Magee Scientific Aethalometer® Model AE33
Maintenance Procedures Guide

Version 1.01

This guide is for users of the AE33 Aethalometer at NOAA observatories. It is intended to supplement the manufacturers AE33 user's manual and provide more detailed instructions on standard maintenance routines for the instrument.

February 2021
Lauren Schmeisser and Betsy Andrews
NOAA Boulder, CO

Photo credits: Will von Dauster, NOAA, Boulder, CO

Table of Contents

MAINTENANCE SUMMARY

The Aethalometer needs to be maintained regularly through instrument performance checks and calibrations. These maintenance tasks will help ensure that the instrument is running properly and output data are not being affected by instrument malfunction. The table below presents a list of maintenance tasks, as well as how often each check should be done. In the following sections, each maintenance check is described in detail.

Maintenance Check	Frequency of Check
Check instrument status – make sure there is a green checkmark	Daily
Check percentage of filter tape left (Install new filter tape roll if needed)	Daily (less often at SPO)
Inspect sample line tubing for kinks and bends	Monthly
Inspect and clean insect screen	Monthly
Verify time and date (correct if necessary)	Monthly
Delete files from compact flash card	Monthly
Inspect optical chamber (clean if necessary)	Biannually
Flow check (flow verification, flow calibration)	Biannually
Clean air test	Biannually
Stability test	Biannually
Leakage test	Biannually
Inlet leakage test	Biannually
Overnight filtered air test	Annually
Tape sensor calibration	Annually
Neutral density filter test[1]	Annually
Lubricate optical chamber sliders	Annually
Check bypass cartridge filter (change if necessary)	Annually

[1]Currently we don't have Neutral Density filters so this test cannot be performed.

Check instrument status

Each day, site personnel should look at the front panel of the instrument to check the status. The lights on the front of the instrument and the screen saver will give a first initial indication of instrument status- the green light or flashing green light will mean the instrument is running without any issues, a yellow light will mean that the instrument is measuring, but some issue may need to be addressed, and a red light will mean that the instrument is not measuring and some maintenance and/or troubleshooting procedures are necessary to get the instrument functioning again. If the instrument is plugged in and on, but the screen is black, then it is likely that a fuse needs to be replaced (check the Fuse Replacement section for more details). Additionally, the user should check to make sure the AE33 instrument is communicating with the data acquisition system. To check communications, open the AE33 module on CPDclient (the blue screen on the aerosol system laptop). If the AE33 is not communicating there will be flashing red text saying 'NO COMMS' in the AE33 CPD window.

Install new tape filter roll

A new tape filter roll must be installed as needed. The tape sensors on the instrument can detect how much tape is left on the un-roll and roll-on spools, but this can also be gauged by eye if the un-roll spool (left spool) is almost out of filter tape. When nearly all of the spots on the tape filter have been used, the instrument will notify the user with a decimal status flag of 128 or 256 on the HOME screen, which indicates that less than 30 spots or 5 spots remain, respectively. To install a new tape roll, AE33 measurements must be stopped by pressing the *Stop* button in the OPERATION menu under the GENERAL tab. Then, in the OPERATION menu under the ADVANCED tab, press *Change tape*, and follow the instructions on the screen. The screen will notify the user when the chamber has been lifted, and then will prompt the user to change the tape. The tape is changed by first removing the transparent plastic cover from the fronts of both the un-roll and roll-on spools, then removing the old tape roll (see Figure 1). The fresh roll of tape can be placed on the left spool (the un-roll spool), with the loose end coming up over the roll and to the left (i.e., counter-clockwise). Then, the loose end of the tape roll is taped onto the cardboard spool that goes on the right, roll-on side, with the loose end going under the spool and then around on the right hand side of the spool (i.e., counter-clockwise). After both spools are replaced, make sure that the tape is fed beneath both the left and right tension posts, and repositioned beneath the optical chamber as shown in Figure 1. Replace the transparent plastic covers for both sides, and screw on firmly. The left spool (the un-roll spool) should roll freely. The right spool (roll-on spool) should not move. Close the door and press OK on the screen. The chamber will return to its initial position, and then the screen will say the tape change is finished. Press OK on the screen again to acknowledge the message.

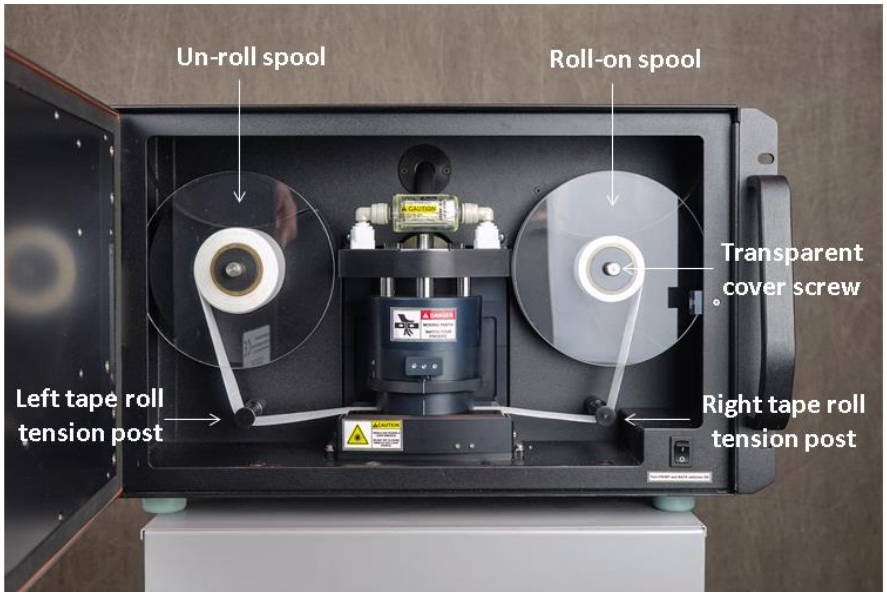

Figure 1. Components of AE33 used when changing the filter tape roll

IMPORTANT: Make note of the type of new filter tape installed. The AE33 instrument is programmed to handle Pallflex Teflon-coated glass fiber filter (TFE) tape, measuring 30 mm wide by 30 feet long. This is different from filter tape used in the legacy Aethalometer models, and the two filter tape types should not be interchanged!

In addition, it is important to record the type of tape installed in the instrument, particularly because this might affect how the data are processed and corrected after collection. Magee Aethalometer part no. 8020 tape was most commonly used prior to 2020, and more recently Magee Aethalometer part no. 8060 tape is recommended instead. Please record the model number of the tape in the message log when replacing. It is also important to run a leakage test on the new tape to see if the leakage factor 'Z' has changed – see section on Leakage Tests. Do not change the 'C' parameter from the set 1.57 value.

Inspect sample line tubing

On a monthly basis, check integrity of sample line tubing. Inspect to make sure the tubing is still connected firmly to the inlet and outlet ports. Ensure that the tubing is conductive and there are no kinks or unintended bends in the line. Check for wear or cracking in tubing, and replace if needed. If tubing replacement is needed be sure to stop the measurement by pressing the *Stop* button in the OPERATION menu under the GENERAL tab. If the inside of the tubing looks dirty, the tubing can be cleaned by disconnecting from the sampling system, rinsing the insides with ethanol, drying thoroughly, and reconnecting to the instrument.

Inspect and clean insect screen

On a monthly basis, inspect the Aethalometer's insect screen (if one is installed on the system). Once instrument measurements are stopped, the bug trap can be inspected by disassembling, checking for any trapped bugs, debris, or water, cleaning if necessary, and replacing. The screen can be cleaned with ethanol and a wipe, though care should be taken to ensure the insect screen is dried thoroughly before being returned to its normal operating position. Remember that if water ingress is possible at the site, the bug screen should be mounted horizontally in the sampling manifold.

Verify time and date

Every month, check the time and date in the OPERATIONS menu under the GENERAL tab (see Figure 2). This is necessary in case data need to be manually downloaded from the instrument and aligned with data logged by the data acquisition system. The time should be consistent with current UTC time, which will likely differ from the local station time. If the date and time differ from UTC by more than 1 minute, then set the correct UTC time and date in the OPERATIONS menu under the GENERAL tab. Alternatively, the date and time can be set by sending a command through the serial port ($AE33:TyyyyMMddHHmmss, where yyyy is year, MM is month, dd is day, HH is hour (24), mm is min and ss is second). Ensuring that the date settings are accurate is important in case data need to be downloaded directly from the instrument as a supplement to data logged on the data acquisition system.

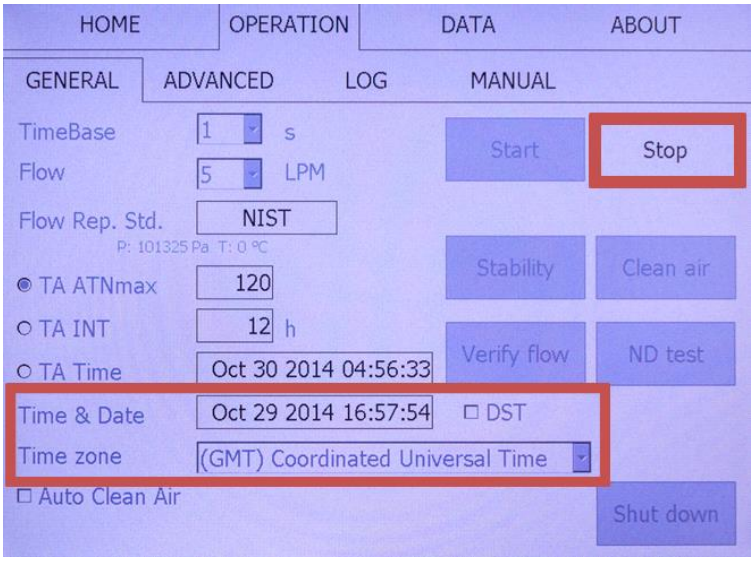

Figure 2. Verify time and date in the OPERATIONS menu under the GENERAL tab

When verifying the date and time settings on the AE33, it is also advisable to check to make sure that the timebase setting matches the actual timebase at which the data are reported. This can be done a

few ways: (1) Check and see if the TimeBase setting in the OPERATION menu under the GENERAL tab matches the timebase reported on the HOME screen, (2) Watch the instrument-reported readings on the HOME screen and see if they match the TimeBase setting in the OPERATION menu under the GENERAL tab (it is easy to tell if the BC readings change every second on the HOME screen, or if they change every minute), or (3) Download and look at a raw data file from the instrument (under DATA menu and EXPORT tab) to see if the time step increments align with the timebase setting.

Delete data from compact flash card

The Aethalometer is supposed to overwrite old data on its CF card when the card is full. However, there have been instances in the past when the card fills up despite the intended functionality. If the card fills up, the data need to be deleted, which can be accomplished via two different methods. The preferred method is to delete the data via the instrument menu on the 'Data' tab. Wait an hour or so to make sure the instrument registers that the data have been deleted. If the instrument does not recognize the free space, shut down the instrument, remove the CF card (found in the rear, upper right, behind a cooling grill), and remount the CF card. Upon restarting, the instrument should recognize the free space. If the primary method does not work, you can shut down the instrument, remove the card (found in the rear, upper right, behind a cooling grill), and delete data files manually from a computer. In order to avoid data loss, it is advised to proactively delete the data on the CF card every 3-6 months. When data from the CF card are deleted, please note this in the log.

Inspect optical chamber

Inspection of the optical chamber should be done twice annually as regular maintenance. The optical chamber should also be inspected if data are uncharacteristically noisy. Inspecting the optical chamber will ensure that there is no dust or fuzzy particles that may be interfering between the light beam and detectors.

To inspect the optical chamber, the optical insert itself must be disassembled from the instrument. First, record a message in the message log stating the procedure, then stop the AE33 measurements by pressing the *Stop* button in the OPERATION menu under the GENERAL tab. Next, the optical chamber must be raised up off the filter tape. This can be done by manually squeezing firmly together the top and bottom of the optical chamber so that it moves upwards on its sliders (Figure 3), and locking the chamber in the up position by pushing in the metal latch (Figure 4). Once the optical chamber is lifted, it is advisable, but not mandatory, to remove the filter tape from beneath the optical chamber to keep it out of the way and prevent it from getting dirty or torn. To do so, unscrew the plastic cover from the roll-on tape spool, remove the tape spool, and slide the tape out from underneath the optical chamber. The filter tape roll can be placed to the side out of the way.

Figure 3. Squeeze the top and bottom of optical chamber once measurements are stopped to lift the optical chamber

Figure 4. Push in metal latch to keep optical chamber locked in lifted position

Once the optical chamber is lifted and latched, the optical insert can be removed from the bottom of the optical chamber. In its locked position, the white line on the bottom of the optical chamber is aligned with the white line on the front of the top of the optical chamber (see Figure 5). With the button on the front of the chamber pushed in (Figure 6 indicates location of button), the bottom of the chamber can be turned clockwise until the white line on the bottom of the chamber aligns with the white line on the left side of the top of the chamber (see Figure 6 and Figure 7). At this point, the optical insert will be

loose and can be removed from the optical chamber by gently pulling straight down, then out towards the user.

Figure 5. When the white lines on the optical chamber are aligned, the chamber is in locked position. Note that the optical chamber here is NOT yet lifted.

Figure 6. Push up button on front of optical chamber to unlock, then twist bottom bayonet clockwise to loosen

Figure 7. When white lines are aligned on the left, the bottom bayonet is loose and can be removed carefully

Inspect both sides of the optical insert for any dust, debris or grime (see Figure 8). If there is anything present that might be interfering with the light source or passage of light through the optical chamber, it should be removed. If necessary, the optical chamber and insert can be wiped clean with ethanol and a Kimwipe™. Additionally, inspect the area below the optical chamber that is usually beneath the filter tape – remove any dirt or debris.

Figure 8. Inspect optical chamber for dust or debris

To replace the optical chamber after inspection, reverse the previous steps: align the white line on the optical insert with the leftmost white line on the optical chamber, then twist counterclockwise until the white line on the bottom piece is aligned with the white line on the front of the optical chamber and the button on front 'clicks' back into place.

The filter tape roll can now be replaced to its normal operating position. The optical chamber can be manually returned to its home position by unlocking the top latch, and supporting the chamber while it lowers. Instrument measurements can now be restarted.

Flow checks

Flow checks consist of a flow verification procedure, followed by a flow calibration if necessary, and can be done manually with any suitable flow meter on site, as well as a manufacturer-supplied flow calibration pad.

Flow Verification

The flow verification procedure is done to ensure instrument-reported flow aligns with the true flow, as measured by a flow calibrator. If the flow verification results show a discrepancy in instrument reported flow and true flow that is greater than ~5%, flow calibration may be necessary. Flow verification should be performed every 6 months.

To begin flow verification, first stop the instrument measurements (press *Stop* in the OPERATIONS menu in the GENERAL tab), then go to the OPERATIONS menu in the GENERAL tab and press *Verify flow* (see Figure 9).

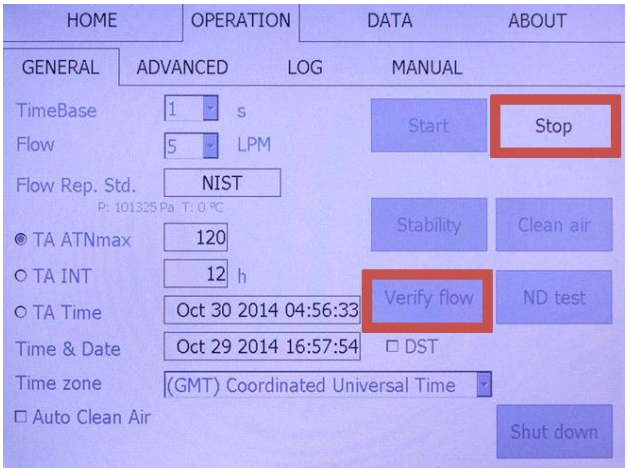

Figure 9. To begin flow verification, stop measurements and press verify flow in the OPERATION menu under the GENERAL tab

The next screen asks if automatic or manual flow verification will be performed. Since automatic flow verification requires a specific flow calibrator (not available at NOAA stations) that may not be available at all monitoring stations, it is recommended to continue with manual flow verification. This document only describes the manual flow verification method. More information on the automatic flow verification method is available through the manufacturer's user's guide. Select MANUAL (Figure 10).

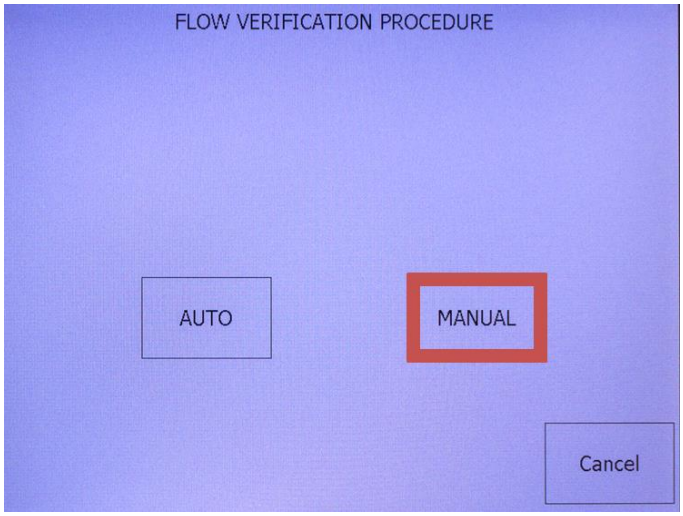

Figure 10. Select manual flow verification

The instrument will prompt the user to insert the calibration pad, and will also provide the option to 'Skip' this step if the calibration pad is already in place (i.e., Figure 11). If the calibration pad has yet to be placed, wait until the instrument has lifted the optical chamber, and then remove the screw and transparent cover from the right hand (roll-on) tape roll. Also remove the right hand (roll-on) tape roll from its post and gently pull the tape out from under the optical chamber. The left-hand (un-roll) tape can remain in its place, and the right-hand (roll-on) tape can be set aside out of the way of the optical chamber. With the optical chamber lifted and the tape removed, insert the calibration pad **with the notch facing the user**, as shown in the photos in Figure 12 and Figure 13. Press OK on the screen. The optical chamber will return to the home position.

Figure 11. The instrument will prompt the user to insert the calibration pad

Figure 12. Insert calibration pad beneath the optical chamber with the notch facing out towards the user

Figure 13. Calibration pad inserted beneath lifted optical chamber

Once the calibration pad is in place, press OK. The screen will prompt the user to wait for the chamber to move back to its home position, as seen in Figure 14.

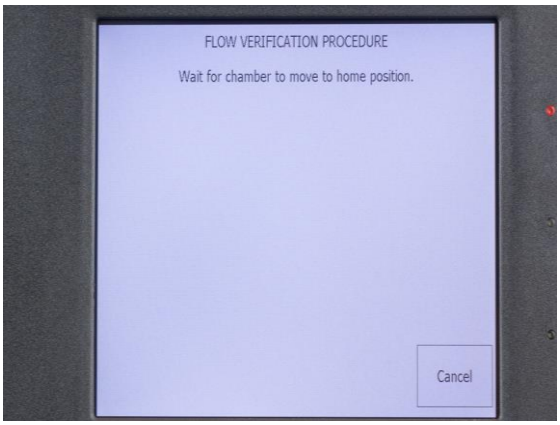

Figure 14. This screen prompts the user to wait to proceed until the chamber has returned to its home position

Now the flow calibration meter can be connected to the inlet of the instrument, as prompted. If the Aethalometer is sampling from a manifold with other instruments connected to it, once the AE33 is disconnected the AE33 connection port on the manifold needs to be plugged so no air from the laboratory enters the aerosol system manifold and affects the other instruments during the stability test. Once the meter is connected, press OK. The instrument screen will prompt the user to enter temperature, pressure, and flow rate measured by the external flow meter (Figure 15). **IMPORTANT: The flow meter reporting temperature and pressure settings need to be noted correctly – the aethalometer software will ask you for them**. The flow meter might report at standard conditions or at ambient conditions but regardless, in addition to a flow rate value, the flow meter also needs to report (or it must be known) at what temperature and pressure the flow was reported. The flow meter settings for reporting temperature and pressure are allowed to be different from the instrument temperature and pressure settings, because the instrument will adjust for this. However, this requires proper reporting of the flow meter temperature and pressure reporting values during the flow verification process. **Note Figure 15B where the aethalometer asks you to input the T and P of the flow measurement device. These values are not necessarily ambient T and P, depending on the sophistication of the flow measurement device.**

To input flow meter temperature, press the blank temperature box and a number pad will pop up where temperature can be entered in Celsius. Press OK. To input flow meter pressure, press the blank pressure box and a number pad will pop up where pressure can be entered in Pa. Press OK. To input the flow reading from the flow meter, press the blank flow box and a number pad will pop up where flow can be entered in mlpm. It is recommended that at least a triplicate reading be taken from the flow calibration meter before inputting the flow value into the instrument to ensure an accurate reading. **IMPORTANT: The external flow meter reading must be input as milliliters per minute (mlpm)**. After flow meter temperature, pressure, and flow are entered, press OK. The instrument will repeat this prompt 3 times (once for a low flow reading, once for an intermediate flow reading and once for a high flow reading (the instrument sets flow levels for each reading automatically)).

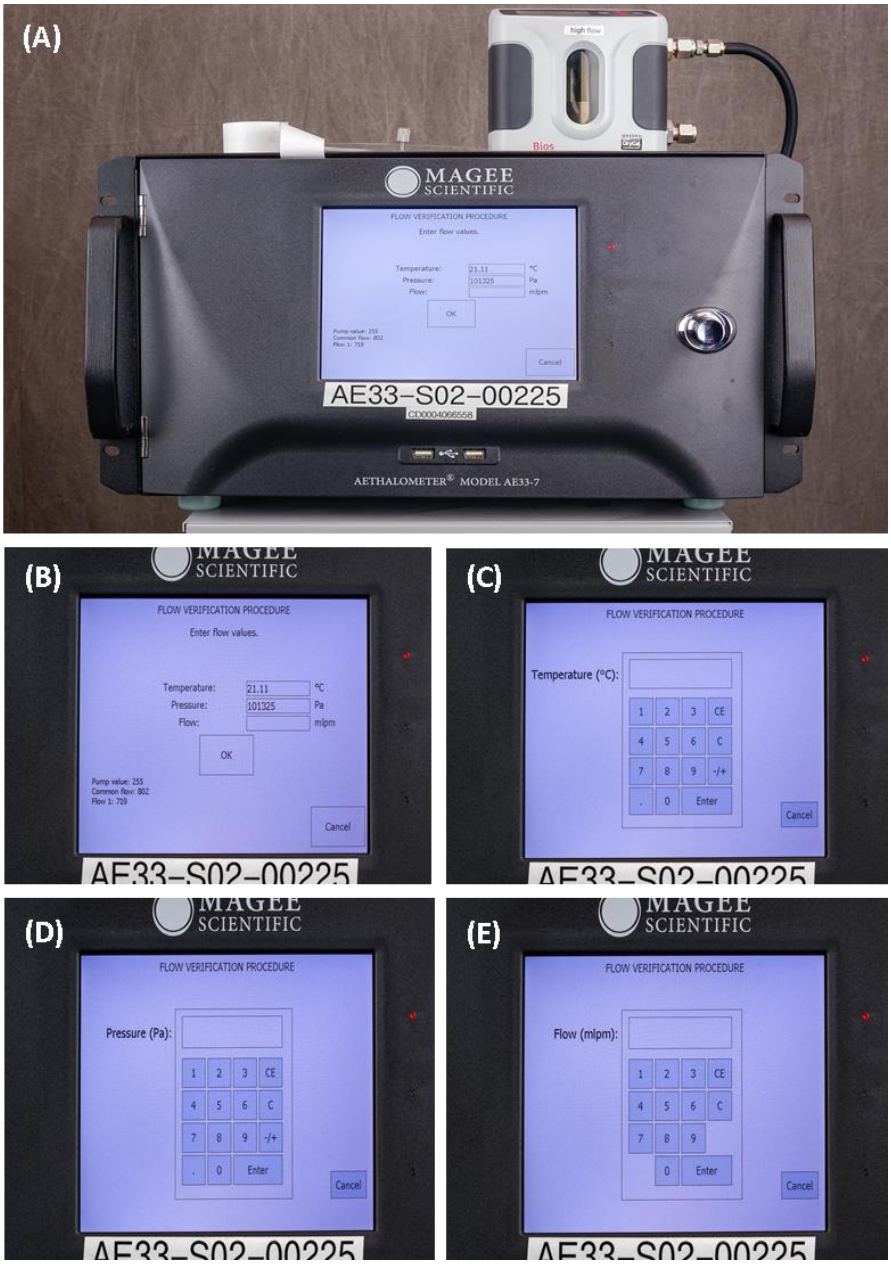

Figure 15. Flow verification procedure

IMPORTANT: When the flow verification procedure is finished, the flow calibration pad must be removed, the filter tape roll replaced to its normal operating position and the optical chamber returned to its home position.

When the procedure is finished, a table will appear with temperature, pressure, and flow values (Fin, F1 and Fc). Fin is the flow from the external flow meter used in the verification, Fc is the 'combined' (or 'total') flow, and F1 is the flow through Spot 1. The air flow is controlled by solenoid vales and during the flow verification test can be routed so that the entire inlet stream goes first through F1 and then through Fc. In this configuration, it is possible to calibrate both flow sensors simultaneously. If reported

flows differ by more than 5% near the instrument's normal operating flow rate range, then the instrument's internal flow meters need to be calibrated, and the flow calibration procedure (outlined in the next section) should be completed. If, for example, the measured flows differ by 10% at the low flow and only 1% at the high flow (which is closest to the normal operating flow rate of 5 lpm), then the user might decide that a flow calibration is not necessary. Flow calibration procedures should be avoided when possible, since it does introduce room for operator error. An example of a flow verification test report is below:

Manual flow verification report:
02 Oct 2014 14:41:54

External flowmeter measurement:

P	T	Fin
101325	25	886
101325	25	3000
101325	25	5000

Flow verification results:
Flow reporting standard: AMCA 101325 Pa 21.11 °C

Fin	F1	(%)	Fc	(%)
874	851	(97)	865	(99)
2961	2921	(99)	2933	(99)
4935	4880	(99)	4880	(99)

All results from flow verification tests are stored in the instrument's history and can be downloaded with the data by checking the box that says 'Copy Flow verification result' before pressing 'ExportToUSB' in the DATA menu under the EXPORT tab.

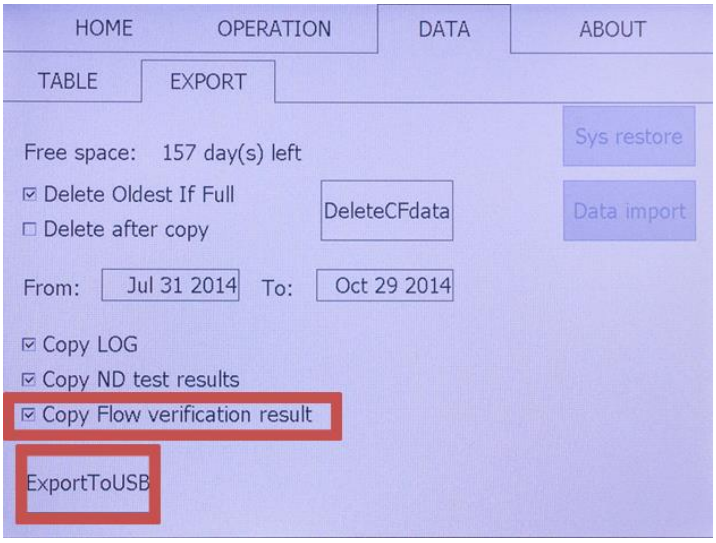

Figure 16. Flow verification results can be downloaded with data onto a USB stick

Flow Calibration

It is important to note that the flow calibration procedure should not necessarily be performed on a regular basis, rather it should only be done when needed. A flow calibration is only necessary if flow verification results show that the instrument-reported flow differs from true flow by greater than 5%.

First, make a note in the CPD message log that the calibration is being done. To begin flow calibration, the instrument operation must first be stopped – go to the OPERATIONS menu under the GENERAL tab and press *Stop*. Then, under the ADVANCED tab click *FlowCal*. Press MANUAL to start manual flow meter calibration and wait for the chamber to lift. Once the chamber is lifted, the filter tape can be removed (unscrew the transparent cover on the right roll-on filter tape side, then slide the tape out from under the optical chamber). Insert the calibration pad (see Figures 12 and 13), with the notch facing towards the user. With the calibration pad in place, press OK on the screen and wait for the chamber to move back to its home position.

IMPORTANT: The flow meter reporting temperature and pressure settings need to be noted correctly. The flow meter might report at standard conditions or at ambient conditions but regardless, in addition to a flow rate value, the flow meter also needs to report (or it must be known) at what temperature and pressure the flow was reported. The flow meter settings for reporting temperature and pressure are allowed to be different from the instrument temperature and pressure settings, because the instrument will adjust for this. However, this requires proper reporting of the flow meter temperature and pressure reporting values during the flow verification process.

Connect the flow meter to the Aethalometer inlet, making sure the orientation is correct (i.e., the flow meter is set up to measure vacuum), and press OK. If the Aethalometer is sampling from a manifold with other instruments connected to it, once the AE33 is disconnected the AE33 connection port on the manifold needs to be plugged so no air from the laboratory enters the aerosol system manifold and affects the other instruments during the stability test. It is recommended that at least a triplicate reading be taken from the flow calibration meter before inputting the flow value into the instrument to ensure an accurate reading. To input flow meter temperature, press the blank temperature box and a number pad will pop up where temperature can be entered in Celsius. Press OK. To input flow meter pressure, press the blank pressure box and a number pad will pop up where pressure can be entered in Pa. Press OK. To input the flow reading from the flow meter, press the blank flow box and a number pad will pop up where flow can be entered in mlpm. **IMPORTANT: The external flow meter reading must be input as milliliters per minute (mlpm)**. After flow meter temperature, pressure, and flow are entered, press OK. The instrument will repeat this prompt 3 times (once for a low flow reading, once for an intermediate flow reading and once for a high flow reading (the instrument sets flow levels for each reading automatically)).

When done, the chamber will lift, and the calibration pad can be removed and the filter tape reinserted and tightened. Press OK and wait for the chamber to return back to its home position. The AE33 instrument then automatically calibrates the instrument based on the user input flow information. The flow meter can be removed and the instrument restored to normal operating conditions.

IMPORTANT: Each time after a flow calibration procedure is completed, it should be followed by a flow verification procedure. The new flow verification results should be better than they were before the calibration. If flow verification results are still poor (flows differ by more than ~5%), then the flow calibration procedure should be repeated.

Clean air test

A manual clean air test should be performed every 6 months. The clean air test runs filtered air through the instrument to check the instrument noise, in order to check if the background measurements remain low and consistent with previous clean air checks. A bad clean air test result could indicate a dirty optical chamber or issues with temperature changes in the room.

Put a message in the CPD message log saying a clean air test is being done. To begin the clean air test, go to the OPERATIONS menu under the GENERAL tab and press *Stop* to stop measurements and then press *Clean Air* to start the clean air test (Figure 17). The test will run for 20 minutes at 5 lpm and 1 s time resolution. Throughout the duration of the test, the instrument decimal status will be set at 2048 on the HOME screen.

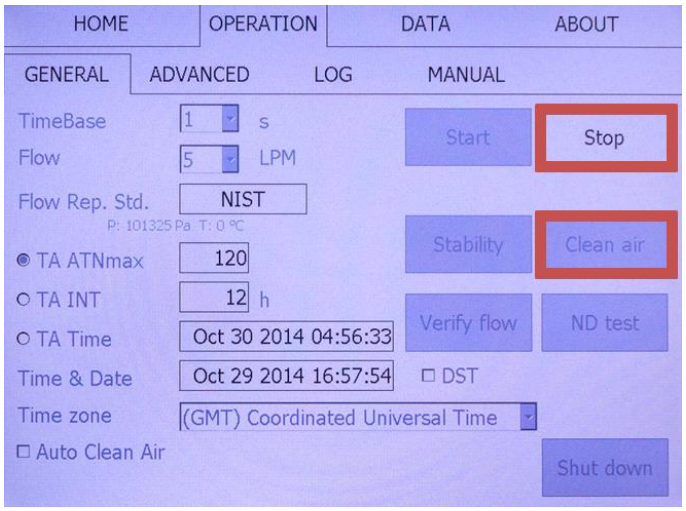

Figure 17. Start a clean air test by stopping measurements and pressing Clean Air in the OPERATIONS menu under the GENERAL tab

Results from the clean air test will appear automatically, and should show BC concentration values close to zero. A short transient in BC may be observed due to filter compression at the start of the sample. The point to point BC value (PPBC) is calculated as an average absolute difference between two

consecutive BC concentration measurements. The results should be less than 450 ng/m^3 for spot1, channel 6 (i.e., PPBC61). If the clean air test yields values higher than desired, the optical chamber should be inspected and cleaned. Persistently high clean air tests may mean the instrument needs to be serviced. An example of a clean air test report is below. In this example the PPBC61 is 385 ng/m^3 which is less than 450 ng/m^3 so the clean air test is good.

Clean air test report.
Serial number: AE33-S02-00232
Date and time: 02 Dec 2014 11:46:03
Duration: 00:20:00, Timebase: 1 sec, Flow: 0 mlpm

	Average BC		PPBC	(ng/m3)
	Spot1	Spot2	Spot1	Spot2
Ch1	92	160	193	398
Ch2	38	76	255	592
Ch3	37	89	268	600
Ch4	46	128	307	672
Ch5	47	108	308	668
Ch6	24	94	385	848
Ch7	32	107	437	916

Result of clean air test is acceptable.

Stability test

The stability test should be performed every 6 months, and is used to check if the light source and light detector are functioning properly. A bad stability test result could indicate a dirty optical chamber or faulty instrument electronics.

The pump should be off and there should be no flow through the instrument when completing the stability test, which allows the user to look at noise from the electronics within the instrument. To turn the pump off: go to the OPERATIONS menu under the GENERAL tab and press *Stop.* Disconnect the AE33 inlet tubing to isolate the instrument from its inlet line. If the Aethalometer is sampling from a manifold with other instruments connected to it, once the AE33 is disconnected the AE33 connection port on the manifold needs to be plugged so no air from the laboratory enters the aerosol system manifold and affects the other instruments during the stability test. Put a message in the CPD message log saying a stability test is being done. To start the test, go the OPERATIONS menu under the GENERAL tab, and then press *Stability* (Figure 18). The instrument decimal status will be 1024 during the stability test. The test will run for 20 minutes at 1 s time resolution. BC values will be computed during the test assuming a 5 lpm flow rate.

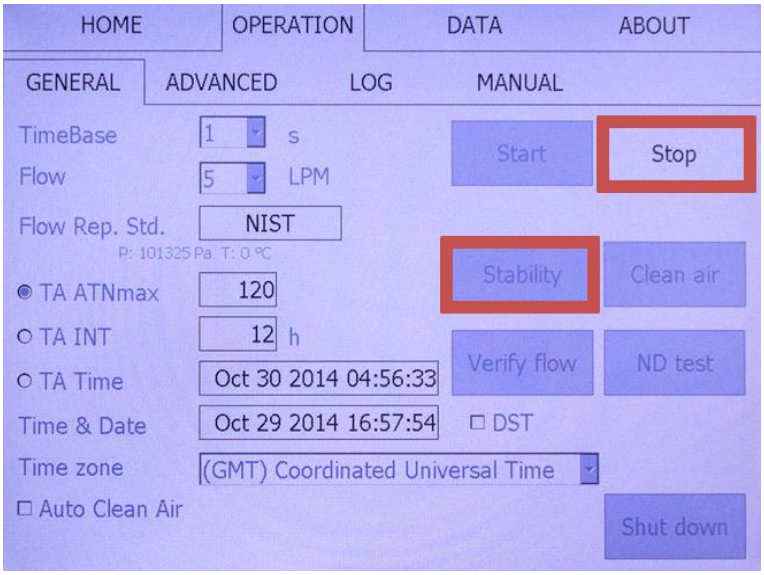

Figure 18. Perform a stability test by stopping measurements and pressing Stability in the OPERATION menu under the GENERAL tab

The results will appear on the instrument screen automatically, and should show BC concentration values close to zero. The point to point BC value (PPBC) is calculated as an average absolute difference between two consecutive BC concentration measurements, just like in the clean air test. The result should be indicate PPBC61 < 450ng/m^3. If results from the stability test are too high, contact the manufacturer regarding how to address the large noise from the instrument electronics. An example of a stability test report is below.

Stability test report.
Serial number: AE33-S02-00232
Date and time: 02 Dec 2014 11:46:03
Duration: 00:20:00, Timebase: 1 sec, Flow: 0 mlpm

	Average BC		PPBC	(ng/m3)
	Spot1	Spot2	Spot1	Spot2
Ch1	-13	4	361	645
Ch2	-5	-3	357	934
Ch3	-3	8	365	899
Ch4	0	16	348	956
Ch5	-2	11	369	1023
Ch6	-23	-29	402	1118
Ch7	-16	-24	473	1230

Result of stability test is acceptable.

Leakage tests

The leakage test should be performed every 6 months, since the leakage factor is part of the instrument's algorithm to calculate BC concentrations. The leakage test checks that the flow going into the instrument is the same as the flow being exhausted from the instrument outlet. The leakage must be measured while the instrument is running, and average leakage values for flow rates around 5 lpm are 7%. A mass flow meter with is needed to complete the leakage test. If using a volumetric flow meter, the difference in air temperature and pressure must be accounted for using the ideal gas law. **If you get a high leakage value (>10%) please lubricate the optical chamber slides (see page 26) and try again.**

The leakage test is different for AE33 instruments running on software versions 1.1.4.5 or older compared to version 1.1.4.6 and newer. You can check what software version is running in the OPERATION menu under the ADVANCED tab (Figure 19).

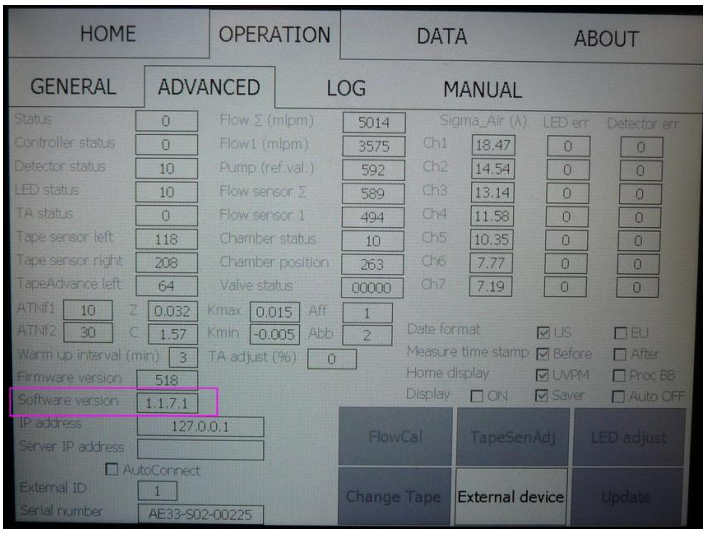

Figure 19. Pink box indicates location of software version information

Leakage test: Software version 1.1.4.5 and older

To start the test, put a message in the log saying a leakage test is being done, stop instrument measurements (go to the OPERATIONS menu under the GENERAL tab and press *Stop*). If the Aethalometer is sampling from a manifold with other instruments connected to it, once the AE33 is disconnected the AE33 connection port on the manifold needs to be plugged so no air from the laboratory enters the aerosol system manifold and affects the other instruments during the stability test. Connect the flow meter to the inlet of the Aethalometer, and resume instrument measurements. Note that the flow meter will be measuring vacuum flow on the inlet and pressure flow on the outlet so be sure to hook it up properly. Once the flow has stabilized (as indicated by a more or less consistent flow reading on the meter), record the flow reading as F_{in}, making sure that the flow is measuring at standard flow and the standard flow settings match that of the aethalometer standard flow (pressure and temperature) settings. **REMEMBER: Never tamper with the AE33 instrument inlet while the AE33**

is on and measuring. The user must stop AE33 measurements before disconnecting inlet tubing and reconnecting a flow meter. Connect the flow meter to the outlet of the Aethalometer with a long ~10m tube to help reduce oscillation, and record the flow reading as F_{out}. The leakage factor can be calculated with the equation: $\zeta = 1 - (F_{in}/F_{out})$.

The leakage factor should be calculated and reported in the log. Most importantly, if the leakage factor has changed from the previous leakage test, it needs to be changed in the instrument settings. Leakage factor can be set in the OPERATIONS menu under the ADVANCED tab. The leakage factor is represented by a 'Z' in the instrument menu, and is found near the middle of the screen on the left side of the ADVANCED tab. Always double check parameters like leakage factors before changing the instrument settings.

Leakage test: Software version 1.1.4.6 and newer

Starting with the AE33 software version 1.1.4.6, a simpler leakage test was implemented. The test can be done manually with a single mass flow meter on site, and the manufacturer-supplied flow calibration pad. The leakage test checks that the flow going into the instrument is the same as the flow being measured in the instrument's flow meters. **REMEMBER: Never tamper with the AE33 instrument inlet while the AE33 is on and measuring**. Stop instrument measurements.

To start the test, go the OPERATIONS menu under the GENERAL tab, and press STOP. Then, press *Leakage test*. The instrument asks whether to conduct an automatic test or a manual one, choose *MANUAL*. The instrument will ask if a filter is installed ('a filter' means the normal filter tape). Assuming that the filter tape is in place, continue. The AE33 will advance the tape and prompt you to connect an external flow meter to the instrument inlet. If the Aethalometer is sampling from a manifold with other instruments connected to it, once the AE33 is disconnected the AE33 connection port on the manifold needs to be plugged so no air from the laboratory enters the aerosol system manifold and affects the other instruments during the stability test. After confirming the installation of the flow meter, select 5 LPM as the flow at which the test will be conducted. If the AE33 usually operates at different flow, you might choose that flow value instead. Wait for flow to stabilize then enter the value measured by the external flow meter in mlpm (milliliters per minute) using the touch box on the screen. Press OK.

The AE33 will lift the optical chamber and ask for the flow calibration pad to be inserted. Once the chamber is lifted, the filter tape can be removed (unscrew the transparent cover on the right roll-on filter tape side, then slide the tape out from under the optical chamber). The calibration pad should be inserted in its place, with the notch facing towards the user (see Figures 12 and 13). With the calibration pad in place, press OK on the screen and wait for the chamber to move back to its home position. Wait for the flow to stabilize, and then enter the value measured by the external flow meter in mlpm (milliliters per minute), using the touch box on the screen. Press OK. The AE33 will lift the optical

chamber. The calibration pad can be removed and the filter tape reinserted and tightened. Press OK and wait for the chamber to return back to its home position.

The AE33 instrument then records the leakage information in the leakage log file (LT_AE33-P00-SPIN1_20150901_104136.dat) and a report is written on the screen. An example of a leakage test report is below:

> Manual leakage test report
> Serial number: AE33-P00-SPIN1
> Date and time: 01 Sep 2015 10:41:36
> Selected flow: 5000 mlpm
> Flow through tape: 4976
> Flow through calibration pad: 5010
> Instrument leakage is: 0.7 %

Record the leakage value in the CPD message log. Additionally, if the leakage factor has changed from the previous leakage test, it needs to be changed in the instrument settings. The leakage factor can be set in the OPERATIONS menu under the ADVANCED tab. The leakage factor is represented by a 'Z' in the instrument menu, and is found near the middle of the screen on the left side of the ADVANCED tab. To change, press the 'Z' box and a new touch pad will come up on the screen. Although the instrument reports the leakage value as a percent (e.g., 0.7%) in the manual leakage test report, here it must be entered as a decimal (e.g., 0.007). Always double check parameters like leakage factors before changing the instrument settings. The flow meter can be removed and the instrument restored to normal operating conditions by going to the OPERATIONS menu under the GENERAL tab, and pressing START.

Inlet leakage test

The inlet leakage test should be performed every 6 months. The inlet leakage test checks that the flow going into the instrument is the same as the flow at the inlet on the station roof (if the instrument has its own inlet) or at the manifold pickoff if the instrument samples from a manifold. Start by putting a message in the log saying an inlet leakage test is being done. If the instrument is sampling off an inlet manifold (as opposed to having its own dedicated inlet line) then you are just looking for leaks between the AE33 manifold and where the tube connects to the manifold.

REMEMBER: Never tamper with the AE33 instrument inlet while the AE33 is on and measuring.
To start the test, stop instrument measurements: go to the OPERATIONS menu under the GENERAL tab and press *Stop*. Next, go to the OPERATIONS menu under the GENERAL tab, and then press *Inlet leakage*. The AE33 will lift the optical chamber and ask for the flow calibration pad to be inserted. Once the chamber is lifted, the filter tape can be removed (unscrew the transparent cover on the right roll-on filter tape side, then slide the tape out from under the optical chamber) and the calibration pad inserted in its place, with the notch facing towards the user (see Figures 12 and 13). With the calibration pad in

place, press OK on the screen and wait for the chamber to move back to its home position. The AE33 will advance tape and prompt you to connect an external flow meter to the instrument inlet. Note the flow meter's temperature and pressure reporting conditions. After confirming the installation of the flow meter, wait for flow to stabilize and enter the value measured by the external flow meter in mlpm. Press OK.

Carefully access the inlet outside the station and connect the flowmeter to the inlet. Confirm this on the AE33 by pressing OK. Wait for flow to stabilize and enter the value measured by the external flow meter in mlpm. Press OK.

The AE33 will lift the optical chamber. The calibration pad can be removed and the filter tape reinserted and tightened. Press OK and wait for the chamber to return back to its home position. The AE33 instrument then records the inlet leakage information in the inlet leakage log file (IT_AE33-P00-SPIN1_20150901_110611.dat) and a report is written on the screen. Record the inlet leakage value in the CPD instrument log. An example of an inlet leakage test report is below:

Inlet leakage test report
Serial number: AE33-P00-SPIN1
Date and time: 01 Sep 2015 11:06:11
Selected flow: 5000 mlpm
Instrument inlet flow: 4950 mlpm
Outdoor inlet flow: 4950 mlpm
Inlet leakage is: 1 %

The flow meter can be removed, and the roof inlet and the instrument restored to normal operating conditions.

Neutral Density filter test

The AE33 Aethalometer manufacturer recommends performing a neutral density filter test on an annual basis. The test requires a neutral density (ND) filter set (neutral density filters can be ordered from the manufacturer). Most monitoring sites should have received the neutral density filter set with shipment of the AE33 Aethalometer. If there is not a ND filter set at the monitoring station, then a visiting scientist can bring one during an annual site maintenance. NOAA currently does not have ND filters so this test is not performed at NOAA stations.

The neutral density filter test assesses sensitivity of the instrument's optical system by measuring attenuation of 4 different neutral density filters. Sensitivity is indicated by the slope of measured attenuation vs. default attenuation, and the instrument fails the test if the slope differs more than 10% from unity.

Put a message in the log saying a neutral density filter test is being done. To start the test, go to the OPERATIONS menu in the GENERAL tab and press *ND test*. Follow instructions on the screen. First, the user is asked to input the serial number of the neutral density filters. This is important since each neutral density filter has its own unique transmission value as measured by the manufacturer. The screen will ask if the user wants to copy to a USB stick, to which the user can reply by pressing NO. Follow the instructions on the screen to complete the ND test. The test results will appear on the screen when the neutral density filter test is complete. Additionally, these results will be reported in the Aethalometer log file. The results from the neutral density test are a crude measurement of the instrument's integrity, to see if its sensitivity has changed at all since evaluation by the manufacturer. If slope differs more than 10% from unity, then the test fails and the instrument should be sent to the manufacturer for servicing.
results

Overnight Filtered Air Test

Similar to the clean air test, the filtered air test quantifies noise in the instrument. However, this test is much longer than the clean air test and allows for the evaluation of instrument noise as a function of averaging time using an Allan plot (see example below). To run an overnight filtered air test, stop measurements on the AE33 (go to the OPERATIONS menu under the GENERAL tab and press *Stop*). Disconnect the AE33 inlet. If the Aethalometer is sampling from a manifold with other instruments connected to it, once the AE33 is disconnected the AE33 connection port on the manifold needs to be plugged so no air from the laboratory enters the aerosol system manifold and affects the other instruments during the stability test. Connect a filter directly to the AE33 inlet (any lightly used filter should do), using the proper fittings depending on the setup of the instrument inlet on site. Make note of the flow rate and time base in the log, and mark the time that the filtered air test is starting. Restart instrument measurements. Put a message in the CPD message log saying an overnight filtered air test is starting. Let the instrument measure the filtered air continuously for at least 24 hours (the data must be uninterrupted for a proper Allan plot), and longer (48 h) if possible. When the filtered air test is over, stop instrument measurements (go to the OPERATIONS menu under the GENERAL tab and press *Stop*), remove filter and restore the connection to the sampling system. Restart instrument measurements and enter a note in the log what time the filtered air test ended. A NOAA scientist will use the start and end times entered in the CPD message log to generate an Allan plot of standard deviation versus averaging time using the filtered air data. This plot will be used to analyze how instrument noise changes with averaging time increases.

If the station is running cpd3, here are some example commands to make Allan plots:
#This is how to do for individual wavelengths for reported BC
da.plot.allan --y=Xf7_A81sfa 2015-12-15T22:00:00Z 2015-12-17T20:00:00Z --file= allan.png

#This is how to do it for attenuation (see DCH email on 20150814) does both arithmetic and difference

*da.get sfa .*_A81 2015-12-15T22:00:00Z 2015-12-17T20:00:00Z | da.export --mode=r | filter_allan> r_filter_allan_output.csv*

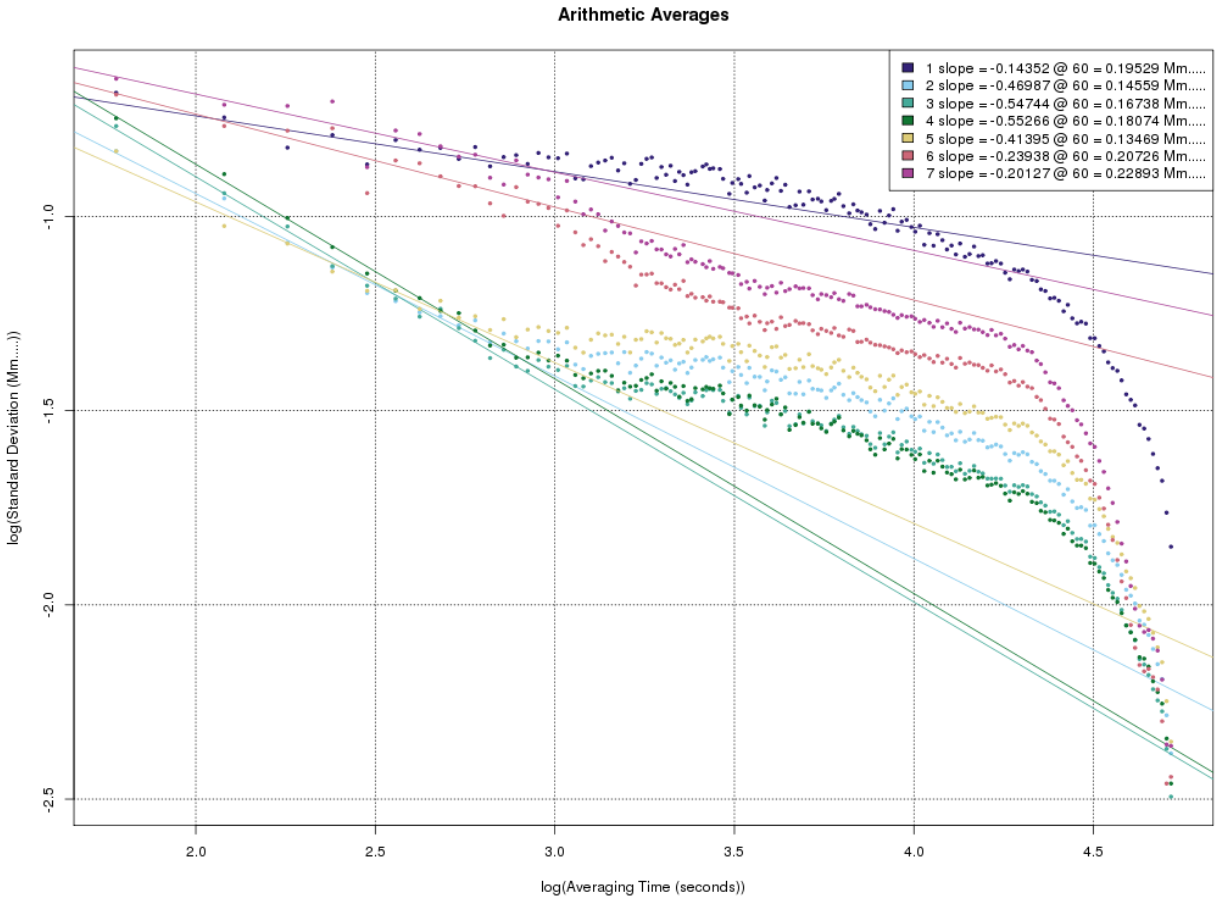

Figure 20. Example of an Allan plot (log of the filtered air standard deviation versus log of the averaging time in seconds) created using data from a filtered air test on the AE33 running at Summit, Greenland

Lubricate optical chamber sliders

On an annual basis, optical chamber sliders should be lubricated. These optical chamber sliders act as guide posts on which the optical chamber is lifted and returned to its home position. To lubricate the sliders, the user needs a brush and brush-on grease – (NOT spray-on grease like WD40). We recommend 'TriFlow'. Using a brush, apply a very thin, even layer of grease to all three optical chamber sliders when the chamber is in its home position which exposes the most area on the chamber sliders. Be sure that no grease gets on other parts of the instrument, especially the tape or optical chamber, and remove any excess grease with a wipe. Make sure to note in the log when the optical chamber sliders were lubricated.

Figure 21. Optical chamber sliders

Change bypass cartridge filter

The bypass cartridge filter should be changed on an annual basis, or earlier if needed at stations with high aerosol loading. The bypass cartridge filter (located above the optical chamber) will need to be changed if the filter looks blackened and dirty, or if clean air test results yield a BC concentration much higher than zero. A Parker 1/4'' in-line disposable filter part number IDN-6G 28NX, or an equivalent filter, is needed to replace the bypass cartridge filter.

Put a message in the log saying the bypass cartridge filter is being changed. To remove the old bypass cartridge filter, first stop measurements: press the *Stop* button in the OPERATION menu under the GENERAL tab. The bypass cartridge filter is held in place with 'grip' connectors. To remove, use a screwdriver or the side of a pair of pliers to press on the white ring of the inner grip connector on one side of the filter and pull the cartridge filter out of the connector. Remove the other side of the cartridge filter using the same method. Remove the connectors from the used cartridge filter and install them on the new filter, then click the connectors into place. Make sure that the arrow on the filter cartridge is pointing to the right (aligned with the direction of flow), and be sure that the ends of the cartridge filter are fit snugly down into the o-ring seals of the grip connectors.

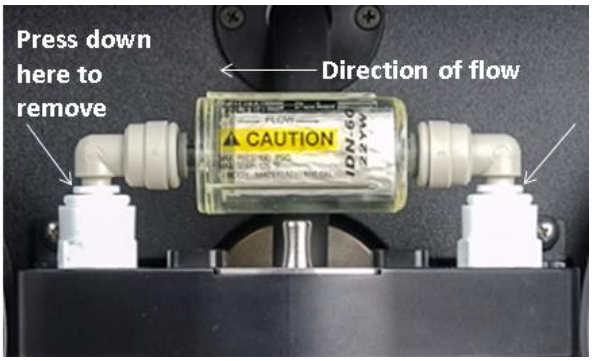

Figure 22. Bypass cartridge filter

Fuse Replacement

If the front panel LCD screen on the AE33 is black, but the instrument still has power, it is likely that there is a blown fuse that needs to be replaced. The fuse that tends to go out most often is the top one, because it is under-sized. It is a 1.25A 250VAC 5X20MM fast-blow fuse, and though the 'normal' current in this circuit is about 1.2A, that is too close to the fuse limit. A 2A or 2.5A slow-blow fuse of the same physical size (5x20MM) is acceptable as a replacement, and that is what is recommended by the manufacturer.

The fuses are accessed by removing the back panel. You can see them in Figure 23 below on the green panel.

It is important to perform the fuse tests as described in the Magee Service Manual (and reiterated here) to detect if fuses need replacement before complete failure:

- The fuse test can only be performed while the interconnection board is installed in the instrument, and the power is switched ON. All voltages are low, and this procedure is safe.
- Press and hold the push-button switch S1. All 6 LED indicators on the board should light up. We also recommend measuring the voltage across each fuse (on both sides), with special attention to the topmost fuse (F1). If the voltage drop across F1 exceeds 0.1 V, replace it.
- The fuse current rating values are as follows:

Fuse	Value (A)	Circuit designation	Value (V)
F1*	2.5	+ PC	5 +/- 0.1
F2	3.15	+12	12 +/- 0.1
F3	0.4	+5	5 +/- 0.1
F4*	1.25	+24_led driver	24 +/- 0.25
F5	0.4	+5_led driver	5 +/- 0.1
F6	0.4	+5_detector board	5 +/- 0.1

NOTE: Even if you measure electrical continuity on a meter between both sides of the fuse and if the fuse test illuminates the LED for that fuse, it is worthwhile to check the voltage drop across

the fuse. In some cases, the wire will age without breaking, and replacing with a new fuse will solve the problem. For reference, the voltage drop across a new fuse is around 0.04 VDC, and values exceeding 0.1 VC indicate fuse aging and replacement is recommended.

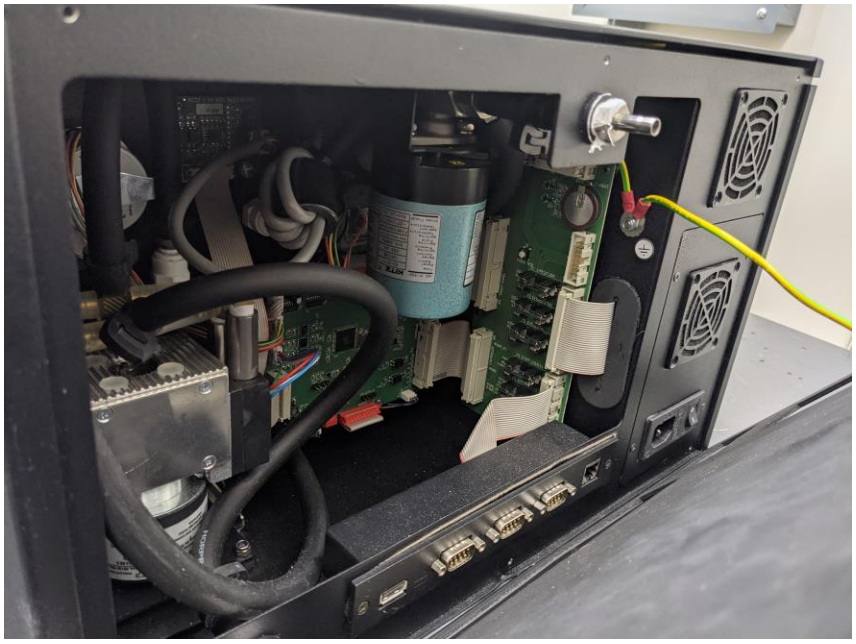

Figure 23. With the back panel open, the fuses are visible on the green panel.