. This parameter affects the triggering of filter tape advances at fixed time intervals, if the 'Filter Change At' value is greater than zero. If the Filter Change At value **is set equal to zero**, then the tape is automatically advanced when optical saturation of the filter spot is

reached. If the Filter Change At value is **greater than zero**, then the tape is advanced only when the determined time period expires.

Security code: This allows access to the following protected functions:  
Exit from Operate to the Main System Menu after pressing the STOP key.  
Upload a software upgrade.  
Change certain 'protected' setup parameters.  
In all cases the user must enter the correct security code within 10 seconds. If this time-out expires, the program reverts to the previous menu item.  
The security code is initially set to **111** when the instrument is shipped from the factory.

Date Format: This parameter controls the conversion of the date to a 6-digit number for the purposes of constructing file names for the 'BC' and 'MF' files written to disk. The filename date is constructed as MMDDYY.

BC Display Unit: Selections: Nanograms / Micrograms  
This selects the concentration unit for the screen display. 'Nanograms' displays no decimal fractions (i.e. XXXX ng/m<sup>3</sup>) and is recommended for use in remote or unpolluted locations; 'Micrograms' displays 2 decimal fractions (i.e. XX.XX ug/m<sup>3</sup>) and is recommended for use in urban or polluted locations.

Data Format: Selections: Expanded / Compressed  
This option controls the format in which data is written to disk and sent to the COM port. In 'Expanded' format, the data record consists of numeric fields, each separated by commas. The file 'DATACOLS.CSV' is written to the floppy disk to identify the data columns for the various instrument options. Many of the columns represent internal signal parameters that are only required for performance verification: the measurement data of value to the user are represented by 'Date', 'Time' and 'Concentration'. In 'Compressed' format, the data record consists of a reduced number of columns. The first entries are 'Date', 'Time' and 'Concentration', while the following column(s) are string(s) of alpha characters whose coding represents all the internal signals. For routine operation, this codeword

may be discarded: it will appear as the final column(s) if the data is imported to a spreadsheet in '.CSV' format. If required, the codeword may be decompressed for instrument diagnosis using the 'COMDECOM' program available from Magee Scientific.

UV Channel ON/OFF:  
Selections: ON / OFF. **All AQSB operated Aethalometers will use "OFF"**.

Hardware Configuration: This allows the user to correctly specify the various hardware options, so that the software will function correctly. The sub-menu items are as follows:

Instrument Type (Optics)

Selections are:

'AE1x – Standard' (e.g. AE16 single wavelength, BC only) ;

'AE2x - UV+LED' (e.g. AE21 combination BC + UV absorption) ;

'AE3x - 7 x LED' (e.g. AE31 multiple-wavelength "spectral" measurement).

Maximum Attenuation: This allows the user to specify the maximum value of optical attenuation that defines the point at which an automatic tape advance is triggered. **All AQSB operated Aethalometers will use a Maximum Attenuation of 75.**

Return to Main: This concludes the *Change Settings* menu, and asks if the user wishes to save the changes by writing the parameters to an internal file.

- 2.5.3 Signals & Flow Display: This selection allows the user to check the optical signals and the flow meter response. It is useful for checking the optics or verifying a desired flow rate.

The lamp(s) may be turned ON and OFF by toggling the UP/DOWN keys. The lamp condition is shown on the right-hand side of the top line of the display screen as follows. AE2- and AE3- series instruments allow for testing of the additional lamps:

"Lamp=0" : lamp(s) OFF

"Lamp=1" : 880-nm lamp turned ON : "wavelength 1" BC measurement

"Lamp=2" : 370-nm UV lamp turned ON : "wavelength 2" UV measurement in AE-2 series instruments

"Lamp=3" to "Lamp=7" : other wavelength lamps turned ON for testing AE-3 series instruments.

- 2.5.4 Self Test: This selection activates a sequence of tests of the instrument hardware. The series of tests are performed automatically and any error messages are shown on the screen.

Lamp test: The lamp(s) are turned on and off, and measurements are made of the optical signals in the sensing and reference detectors. For multiple-source instruments, this procedure is repeated. Comparison of the signals allows for the following fault analyses:

LAMP is burned out (OFF all the time)

LAMP is ON all the time (electronics fault)

TAPE torn or ended (signals too large)

LAMP TEST PASSED.

Pump & bypass test: This test measures the air flow: the user is prompted to connect the pump (in case the instrument is configured for 'External Pump'). The air flow is calculated using the flow meter zero voltage and the flow scale factor that were set by the Calibrate Flowmeter routine. If the flow rate is smaller than 1 LPM, an error message is displayed. The flow rate is compared for both positions of the bypass valve, to make sure that it is not blocked in either position.

Analog output test: The analog output connector on the rear panel is presented with a sequence of voltages to allow an external data logger or alarm relay to be tested. The sequence is: V = 0 ; +1 VDC; +2 VDC; +5 VDC.

COM port test: This routine allows the user to test the transmission of RS232 code from the COM port on the rear of the instrument, in order (for example) to test communications with a data logger or other receiver. This routine first allows the user to change COM parameters (baud rate, etc.) if desired. The screen then prompts "ENTER to send data". Press ENTER to transmit one data line using the COM parameters. This may be repeated as often as desired. Press ESC to escape.

Screen test: This routine tests the display screen as follows:  
All LED's are turned ON.  
All LED's are FLASHED.  
All LED's are turned OFF.  
The screen is filled with characters.  
The screen backlight is turned OFF.  
The screen backlight is turned ON.

Tape advance test: The tape feeder is activated: the user is prompted to watch the mechanism to verify correct operation. A countdown timer indicates the approximate duration of the test.

#### 2.5.5 Calibrate Flowmeter:

**The program first allows the user to switch between 'Standard' and 'Volumetric' flow units. Select Standard Units to report the air flow rate as SLPM, i.e. volume occupied by a given mass of air at a temperature of 20°C and a pressure of 1013 mb. (If 'Volumetric' flow units are selected, it is necessary for the barometric pressure and ambient air temperature be entered by the user – they are not measured by the instrument). If not measured the Aethalometer cannot control volumetric flow.**

#### Flowmeter Re-Calibration:

Only perform this re-calibration if you have reason to believe that the flow meter response is incorrect. This is 'protected' and requires the Security Code as a

password. This procedure calibrates the flow meter response by measuring the flow meter zero voltage and determining the flow scale factor. These two factors are used during measurements to calculate the actual air flow through the flow meter.

You will need a standard external flow meter or calibrator capable of reading air flow rates in the range of 2 to 10 slpm, with a low resistance to flow. Connect this calibrator firmly to the Sample Inlet Port with no possibility of an air leak. . Allow the instrument to warm up for at least 30 minutes with power and air flow 'on', before performing the re-calibration.

Aethalometers with an **internal** pump are controlled by a microprocessor and electronics, and this allows the program to set 'zero' and 'span' flows. All that is required of the operator is to connect a standard external flow calibrator, and observe its reading.

The routine first automatically reduces the pump speed slowly to zero, while measuring the signal from the internal flow meter. When this has reached a steady low value as determined by no more change in voltage output, the value of the reading is used as the flow meter zero voltage. The pump is then re-started and run up to its previous speed. When the flow meter signal is steady, the screen displays the flow rate in liters per minute derived from the new zero and the previous scale factor. By pressing the keypad UP- and DOWN-arrow keys will change the flow scale factor. Press these keys until the displayed value agrees with the measurement from the external calibrator. Press ENTER when the displayed value is correct.

On Aethalometers with an **external** pump, close the external valve to bring the flow rate to zero. Compare the displayed value of flow with the actual value as measured by the external standard. Open the valve to set the flow. Compare the displayed value of flow with the actual value as measured by the external standard. By pressing the keypad UP- and DOWN-arrow keys will change the flow scale factor.

Press these keys until the displayed value agrees with the measurement from the external calibrator. Press ENTER when the displayed value is correct.

Upon return to the main system menu the user is asked to confirm writing the newly measured response factors to the setup file. The previous flow calibration values are not replaced until this confirmation is made. In case of any doubt, repeat the procedure.

#### 2.5.6 Software Upload

This is a 'protected' function and requires the Security Code as a password. The Software Upgrade selection provides a convenient means to load new software

from floppy disk.

### 2.5.7 Optical Test Procedure

This is a 'protected' function and requires the Security Code as a password. This procedure performs a routine QC/QA check on the correct operation of the photodetectors, whose signals are the fundamental basis of the measurement. It uses the Optical Test Strip provided with the instrument. **Do Not Lose This Strip! Keep the Test Strip Clean, Flat and Smooth !** Contact Magee Scientific if a replacement is required, but be informed that the test is only relevant when repeatedly performed with the same test strip.

The Optical Test Strip consists of laminated material whose optical density at one end is greater than that at the other. The test procedure automatically determines the optical densities measured by the photodetectors, and writes the results to disk as a user-friendly ASCII text file. The significance of the test is to verify that the photodetectors output remain constant over time, i.e. from one test to the next. The actual numerical values of the calculated parameters are intrinsically meaningless: it is their constancy when measuring the same test strip that assures consistent performance of the instrument. The Optical Test Procedure guides the user through the various actions that are necessary, with prompts on the display screen.

The Optical Test Strip has a serial number printed at one end that should match the serial number of the instrument. Enter this number when prompted. Check that there is a floppy disk in the disk drive.

Open the door, and remove the two thumb screws that secure the rectangular metal cover over the sampling chamber in the center of the instrument. This provides access to the area where the filter tape passes through the analysis system.

Cut the filter tape on the left side of the chamber with scissors. Press ENTER when prompted. The remaining tape will be pulled out onto the right-hand spool. When prompted, insert the test strip from the left-hand side. Its printed serial number should be facing upwards on the right-hand side. Push it in from the left until the tip of the arrow printed on it is just visible in alignment with the edge of the base block. Press ENTER when ready.

The first phase of the test will proceed automatically: the lamp will turn ON and OFF to determine the optical transmission signals for the 'front' portion of the test strip.

At the end of the first set of measurements, the transmission values will be displayed. It is not necessary to write them down, as they are saved to disk. Press ENTER to proceed. The mechanism will go through three tape-advance

cycles in order to pull the test strip forward, taking approximately 5 minutes. The second phase of the test will cycle the lamps again and measure the optical transmission signals for the 'rear' portion of the test strip. The program will then calculate the quantities 'S Density', 'R Density', and 'Balance'. The signals, results and other information will be written to a file on the disk under file name 'OTxxxxxx.TXT' where 'OT' represents Optical Test, and 'xxxxxx' is the date.

This text file provides the definitive report on the optical transmission signals and the balance between the Sensing and Reference signals. This text file should be printed out and saved. The display screen will then prompt the user to re-insert the filter tape from the left-hand side. After pulling it through, re-attach it to the tape on the right-hand take-up spool. Replace the rectangular metal cover with its two thumb screws.

#### 2.5.8 Install New Roll of Tape:

This is a 'protected' function and requires the Security Code as a password. The display screen shows an estimate of the percentage of the tape roll that remains: when this falls below 10%, the 'Check' lamp on the display panel will be lit.

The menu item 'Install New Tape' contains an option to display an abbreviated set of sequential instructions with prompts. This not only guides the user through the necessary steps, but also re-sets the tape percentage counter to 100%. For this reason, the software procedure must be used when installing a fresh roll of tape, even if the user is very familiar with the procedure.

The first screen asks '**List Instructions ?**'. If **NO** is selected, the instrument assumes that the operator is familiar with the tape installation procedure, and will not require guidance. The software skips the detailed instructions, re-sets the tape counter to 100%, and returns to the Main Menu.

If **YES** is selected, the display screen guides the user through all the operations required for changing the tape. After each phrase, the user must press any key to proceed to the next:

- (a) Remove spool screws
- (b) Remove cover screws
- (c) Pull out guide rod
- (d) Cut old tape
- (e) Remove supply roll
- (f) Remove take-up roll
- (g) Install new roll
- (h) Lift up chamber 2 mm
- (i) Push tape through
- (j) Lift up chamber 2 mm

- (k) Pull 10 cm tape
- (l) Install take-up hub
- (m) Clip tape to hub
- (n) Push in guide rod
- (o) Replace cover
- (p) Replace spools
- (q) Tighten spool screws

The screen then asks: 'Is the tape properly replaced?' Entering **YES** will re-set the tape counter to 100% and concludes the process.

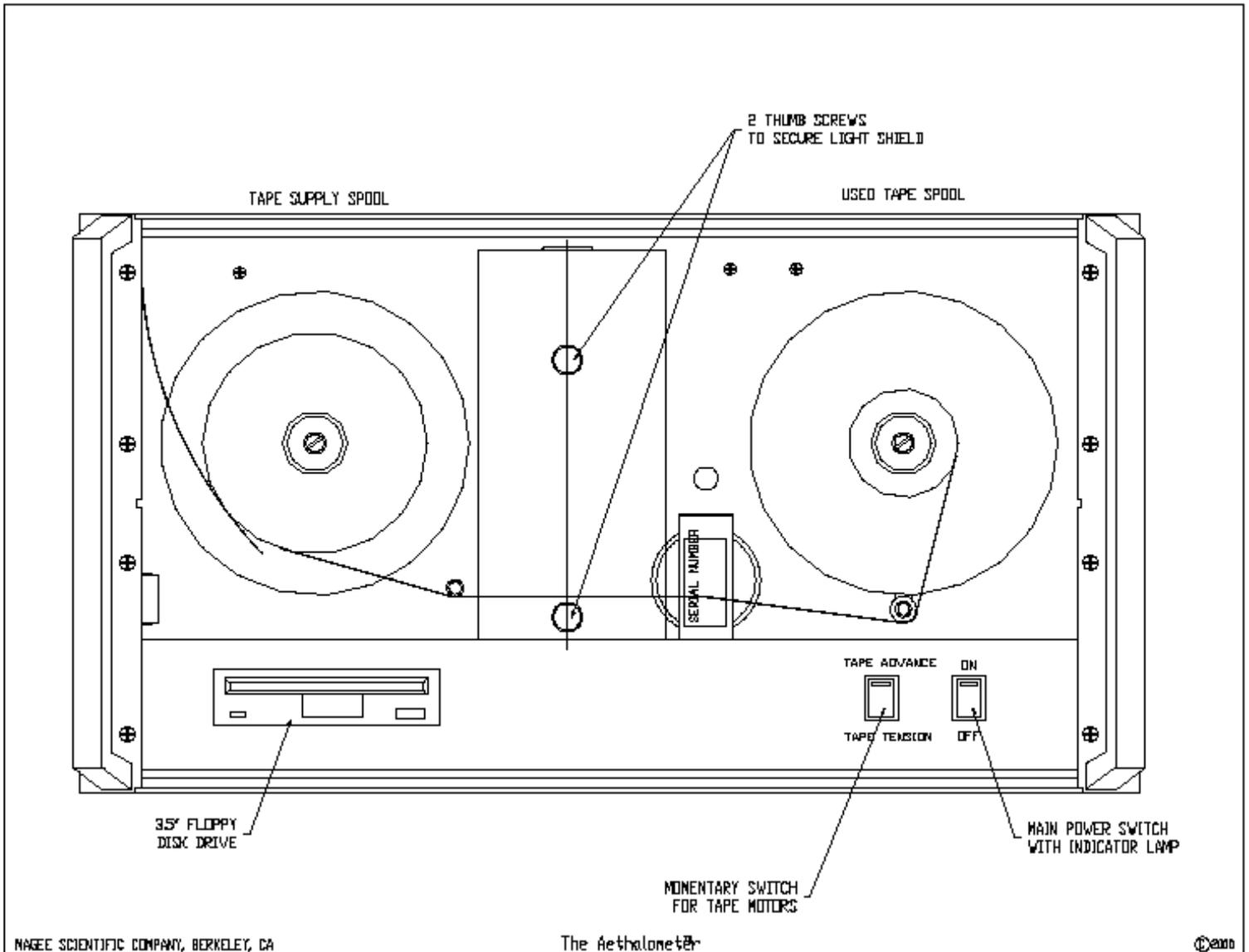


Figure 2  
Front View Interior

## 2.6 Datalogger Connection:

Analog Output Port – Selections: **SIGNAL OUTPUT / ALARM**. This function allows the analog voltage output connector either to provide a data output, for connection to an analog datalogger or chart recorder, or to operate as an alarm switch.

Select **SIGNAL OUTPUT**:

### Output scale factor:

1-100,000 (ng BC /m<sup>3</sup>) / V, when the BC display unit is set to ng/m<sup>3</sup>;

1-1000 (ug BC /m<sup>3</sup>) / V, when the BC display unit is set to ug/m<sup>3</sup>.

This parameter defines the scaling factor of the analog voltage on the output connector that represents the measured black carbon concentration in “Signal Output” mode. This output voltage decreases to the value of –5 V to indicate “No Valid Data” during periods of instrument warm-up, operator intervention and menu selection, and also during the tape advance process. The analog output voltage is scaled with its factor from 0 to +5 V to represent data when it is valid. Note that when BC concentrations are extremely low, instrumental noise can lead to computed values of BC that are slightly negative. These noise values will be presented as slightly negative analog output voltages, but still represent valid data.

The analog voltage output range is –5 to +5 volts DC. It has 3 modes of operation. The operator can choose between “Signal Output” and “Alarm” in the software setup. The –5 volt “Data Not Valid” flag is always active.

### **WARNING**

In the Aethalometer Book 2005.07, Section 15.2.1 Analog Output Port Principle states that when the analog output port is connected to a D/A converter operated by the embedded computer; **“It is intended as an indicative signal voltage output only. It is not intended to be the primary definitive data output of record”**. “Primary definitive data is the digital data either on diskette or transmitted by the COM port”. See Appendix C, Example of a Typical Data File.

### **3.0 CALIBRATION INFORMATION**

#### **3.1 Calibration Introduction:**

The purpose of this section is to outline the Magee Scientific Aethalometer calibration procedures used by the Air Quality Surveillance Branch (AQSB) of the California Air Resources Board (ARB).

The Magee Scientific Aethalometer Operation Manual is an important resource of information, and the AQSB recommends a thorough review of the manual before calibrating the instrument. Under normal operating conditions, the Aethalometer should not need to be calibrated. The internal mass flow meter has been calibrated at the factory and re-calibration should only be performed if the flowmeter response is more than +/-10% of set flow. NOTE: If size selective inlet is used, refer to manufacturers flow tolerances. A calibration report is required when installed and when verified/calibrated.

#### **3.2 Calibration Overview:**

This procedure calibrates the flowmeter response by measuring the flowmeter zero voltage and determining the flow scale factor. These two factors are used during measurements to calculate the actual airflow through the flowmeter. An external flow-measuring device, which is traceable to a National Institute of Standards and Technology (NIST) primary standard, is used to calculate the actual airflow of the instrument. The instrument response is then adjusted until the internal flowmeter is reading the actual flowrate.

#### **3.3 Calibration Transfer Standards and Equipment:**

Standard external flowmeter capable of reading air flow rates in the range of 2 to 10 slpm, with a low resistance to flow, traceable to a primary standard such as NIST.

#### **3.4 Calibration Procedures:**

If the instrument incorporates an internal pump, it will be necessary to remove six screws securing the rear cover plate; open the rear cover; and disconnect either the suction connection or the electrical plug to the internal pump.

If the instrument incorporates an external pump, disconnect the airflow.

Wait for the flowmeter to settle to a zero level. After a short time, the flowmeter zero voltage is measured. Reconnect or restart the airflow, and set a flow rate that is verified by a standard external flowmeter.

The flowmeter voltage is measured again, and an estimated airflow is calculated using the flowmeter zero voltage and the previous flow scale factor. The

displayed value of air flow must then be changed by the keypad arrow keys in increments of 0.1 LPM until it equals the actual flow measured by the external standard. In this way the flow scale factor is updated. The default value of the flow scale factor is set to 2.0 LPM/V.

### 3.5 Optical Test Strip:

Use of the Optical Test Strip is a simple means of verifying the ratiometric performance of the photodetectors as part of a routine QA/QC program.

### 3.6 Optical Test Strip Procedure:

Refer to section 2.5.7 of this document for optical test procedure. Six signals are measured during the Optical Test Strip procedure. These signals are denoted SEN0, REF0, SEN1, REF1, SEN2, REF2.

The following quantities are calculated using natural logarithms:

$$\text{Sensing Beam Test Value} = 100 * \ln((\text{SEN1}-\text{SEN0})/(\text{SEN2}-\text{SEN0}))$$

$$\text{Reference Beam Test Value} = 100 * \ln((\text{REF1}-\text{REF0})/(\text{REF2}-\text{REF0}))$$

$$\text{Optical Test Ratio} = (\text{Sensing Beam Test Value})/(\text{Ref. Beam Test Value})$$

These test values should be positive numbers in the region of 30 to 50, depending on the individual Optical Test Strip itself: The Optical Test Ratio should be close to unity.

It is important to ensure that the numbers do not change appreciably over time. Changes from measurement procedure to the next should be less than 10 % of the test values, less than +/- 0.1 in the Test Ratio. If these specifications can not be met, contact Magee Scientific for further instructions.

The Aethalometer operation manual should be consulted for specific procedures regarding the Optical Test Strip.

## 4.0 ROUTINE SERVICE CHECKS

### 4.1 General Information:

Perform the following service checks according to the procedures documented in this section. Routine service checks may be performed more frequently, but should be performed at least at the prescribed intervals. All field data sheets should be filled out accordingly and stored in an appropriate place. These sheets would be used to validate data.

### 4.2 Daily Checks:

Review data to ensure instrument is operating properly.

### 4.3 Weekly Checks:

Check the system date and time on the Aethalometer. The time should be within five (5) minutes of the external data logger.

Check the sample flow on the Aethalometer display and record value on the checksheet. Ensure sampler flow as displayed is within 0.2 lpm of previous week.

Check the filter tape supply and re-tension the tape roll take-up spool if needed.

### 4.4 Monthly Checks:

Perform flow verification with an independent flowmeter and recalibrate as necessary.

Clean inlet cyclone.

Label and replace 3.5" floppy diskette or solid state memory drive.

### 4.5 Semi-Annual Checks:

Perform Calibration, Optical Test Strip procedures and Self Test.

### 4.6 Annual Checks:

Clean or replace sample inlet probe line.

Remove and clean optical sampling and analysis cylinder as outlined in the instrument operation manual.

AQSB MONTHLY QUALITY CONTROL MAINTENANCE CHECK SHEET 407  
Magee Scientific Aethalometer

Location: \_\_\_\_\_ Month/Year: \_\_\_\_\_  
 Station Number: \_\_\_\_\_ Operator: \_\_\_\_\_  
 Analyzer Property Number: \_\_\_\_\_ Agency: \_\_\_\_\_

Date	Weekly Checks		Monthly Checks		
	Flow Display	Correct Time/Date	Standard Flow (LPM)		Inlet Cleaned
	LPM	Yes or No	Pre-Cal	Post-Cal	Yes or No

Operator Instructions:

- 1) Daily Checks: Review daily data. Verify Aethalometer status and there are no error messages.
- 2) Weekly Checks: Assure sampler flow on display reads to within 0.2 lpm of previous week. Verify time and date is within five (5) minutes of datalogger.
- 3) Monthly Checks: Check flow with standard. Recalibrate as necessary. Clean inlet cyclone. Label and replace 3.5" diskette or solid state memory drive.
- 4) Semi-Annual Checks: Perform Calibration and Optical Test Strip procedures. Perform Self Test.  
 Date of last calibration: \_\_\_\_\_ Date of last Self Test: \_\_\_\_\_
- 5) Annual Checks: Clean or replace inlet probe line. Date last cleaned: \_\_\_\_\_  
 Determine residence time: \_\_\_\_\_ seconds (not to exceed 20 seconds).

Date	Comments or Maintenance Performed

Reviewed by: \_\_\_\_\_ Date: \_\_\_\_\_

Appendix A  
 Monthly Quality Control Maintenance Check Sheet

## ARB Calibration Report - Aethalometer

Magee Scientific Aethalometer

Includes Mass Flow Meter (MFM), FTS Streamline and BGI Delta/Tri Calibration

**ID Information:**

<b>Station Name:</b>	Station		<b>As Is:</b>	
<b>Site #:</b>	00-000		<b>Final:</b>	X
<b>Property #:</b>	20000000		<b>Calib. Date:</b>	07/17/07
<b>Agency:</b>	ARB		<b>Last Cal:</b>	02/18/07

**Transfer Standard:**

<b>slope (m) :</b>		<b>Intercept (b):</b>		
True Flow. =	1.00	* Display +	0.00	Flow Std. ID#:
				Flow Cert.Date:

<b>Flow Controller Check</b>	<b>Pass/Fail</b>
14.0 LPM:	
17.5 LPM:	

<b>Flow Device Used:</b>	<b>MFM</b>
	FTS
	BGI

**Flow Calibration:**

			<b>MFM Flow:</b>	<b>FTS Flow:</b>	<b>BGI Flow:</b>
Aethalometer Flow Display:	Std. Display:	Standard Flow:			5.00
5.00	5.00	% Diff.:			0.0%

Flow Calibration (5.0 L/min +/- 5% = 4.75 to 5.25 L/min):

**Flow Verification:**

			<b>MFM Ver.:</b>	<b>FTS Ver.:</b>	<b>BGI Ver.:</b>
Aethalometer Flow Display:	Std. Display:	Standard Flow:			
		% Diff.:			

Flow Calibration (5.0 L/min +/- 5% = 4.75 to 5.25 L/min):

<b>Comments:</b>			
<b>Calibrated by:</b>		<b>Checked by:</b>	

Thermo  
 Environmental Instrument Serial No. 636 Operation Mode: BC (AE-  
 Aethalometer 16)  
 Channel (1) = white

date	time	conc	flow	sz	sb	rz	rb	fraction	attenuation
1-Oct-07	0:00	279	4.9	0.0212	2.1818	0.0212	2.3426	1	27.789
1-Oct-07	0:05	204	4.9	0.0212	2.1777	0.0212	2.3426	1	27.974
1-Oct-07	0:10	805	4.9	0.0212	2.1619	0.0212	2.3424	1	28.703
1-Oct-07	0:15	280	4.9	0.0212	2.1565	0.0212	2.3424	1	28.956
1-Oct-07	0:20	274	4.9	0.0212	2.1512	0.0212	2.3424	1	29.205

A typical line in the data file might look like:

**“01-Oct-07”, “00.00”, 279, 4.9, 0.0212, .2.1818, 0.0212, 2.3426, 1.00, 27.789**

*“date”, “time”, (**conc**)BC concentration (ng/m3), (**flow**) air flow (LPM), (**sz**)sensing zero signal, (**sb**)sensing beam signal, (**rz**)reference zero signal, (**rb**)reference beam signal, (**fraction**)bypass fraction, (**attenuation**)optical attenuation*

Note that the recorded time corresponds to the starting time of the measurement cycle.

Only the date, time and black carbon concentration are used in normal circumstances: namely the **first three columns** of data as shown **bold** in the above example. The other columns of data only verify correct operation of the instrument. For this reason, the data may also be written in a ‘*compressed*’ mode which preserves the diagnostics but in a more compact form: