Maintenance Manual – NOAA/GML Aerosol Sampling System

Station Computer Acquisition System: FORGE

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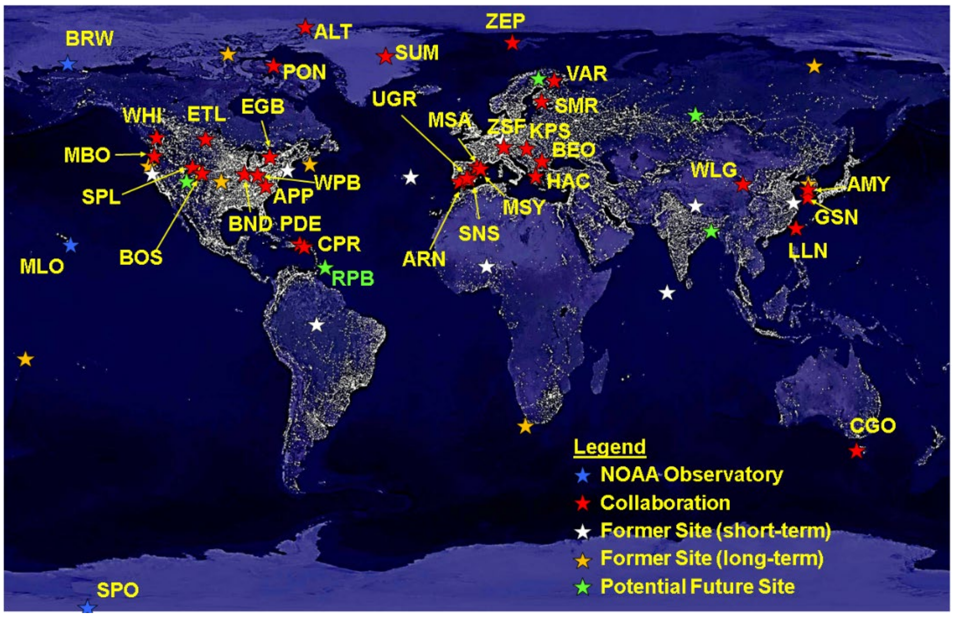

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1. Maintenance Introduction and Timeline

Here, a list of maintenance checks that are common for an NFAN system are provided. These checks and tasks are broken down on a daily, weekly, and monthly time scale. Some of these tasks are instrument specific and do not apply to all sites. For the annual maintenance visit all of these tasks will likely be performed, and a detailed list of the annual visit tasks are provided in the next section. Detailed instructions for all of the tasks can be found in the appendices of this document.

1.1. Daily Maintenance and Tasks

INSTRUMENT	MAINTENANCE CHECK and/or TASK
Aerosol System	Fill out any daily checklists at the site, and check the emailed data report for any issues.
	Check that the computer is on, responsive (i.e. not frozen), and that the clock is correct and updating.
	Check the status letters (bottom right of FORGE screen) and blue buttons for all of the instruments. Make sure that you have all appropriate letters for your station and that all of the letters appear green (red indicates a problem). Check the instrument menus under the blue buttons and make sure the information is updating for all instruments.
	Check the data using the 'Data Viewer' to ensure that data is updating and that the reported values by all instruments are reasonable.
	Check on the flow and pressure gauges on the aerosol rack and pump box to make sure the system is operating correctly.
TSI Nephelometer	Check that the lamp is on.
	Check that the data is updating under the instrument menu.
	Using the 'Data Viewer', check the signal from the nephelometer's zero and make sure the signal has remained steady.
Ecotech Nephelometer	Check that the data is updating under the instrument menu.
	Check the onboard system status menu and make sure all parameters report a "PASS" (on the front of the instrument press 'Enter', use the arrow buttons to navigate to 'Sys Status', and select this menu)
	Using the 'Data Viewer', check the signal from the nephelometer's zero and make sure the signal has remained steady.
CLAP	Check that the data is updating under the instrument menu.
	Check that the transmittance on the current spot is above 0.7 for all wavelengths.
	Check that the flow of the CLAP is at the correct setting for your station. Use the flow value on the FORGE screen, not the instrument screen.
	Check the spot number. If the CLAP is on spot 8, ensure that the transmittance is greater than 0.75 at all wavelengths. If it drops below 0.75 on any wavelength, change the filter.
Aethalometer	Check that the data is updating under the instrument menu.
	Check that the dot on the black screen is green with a check mark or pink with an exclamation mark.
	Check the tape status by opening the door of the aethalometer.
TSI CPC (Butanol)	Check that the data is updating under the instrument menu.
	Check that the instrument flows are correct.
	Check butanol level; fill to just below the fill line in the butanol window if low.
	Fill butanol fill bottle from 4L glass bottle (when needed).
Magic CPC	Check that the data is updating under the instrument menu.
	Check that the instrument flows are correct.
	Check water level in the reservoir bottle; fill if needed.

1.2. Weekly or Biweekly Maintenance and Tasks

In addition to the daily tasks, approximately once a week or every other week the following should be performed.

INSTRUMENT	MAINTENANCE CHECK and/or TASK
Aerosol System	If applicable, check the main aerosol stack for snow buildup. If necessary, clean the rim or snow off the inlet head. If you clean the stack, write a note in the log file on the aerosol computer. (weekly)
	If you are in a dirty environment or have experienced extreme smoke or dust events, service the impactors (i.e. clean and re-grease).
	If the impactors are serviced, perform a system leak test as well.
TSI Nephelometer	Using the 'Data Viewer', check the signal from the nephelometer's zero and make sure the signal has remained steady over the past week.
Ecotech Nephelometer	Using the 'Data Viewer', check the signal from the nephelometer's zero and make sure the signal has remained steady over the past week.
Aethalometer	On the 'Home' screen, check that 'Reported Flow' is standard (sea level) units and that Tstd = 0°C, 'Timebase' is 1 second, 'Status' has a green check mark with a status code of zero, and the UTC time is correct within a few minutes.
	Make sure that the tape is aligned properly and that there isn't extra slack in the tape.

1.3. Monthly Maintenance and Tasks

At the end or beginning of every month the following tasks should be completed.

INSTRUMENT	MAINTENANCE CHECK and/or TASK
Aerosol System	Inspect sample line tubing for kinks and bends.
	Check the integrity of external wiring, tubing, fittings, insulation, etc.
	Service the impactors (i.e. clean and re-grease).
	Perform a system leak check.
TSI Nephelometer	Preform a span check, and note the status of the CO_2 gas available at the site.
Ecotech Nephelometer	Preform a span check, and note the status of the CO_2 gas available at the site.
Aethalometer	Delete data from CF card.
Magic CPC	Using the 'Data Viewer', check the pulse height for the instrument. If you start to see periods of significant drop preform a wick wetting and humidifier prep procedure.

2. Annual Maintenance Tasks

The tasks below are described in no particular order, although it's good to do a system overview check and overnight filtered air test at the beginning of the site visit. The rest of the tasks can be done in an order dictated by priorities, weather, or whim. A paired down checklist of these tasks is available in **Appendix A** and a list of general supplies needed for annual maintenance can be found in **Appendix B**.

Detailed instructions for maintenance tasks are not listed in this document. Specific documents for all of the procedures referenced in this document can be found at:
https://gml.noaa.gov/aero/maintenance/maint_info_docs.html

1.4. Initial on-site tasks

- **Begin and keep an electronic maintenance log document.** This is helpful for looking back at what you did at the site as well as noting tasks to follow up on. If you keep a written log make sure to update the electronic log daily so there are not gaps in the document. There is an example maintenance log document in the back of this document (**Appendix C**).

- Look at current system parameters displayed on acquisition screen - look for anything that seems like it might need further work (i.e., if it seems too high or too low or too noisy).

- Visually check system for proper operation – it's good to do this early so parts can be requested from NOAA and perhaps arrive during the maintenance visit. Check for:
  - Loose or cracked tubes or wires
  - Front panel readings that are outside of the normal range
  - Manual valve positions, to make sure they are all in the proper position

- Check station flow diagram against existing diagram. Update flow diagram if needed. Station flow diagrams can be found in three places:
  - Under the help menu (question mark icon in lower right) of station laptop
  - Online at https://gml.noaa.gov/aftp/aerosol/doc/drawings/stn/
  - Under the /aer/doc/drawings/stn/ directory

- Note if the site has a humidigraph - if so the temperature and RH sensor calibrations and checks will be critical, however, if the site does not have such a system then these checks are not critical.

- **Begin the overnight filtered air checks** (described below).

1.5. System Maintenance Tasks

1.5.1. Overnight filtered air check and CN comparison

The overnight filtered air test provides an indication of instrument noise. Place a HEPA filter with the appropriate ¾" fittings on the inlet of the nephelometer. Place an in-line filter on the inlet line of the CLAP. Put a note into the message log with the start of the filtered air check. When the filtered air check is finished put a note into the message log with the end time. Remove filters and return inlet lines to normal sampling configuration.

The overnight CN comparison allows you to compare the CN counter at the site with a CN counter that is comparable to the NOAA lab standard. This is not always preformed at an annual maintenance visit, but it is useful if concentrations from the site CN instrument has been suspect. To start the comparison, connect the transfer standard CN counter to the data system and connect the inlet for the transfer standard CN and the rack system CN to a mixing chamber (or at least make sure that the inlet tubing to both CN counters is of similar length and bendiness and sampling through a tee so the two instruments are sampling the same air.) Measure the sample flows for both instruments and update the configuration file. Collect the data overnight and evaluate the next day after the data have been processed to determine whether the site CN counter needs to be worked on.

To analyze the data from the overnight filter there are several options:

- Use the db system program '*nephstat2*':

  `nephstat2 stn 2012-08-15 2012-08-16` **this will pull from default neph
  `nephstat2 stn S11a 2012-08-15 2012-08-16` **this pulls specific neph

- You can also use the '*da.summary.general command*':

  ```
  da.summary.general stn S11a,A11a –rows=flavorless –wavelength 2012-08-15
  2012-08-16
  ```
  **this will print the averages in the command window

- Alternatively, you can analyze the raw data stored locally:

  ```
  data.get –localdata bnd A11a,A12a,S11a "2011-11-25 01:30" "2011-11-25
  15:30" raw | data.avg --cut=off --count=off --stddev=on --contam --decimal-
  format=%9.4f,9999.9999 --interval=forever | data.consolidate --source=-
  'Bs*' 'Bbs*' 'Ba*' |  data.export –mode=csv | transpose > noise_test.csv
  ```

It is also useful to make a time series plot of the filtered air to see if there are any obvious issues. This is easily done using the data viewer interface on the site computer (accessed using the desktop icon 'Data Viewer'.

1.5.2. Filter Replacements

There are several filters that need to be replaced in the aerosol system on an annual basis. The location and types of filters is listed in Table 1, and a more exact description of the filters needed is listed in **Appendix B**.

General notes for filter replacement:

- Put the date and location of installation on the filter - that way you know how long it's been in operation - e.g., 2021-08-27 installed BRW neph
- Make sure the filters are installed in the proper direction
- The old neph HEPA filter can be re-used as the filter upstream of the analyzer MFC. Likewise, the old neph inline filter can be re-used upstream of the CN flowmeter.

Notes for Neph filter replacement

- The neph filter replacements are described on pages 8-15 thru 8-18 of TSI neph manual.
- Make sure the filters are installed going the right directions! The manual has details on that if you pull them out and can't remember.
- Make sure that the position sensor 'blade' for the zero valve doesn't touch the HEPA filter when it rotates. This shouldn't happen if the filter is installed properly and facing the right direction, i.e., arrow down towards end plate. If this does happen it can cause a leak in the zeroing system (at best) or destroy the zero valve motor (at worst).
- The neph manual suggests using RTV silicone sealer on the HEPA filter fittings. We use teflon tape instead and that seems to be fine.
- The 1/2" plastic fittings for the neph HEPA filter can be hand tightened - but make sure they are as tight as your hand can make them.
- It is possible to replace the neph HEPA filter without removing the end plate on some of the older nephs, but it's SO much easier to do the replacement by removing the end plate.
- Do a neph zero after the filters are replaced to make sure the background values haven't shifted (a shift in background values could indicate a leak).
- Check the integrity of the silicone tube (the squishy tubing) that holds the small inline filter. The end of this tube can degrade where you push the filter into the tubing and so is another potential source of a nephelometer leak. Usually there's enough extra tubing that you can snip off the degraded end and still install the filter. This tubing also tends to get stuck between the neph cover and the electronics so make sure when you put cover back on not to squish it.

Table 2: List of filters in the aerosol system, their type, and where they are located.

Instrument / System	Type of Filter and its Approx. Location
TSI Nephelometer	(1) Large HEPA filter for instrument zeros, located inside the instrument directly under the inlet (2) Inline filter, located inside the instrument directly above the inlet
Ecotech Aurora 3000 Nephelometer	(1) Inline HEPA filter, located inside the instrument attached to the zero intake port (2) Inline filter, located inside the instrument and clipped into place above the column exhaust port
Teledyne API	Small internal HEPA filter
Aerosol Rack*	(1) Inline filter (preferably blue balston filter), that is upstream of the MFC for the CPC flow (2) Inline filter that is upstream of the second MFC in the CN box, used to control the drier flow (3) HEPA on filter rack (only BRW) (4) For systems with a dilution system there is an inline HEPA filter
CO_2 Flow (for span checks)	Inline filter, intalled relitively near the output of the CO_2 tank used for nephelometer span checks
Pumpbox	A general air filter is attached to the exhaust of the carbon vane pump (https://www.knfilters.com/rc-1200-universal-clamp-on-air-filter)

*Note that not every filter listed in this section will be required at every site

1.5.3. Pumpbox Maintenance

- Unplug pumps (turn off stack heater, impactor box heater, and any other system heaters while pumps are unplugged!)

- Check carbon vanes – replace if necessary (cracked, really short). It helps to measure vanes and record the length in the maintenance log so you can track approximately how much they wear down over time.

- Remove, clean and adjust pitot tube – described in **Appendix D** or at: ftp://ftp.cmdl.noaa.gov/aerosol/doc/maint_docs/pumpbox_pitot_clean.ppt

  Note: make sure you blow the liquid out of the pitot tube after cleaning or you will get anomalous readings.

- Calibrate pressure transmitter (described in **Appendix C: Calibration of the Pump Box Pressure Transducer (Pitot Tube)).**

- Clean/replace carbon vane pump filter. Change fiberglass filter material in pump exhaust (if you have old style long tube filter) or filter and filter cover (if you have new style filter). For the new filter – the filter starts out pale pink. Filter cone points toward incoming air.

- Replace diaphragm in diaphragm pump if site uses those instead of or in addition to carbon vane pump (e.g., SPO, SUM...).

- Clean/replace rotameters as needed. It's helpful to have a supply of cotton swabs and alcohol to do this. You can remove the adjustment knob and insert a swab into the flow volume of the rotameter to scrub out any deposits. Check the o-rings in the rotameters - they tend to degrade.

- Clean pump box (i.e., vacuum up the detritus that collected since it was last cleaned).

- Check that pump box ventilation fan is working.

1.5.4. Stack and Inlet Maintenance

- Inspect all tubing for cracks or other problems (8" PVC, spare line tubing, sample tubing).

- Inspect tower, guy wires, and anchors for rust or other problems.

- Climb tower and inspect rainhat and screen on rainhat. Look for anything that might block flow of sample down stack (i.e., slipped rainhat or clogged screen). Wear helmet and harness and be up-to-date on your tower climbing training to do this.

- If there is stack port access, perform leak check with HEPA filter as described in operations manual before and after taking apart flow splitter.

- Remove flow splitter and clean with water and then alcohol. A small bottle brush is helpful for this.

- Clean 2" stack with water, rope and scrubber - we tie a dish scrubber in the middle of a 20-foot long rope and pull it back and forth through the 2" inlet tube to clean it. Finish with an alcohol scrub.

- Calibrate stack RH sensors (**Appendix C: Calibration of the RH Sensors**).

- Insulate tubing exposed to sunlight against UV (use aluminum tape or foil & duct tape).

- Clean inlet tubing from splitter to instruments. This is probably easiest to do with an appropriately sized bottle brush, string and tiny sponge. Pull the bottle brush through the tube using the string to abrade off deposited particles. Follow that with the sponge on a string with water then alcohol.

  NOTE: You want the tubing to be relatively dry before re-installing on system.

1.5.5. Impactor Box

- Clean the impactors and inspect impactors for rust and clogging (**Appendix D: Cleaning the Impactors**).

- Check o-rings in impactors – are they all there and what is their condition?

- Clean tubing.

- Check impactor valve switching by switching size cuts and looking at position of ball in Whitey valve.

- Replace HEPA filter upstream of mass flow controller (**Section 1.2.2**) (can use HEPA from neph - write date installed in impactor box on the filter).

- Calibrate mass flow controller (**Appendix C: Flow Calibration Procedures**) and enter calibration into configuration file.

- Calibrate RH sensor at inlet to impactor box (**Appendix C: Calibration of the RH Sensors**).

- If the solenoids are making a buzzing noise disassemble and clean them or decide if replacements are needed and order them for next year.

1.5.6. µMAC or CR1000 Box

- Check that the cooling fans on the sides of the uMac/CR1000 are working.

- Calibrate the pressure sensor array (**Appendix C: Calibration of the µMAC and CR1000 Pressure Sensors**)

1.5.7. PID Box

- Check that the cooling fans in the PID are working

- Replace any PID controllers that have issues (i.e. techs notify you of an issue or you see numbers in the data stream that don't make sense)

1.5.8. UPS

- Do a battery runtime test by unplugging the UPS from wall power. The UPS should run for at least 5 minutes. If it runs for less than that new batteries should be ordered.

1.6. Instrument Maintenance Tasks

1.6.1. Nephelometer

- Overnight filtered air test.
- Replace the filters (**Section 1.2.2**).
- Inspect nephelometer tubing for any cracks or degradation.
- Clean nephelometer light trap. Instructions in **Appendix D: Nephelometer** or in this link.
-

1.6.2. CLAP

- Overnight filtered air test.
- Check CLAP flow (**Appendix C: Flow Calibration Procedures**), remember that the desired flow is 1 lpmv to keep the face velocity comparable with all the other sites in the network. However, the calibrations are done in slpm. So you'll need to figure out what slpm flowrate corresponds to 1 lpmv at your site.

1.7. Inventory

- Update the station inventory file. The inventory is an electronic document that lists instrument serial numbers, NOAA CD tags (where applicable), and general supplies. It can be useful for tracking instruments after the fact and for figuring out what supplies you need to bring. It can also help tell a station tech where to look for something or for someone else visiting station where to find something.

1.8. Miscellaneous Tasks

- Fix and/or add labels where needed on cables, tubing, readouts, etc.
- Clean up around the instruments area.
- Take final pictures around the site, once everything is put back together

1.9. Back in Boulder

- Download pictures to `/aer/photos/{stn}/maintYYYY/`
- Put the maintenance documents (calibrations, inventory, maintenance log, etc.) in: `/aer/{stn}/doc/maintYYYY`
- Put updated flow diagram in correct directory and provide to station collaborators. `/aer/doc/drawings/stn/STN_yyyymmdd.odg`
- Follow up on tasks that need completion

Appendix A: Checklist of System Maintenance Tasks

Initial on-site tasks

- ☐ Begin your electronic maintenance log document
- ☐ Visually check the cpd client screen – note if any of the instrument parameters seem off (i.e. too high or too low)
- ☐ Visually inspect the system for proper operation. Some things to look for:
    - o No loose / cracked tubes or wires
    - o All front panel readings are normal
    - o All manual valves in proper positions
- ☐ Check the station flow diagram against the existing system – note any discrepancies in the log and update the diagram [/aer/doc/drawings/stn/]

Overnight filtered air check and CN comparison

- ☐ Place HEPA filter with a ¾" fitting on the inlet of the nephelometer – make a time note in log
- ☐ Place an in-line filter on the inlet line of the PSAP – make a time note in log
- ☐ Place an in-line filter on the inlet line of the CLAP – make a time note in log

- ☐ Connect the transfer standard CN counter to the data system
- ☐ Connect the inlet for the transfer standard CN and the site CN to a mixing chamber or make sure the two have similar inlet lengths and conditions – make a time note in log
- ☐ Measure the sample flows for both instruments – note the flows in the log

- ☐ Leave the filters and CN set-up overnight
- ☐ The next day, make a time note in the log for when each HEPA filter is removed, when the transfer standard CN is removed, and when the site CN is back in line

- ☐ Analyze the overnight data
    - o Timeseries plot of Neph, PSAP, and CLAP zero periods – add to log
    - o Timeseries plot of CN concentrations to ensure the two line up – add to log
    - o Report the average values in the malignance log – see the maintenance manual for how this can be done through the command line

Filter Replacements

- ☐ For each filter that needs replaced observe the following
    - o Note the time of filter replacement in the maintenance log
    - o Write the date and location of installation on the filter
    - o Check that the filter has been installed in the proper direction
    - o For smaller filters held in place by tubing, check that the tubing is still in good condition
    - o After the new filter is in place do a leak check on the system to ensure a proper install
- ☐ The following instruments and system points have filter replacements:
    - o TSI Nephelometer – two HEPA filters, one large and one small
    - o Ecotech Nephelometer – two small internal HEPA filters

    - Upstream of mass flow controllers and mass flow meters
        - Analyzer flow – HEPA filter
        - CN Flow – inline small filter (ideally a blue balston)
        - CN drier flow – inline filter
        - Filter rack – HEPA [**ONLY FOR BRW**]
        - Dilution Flow – in-line HEPA
    - CO2 flow – Inline HEPA filter

<u>Pump Box</u>

- ☐ Unplug all the pumps and then turn off the stack heater, impactor box heater, and any other system heaters while the pumps are unplugged
- ☐ Check the carbon vanes
    - Replace any that are cracked or too short
    - Measure the vanes and report it in the maintenance log – so you can track wear over time
- ☐ Remove, clean, and adjust the pitot tube (**Section 4.1**)
- ☐ Calibrate pressure transmitter (**Section 3.1**)
- ☐ Clean or replace the carbon vane pump filter
- ☐ If there are diaphragm pumps on site replace their diaphragms
- ☐ Clean or replace the rotameters as needed
- ☐ Vacuum out any debris inside the pump box
- ☐ Check that the pump box ventilation is working

<u>Stack and Inlet</u>

- ☐ Visually inspect all the tubing for cracks and other problems
    - 8-inch PVC
    - Spare line tubing
    - Sample tubing
- ☐ Visually inspect the tower, guy wires, and anchors for rust or other problems
- ☐ Climb the tower and inspect the rainhat and the screen on the rainhat. Look for anything that may block or disrupt the flow through the stack
- ☐ Cleaning the Flow Splitter
    - Perform leak check with a HEPA filter
    - Remove the flow splitter and clean with water then alcohol
    - Perform leak check with a HEPA filter
- ☐ Clean the 2-inch stack with water-rope-scrubber combo then alcohol
- ☐ Calibrate stack RH and temperature sensors (**Section 4.2**)
- ☐ Insulate any exposed tubing
- ☐ Clean the inlet tubing (splitter to instruments) with a water-string-scrubber combo and then with alcohol
- ☐ Ensure that all cleaned tubing is dry before reinstalling it

Impactor Box

- ☐ Inspect the impactors for any rust or clogging
- ☐ Check the o-rings inside the impactors
- ☐ Clean the tubing using the same methods as the inlet cleaning
- ☐ Check the impactor valve switching
- ☐ Replace the HEPA upstream of the mass flow controller (Section 1.2.2)
  NOTE: Can use the HEPA from the Nephelometer
- ☐ Calibrate the mass flow controller
- ☐ Calibrate RH and temperature sensors at the inlet of the impactor box
- ☐ If the solenoids in the box are making a buzzing noise clean them or decide to order new ones for next year

uMAC or CR1000 Box

- ☐ Check that the cooling fans on the sides of the uMAC/CR1000 are working
- ☐ Calibrate the pressure sensor array (**Section 3.5.1**)

PID

- ☐ Check that the cooling fans in the PID are working
- ☐ Replace any PID controllers that have issues

UPS

- ☐ Battery runtime test

Instrument Tasks

- ☐ Nephelometer
  - Inspect tubing for cracks and degradation
  - Clean the light trap
  - Preform a span check
  - Check voltages and counts to make sure there are no problems – note counts in log
- ☐ CLAP
  - Check the CLAP flow (**Section 3.4.3**)
  - Check offset
  - Inspect the blower block
- ☐ CN Box
  - Replace drier if there is one (**Section 6.2.1**)
  - Clean critical orifice and focusing nozzle (**Section 6.2.2**)
  - Measure the flows
  - Replace in-line filters upstream of the mass flow controllers
  - Flush CN sample line with denatured ethanol
  - BMI/MAGIC
- ☐ API
  - API filtered air test (**Section 2.1.1**)
  - Inspect the tubing to ensure that it is in good condition
  - Change the disposable filter (**Section 2.2.1**) unit and make a note of the pump performance "PWM" value
  - Check the flow on the API (**Section 3.4.5**)

    - Inspect and clean the optical chamber (**Section 6.3.1**)
    - Check and adjust the PMT with SpanDust (**Section 4.2**)

Inventory

- Update the station inventory file.

Miscellaneous Tasks

- Fix or add labels to places where needed (tubing, wires, etc.)

Back in Boulder

- Download pictures to: `/aer/photos/{stn}/maintYYYY`
- Put the maintenance documents (calibrations, inventory, maintenance log, etc.) in: `/aer/{stn}/doc/maintYYYY`
- Put updated flow diagram in the correct directory and provide to station collaborators: `/aer/doc/drawings/{stn}/STN_yyyymmdd.odg`
- Follow up on any tasks that need completion (i.e. ordering new parts)

Appendix B: List of Supplies for Annual Maintenance

The lists of supplies below are split into categories and are based on the assumption that the site being visited doesn't have any supplies. Before packing, check what is already at the site either by talking to the station technicians or looking at the station inventory from a previous maintenance visit.

Inventory logs and maintenance logs from previous visits can be found in: aer/stn/doc

- **General**
  - Check station inventory from last maintenance visit for available on-site supplies.
  - Check with site manager for site access (keys, contact phone numbers, directions, helper), disposable needs (filters, neph bulbs, butanol, etc).
  - Documents from previous station visit (inventory, maintenance log, calibration file).
  - Station flow diagram (in /aer/doc/drawings/stn/).
  - List of basic computer commands – e.g., calculating neph stats, CPC comparison plots etc.
  - Daily/weekly checklist form (hard-copy and electronic copy).
  - Return shipping labels for maintenance supplies if applicable.
  - Hard copy of stn config file or channel assignments (useful, but not necessary).
  - Most recent version of operations manual – hard copy for station techs.
  - Spare cables (RS232, instrument power cord, etc.)
  - Tools, including: large adjustable wrench, allen wrench set (for the splitter), assorted screwdrivers and wrenches (7/16", 1/2", 9/16" and 7/8"). Screwdriver for blower adjustment during pitot tube calibration.
  - Electrical kit: contact renewer (Jim's magic drops), chip puller, anti-static mat and/or grounding strap.
  - Assortment of tubing, fittings and ferrules (1/4", 1/2", 3/4"). ¼" nylon ferrules are especially useful!
  - Tape: duct, packing, labeling
  - Climbing harness and helmet (if needed)
  - Camera (NOTE: take lots of photos to document station and instrument configuration and status).
  - Cleaning: denatured ethanol, shop rags, paper towels, cotton swabs, dish scrubbers, thin bottle brush for splitter, thick bottle brush for 2" inlet tube.
  - Silicone sealant
  - Cable ties: long (pump filter), medium (tubing), short (wiring)
  - Plastic bags: Garbage, Ziplock
  - Multi-meter (useful for troubleshooting, also for T sensor calibration)
- **Flows**
  - Flow calibrator (with tubing and some ¼" and ½" connections). Need capability to calibrate low (~1 lpm (e.g., CLAP, CPC)), medium (10 lpm (e.g., CN drier, aethalometer)) and high (30 lpm (e.g., impactor box)) flows
- **System Filters**
  - HEPA filters (e.g., Gelman Sciences product#12144)
  - 1 for each nephelometer (use HEPA filters removed from nephelometer for 30-lpm mass flow controller (MFC) in impactor box)
  - Inline filters (1/4" tube ends, Parker finite filter IDN-4G or Balston DFU Grade AQ)
    - 1 for CN drier line (with ¼" nylon ferrules)

- 1 for CN flow line (with ¼" nylon ferrules), preferably the blue balston chemically resistant filters
- 1 for CO2 span check line (with ¼" nylon ferrules)
- 1 for each nephelometer, (with ¼" nylon ferrules)
- 1 for dilution system (if exists)
- 1 for aethalometer

  - Fiberglass filter mat for pump exhaust filter (36" wide) (if station has old homemade filter mat type filter) or replacement filter for new style pumpbox (pump box filter: RU-1200; pump box wrap: 22-8029PK, purchased from http://www.knfilters.com/)
  - Also need HEPA filter with correct fittings and inline filters for overnight zero measurements on neph and CLAP/PSAP (section 2.2). Don't assume site will have correct fittings to attach HEPA filter to nephelometer inlet unless specifically stated in station inventory!

- **T/RH sensor calibration**
  - Extension cables for RH sensors (neph and vaisala)
  - Spare Vaisala RH sensor.
  - Sleeve for RH sensors that allow you to put them in ¾" fittings
  - Handheld digital RH sensor readout.
- **Pressure calibration**
  - Magnehelic vacuum gauge for pitot tube calibration (0-0.5" H2O; if not on pumpbox)
  - Magnehelic vacuum gauge for neph impactor (0-15" H2O)
  - Magnehelic vacuum gauge for system vacuum (0-10 psi)
  - Magnehelic vacuum gague for chemical filters (XX-XX units), only for BRW
  - Manifold for pressure sensor calibration, with tubing, plugs as needed
  - Handheld vacuum pump, with tee fittings.
- **Pumpbox**
  - Pump repair kits (Check the manufacturer and model numbers of your pumps to determine the appropriate repair kit)
  - Gast carbon vane pump series#0823 and series#1023 both take kit# K479 - make sure kit has gasket, internal felt filters and replacement felt filter supports since those tend to break. Jim Wendell suggests not using felt filter on exhaust side since we have a big KNF filter and those filter clog and can cause the pump to stop working - need to keep the plastic support in there though.
  - Gast diaphragm pump #DOA/DAA takes kit#K294A and diaphragm #AF818B.
  - Pitot tube and acrylic tube (in case replacements are needed)
  - There are not repair kits for the pumpbox blower (we use Ametek Windjammer blowers model#116636 (120 VAC) and model#117636-51 (240 VAC))
- **CN Counter**
  - For overnight CPC comparisons (which only need to be done if the values from the current CPC have been problematic or suspect.
    - Reference CPC for overnight comparison (with power and serial cables).
    - Pulse counter (with power adapter, serial cable, BNC cable) if using CPC 3760
    - Mixing chamber, power for mixing chamber fan, and conductive tubing. Or sample room air through a tee to both CPCs.
  - Replacement drier tube (Permapure MD-110-12E-S)

- Stuff for BMI CPC
- Stuff for MAGIC CPC

- **Nephelometers**
  - Spare bulbs (GE EYC/CG)
  - Zero check HEPA filter, with ¾" Swagelok fitting for inlet of Neph
- **CLAP**
  - Zero check filter
  - CLAP sample filters (Pallflex E70-2075W, reorder #7192, 47 mm dia. or AZUMIs depending on station)
  - Filter bags (2"x3"/5cmx7.5cm, e.g., part#MGRL2W0203, from www.minigrip.com)

Appendix C: System and Instrument Calibration Procedures

Calibration of the Pump Box Pressure Transducer (Pitot Tube)

The excess (stack) air flow pulled by the blower is determined using the pressure difference across a pitot tube. The standard pitot tube setup in the pumpbox is shown in the figure below (**Fig. C1**).

The theory of getting a flow measurement using a pitot tube is described in depth here: http://www.engineeringtoolbox.com/pitot-tubes-d_612.html. In summary, the tube determines a flow velocity by using the pressure difference between the high-pressure flow through the central cavity of the tube and the low-pressure flow through the outer cavity of the tube (created using small holes in the sides of the central cavity – see schematic of pitot tube tip in **Fig. C1**).

We have redundant pressure difference readouts for the pump box. First, the magnehelic gauge (0-0.5 inches H_2O) is used to give a visual reading of the pressure difference. Typically, for a sea level site, the magnehelic should read ~0.25 inches H_2O to give a flow of ~850 lpm. Second, the pressure transducer sends a voltage to the µMAC that is related to the pressure difference – this way we have a value in the data files indicative of the stack air flow. The pressure transducer is calibrated using the magnehelic gauge so that the analog and digital information are consistent.

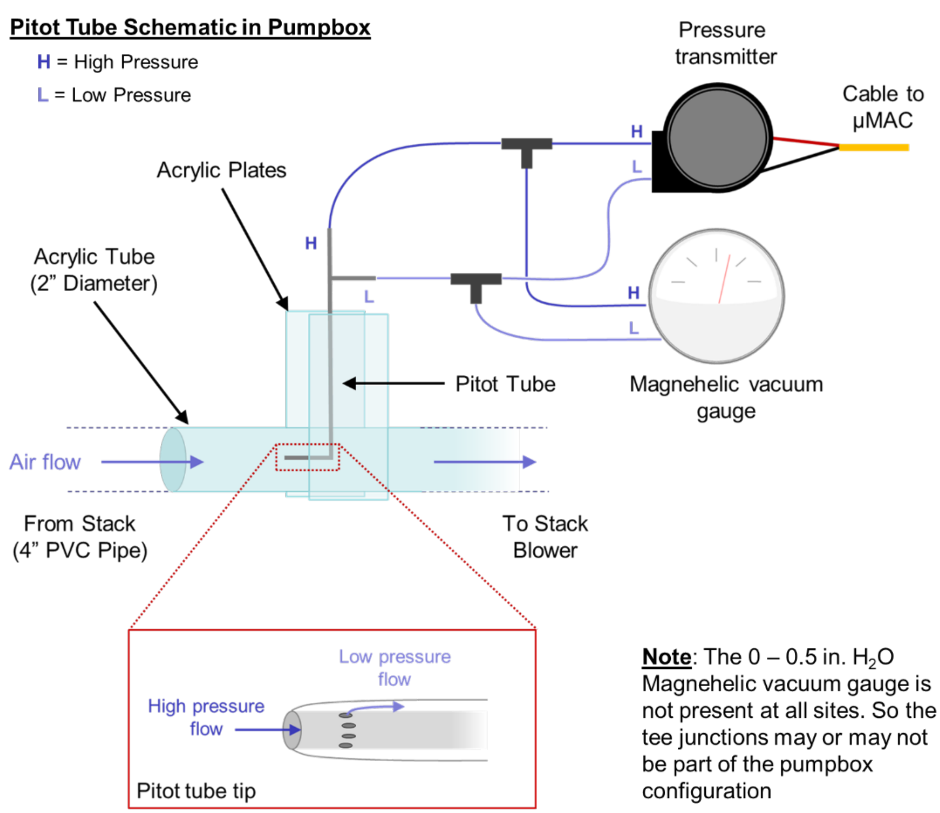


Figure C1: Schematic of the pitot tube set up in the pump box. This shows the pitot tube nested into the acrylic tube, with the tip oriented towards the oncoming airflow. A more detailed schematic of the pitot tip shows the direction of high (dark blue) and low (light blue) pressure flows within the tube.

Calibration Procedure

1. Figure out which µMAC or CR1000 channel the pressure transducer voltage is recorded on (pressure transmitter is typically, but not always, on channel 19). You will need to look at the configuration file to determine the channel assignment for your station. Use the desktop icon labeled 'Acquisition Configuration' to open the configuration file. Scroll down until you see a set of lines that look like this:

```
[instrument.X1.data.Pd_P01]
channel = 19
description = "stack pitot tube"
calibration =  [-0.50,3.42] # 20231027/ekb
cut_size = false
```

   This section should be grouped with the other lines for the µMAC or CR1000. This shows the variable identifier (Pd_P01), identifies that it is on channel #19, confirms that this is the pressure for the "stack pitot tube", and lists the calibration values. The calibration should be annotated with "#YYYYMMDD/nnn" where 'YYYYMMDD' is the year, month, and day of the calibration and 'nnn' is the initials of the person who did the calibration.

2. Open the µMAC or CR1000 instrument window on the FORGE acquisition screen by clicking on the blue button for the instrument. This will bring up a screen showing the voltages for each channel (**Fig. C2**).

3. Identify the voltage readout of the pressure transmitter channel (there is a red box drawn around channel #19 in **Fig. C2**)

4. Record the voltage (in this case 0.237) and then the pressure reading on the magnehelic gauge on the pump box (for example, 0.25 inches H2O).

5. Adjust the blower flow by turning the blower set screw. You should hear the blower change speed and see the magnehelic gauge value change.

   NOTE: there can be a slight lag time (~30s) between adjustment of the blower flow and response of the magnehelic. See **Fig. C3** for a picture of where the flow adjustment screw is on the blower.

6. Write down/ log the new magnehelic pressure reading and the corresponding new µMAC voltage reading.

7. Repeat this several times until you have a list of at least 5-6 values over the range of the magnehelic gauge, with several readings close to the typical value of 0.25 inches H_2O (at sea level) or whatever the appropriate value is for your station.

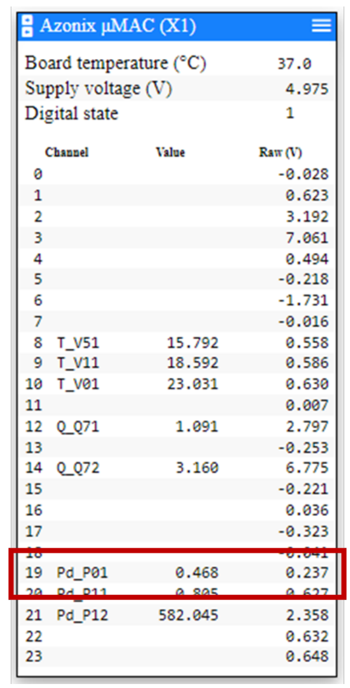


Figure C2: Example of a µMAC window and identification of the voltage readout of the pressure transmitter channel.

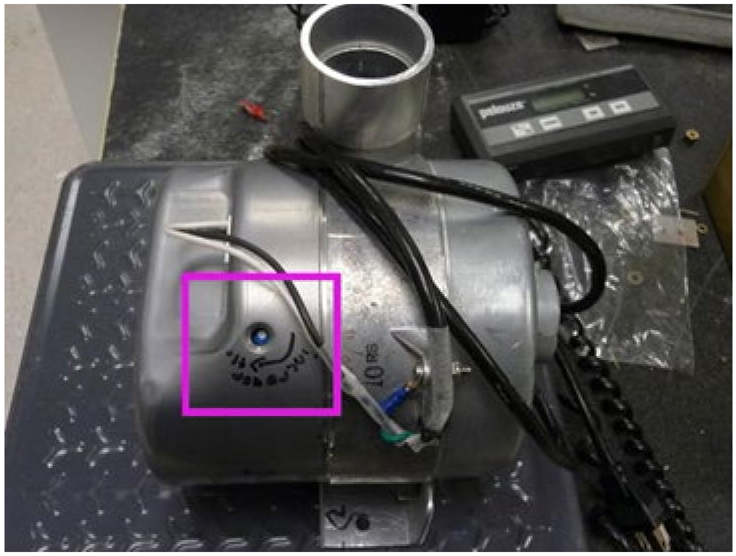


Figure C3: Position of the flow adjustment screw is on the blower, highlighted in the purple box.

8. Convert the Magnehelic_dP reading from 'Inches of water' to 'hPa' using the relationship:

$$1 \text{ inch } H_2O = 2.491 \text{ hPa}$$

9. Calculate the linear fit equation between voltage and hPa. An example calibration is shown in **Fig. C4**, with the dP values shown in the original units of in. H_2O, the values converted to units of hPa, and the corresponding voltages. The plot in **Fig. C4** shows the dP values vs. the recorded voltages and the best fit line (y = 3.9944 x -0.4787).

Calibration Data (Ch. 19)		
dP (in H2O)	dP (hPa)	Voltage
0.18	0.44838	0.232
0.21	0.52311	0.254
0.135	0.336285	0.203
0.24	0.59784	0.269
0.33	0.82203	0.327
0.3	0.7473	0.304

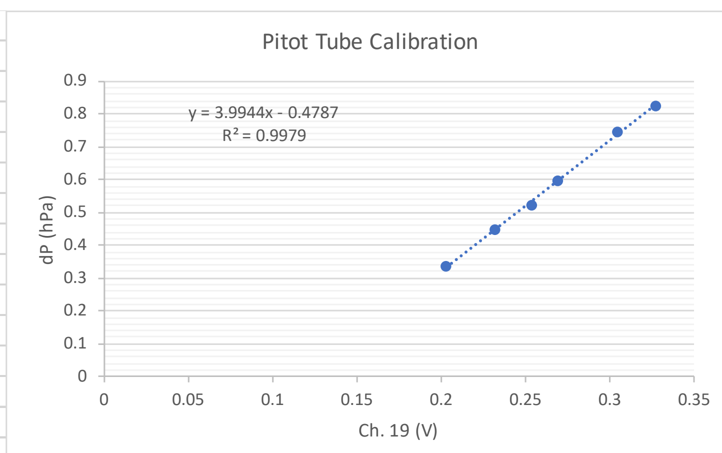


Figure C4: An example work-up of the pitot tube calibration.

10. Enter the new calibration in the configuration file. For the example above, the entry would be:

```
[instrument.X1.data.Pd_P01]
channel = 19
description = "stack pitot tube"
calibration =  [-0.48,3.99] # 20240412/ekb
cut_size = false
```

The intercept is the first variable listed, and the slope is the second in the calibration line. The annotation should also be updated with the date of the most recent calibration and the initials of the person who performed it.

11. Restart the acquisition software for the changes to take effect.

NOTE: You can also use the pitot tube equations to derive the flow. The equations are described in Dwyer's bulletin# H-11 available at http://www.dwyer-inst.com/PDF_files/160_IOM.pdf

The inner diameter of the tube that the pitot sits in is 1.75 inches.

You can do the calculations yourself or ask us for an excel spreadsheet template which you can enter the measured voltages and pressures and get the calculated flow rate.

Calibration of the RH Sensors

There are several Vaisala temperature/relative humidity sensors (Model#HMP50) incorporated into the GML-style aerosol rack. The nephelometer also has a relative humidity sensor that measures the RH of the nephelometer sampling volume. These sensors should be calibrated annually to maintain optimal performance of the aerosol system. The sensor calibrations are entered into the configuration file so that the recorded relative humidity data reflects the calibrated value.

Experience has shown that the factory calibration of new RH sensor modules for the Vaisala sensors is very good, and annual replacement of the sensor is an acceptable alternative to a full calibration. Adjustments can also be applied to the RH values of the Vaisala sensors, based on a comparison with a trusted (relatively new) sensor as long as the difference between the two sensors is not extreme.

This approach does not work for the RH sensor in the TSI nephelometer. Additionally, it is also not as accurate as generating a full calibration using saturated salt solutions. If you require high accuracy RH measurements in your system (i.e. if you are operating something like a humidograph system) then preforming full calibrations with saturated salt solutions is recommended. This procedure is not described in detail here, please contact us I you would like further information on the procedure for this calibration.

Measurement and application of an offset to RH sensors

Tools Needed:

- Relatively new Vaisala temperature/relative humidity sensor
- Zip tie, twist tie, or some tape to hold the reference sensor and system sensor next to each other
- Handheld RH sensor reader for the reference sensor

Procedure:

1. Carefully remove the RH sensor from the sample line.
2. Remove any debris from the outside of the sensor by blowing on it. Avoid the use of water or other solvents to clean the sensor.
3. Set the offset for the RH sensor in the configuration file to zero. The lines in the configuration file for the RH sensor in the splitter will look something like this:
4. Remove the outer cover of the reference RH sensor and use a zip tie, twist tie, or some tape to hold it next to the system sensor.

Flow Calibration Procedures

For the basic aerosol system there are several flows that need to be calibrated or checked. The following sections outline the flow checks and calibrations that need to be done on the aerosol system. Most flows are reported in terms of standard temperature and pressure where T=273.15 K and P=1013.35 mb. This is denotated as slpm, for standard liters per minute. The CN sample flow is the exception – that flow is controlled by a critical orifice and is measured in terms of volumetric flow. This is denotated as lpmv. For all flow measurements in the following sections make sure to use a calibration device (i.e. a BIOS or Gilibrator) to measure the flow and not a rotameter.

Impactor box flow calibration

Flow Measurement: Standard Liters per Minute (slpm)
Range of Flow Calibration Device: High (20 – 40 slpm)

Other items needed: A ½" Swagelok nut and a reducing ½" to ¼" port connector, or other Swagelok so the flowmeter can be attached to the impactor box.

<u>Procedure</u>:

1. Connect your flow calibration device to the ½ inch fitting on the back of the impactor box labeled 'Return Flow From Neph' (**Fig. C5**)

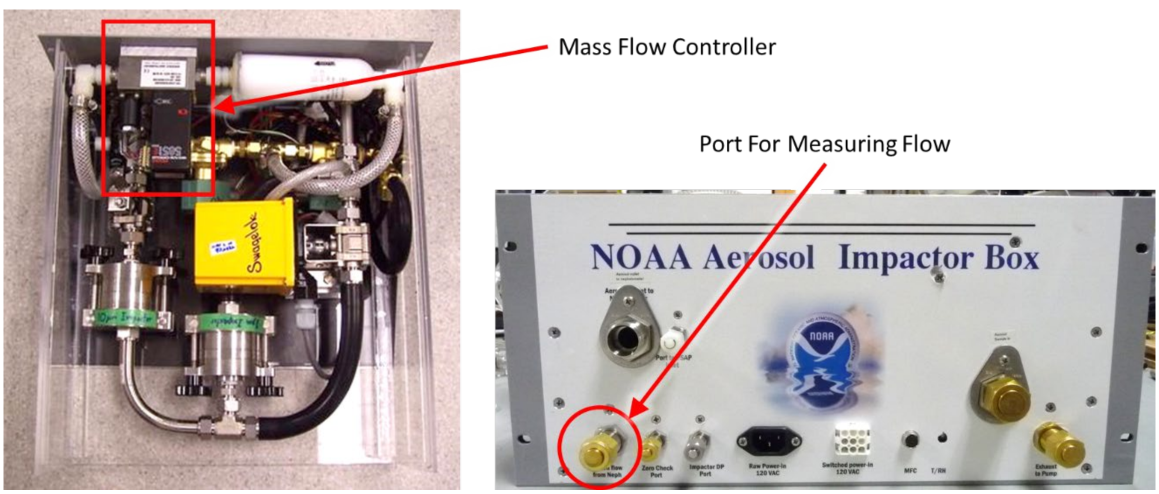


Figure C5: Top view of the impactor box (left) with the mass flow controller highlighted in a red box. The port where the flow meter should be attached is on the bottom of the impactor box panel (right image) in the bottom left corner and is labeled "Return Flow From Neph".

2. Use the PID setpoint control to adjust the flow over a range of values centered around the typical flow rate for the impactor box (30 lpmv). To change the setpoint using the FORGE acquisition interface select the blue button for the 'Love PID', then open its instrument menu and select 'Change Setpoint'. A box will come up with a drop-down menu. Select the flow variable (starts with 'Q'), input the new set-point, and press 'ok' to confirm the new set-point (**Fig. C6**).

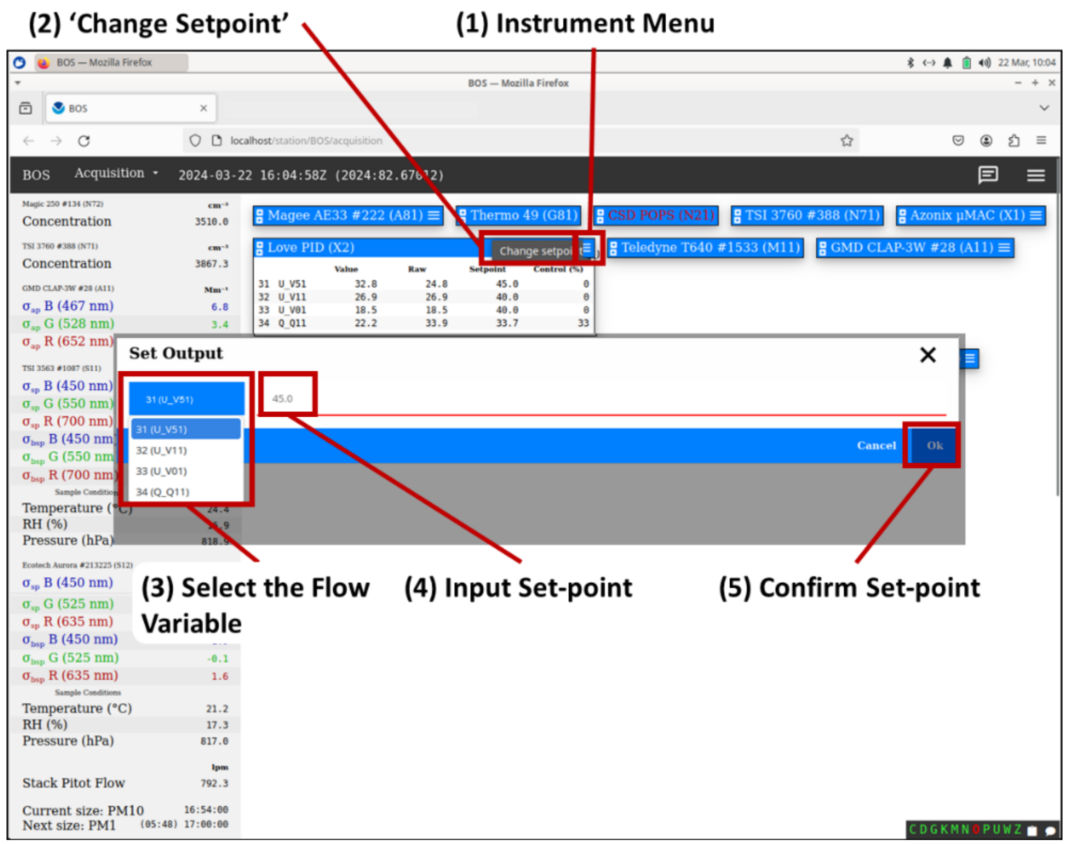


Figure C6: Visual steps for changing the PID set points using the FORGE acquisition interface.

3. The desired flow rate is 30 lpmv, but the calibration is done in slpm, so you'll need to calculate the proper slpm flow rate to get 30 lpmv – the slpm will be lower than the lpmv. To do this, the following equation can be used:

$$Q_{Target} = Q_{MFC} * \left(\frac{P_{site}}{1013.25}\right) * \left(\frac{273.15}{T_{site}}\right)$$

Q_{Target} – the flow (slpm) that you are trying to achieve.
Q_{MFC} – the flow (lpmv) needed at the impactor box MFC
P_{site} – approximate pressure at the site in mbar
T_{site} – approximate temperature at the site in Kelvin

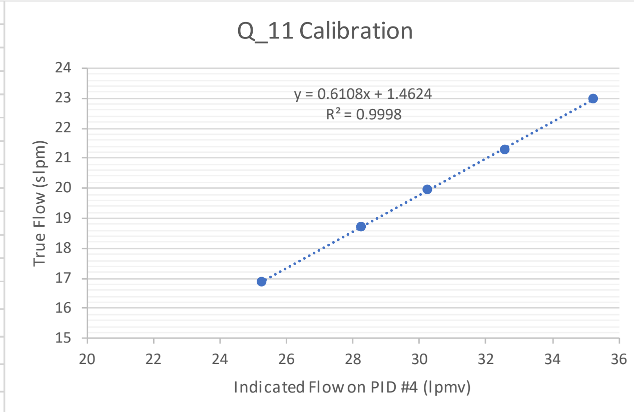
At sea level 27.2 slpm is ~ 30 lpmv assuming standard temperature of 0°C.

<u>**NOTE**</u>: At sites where there is a TAP or CLAP pick off from the nephelometer, the TAP/CLAP flow is subtracted from the target flow of 30 lpmv. This is the case for the calibration shown in **Fig. C7**, in the top lines of that example this subtraction is shown with the TAP/CLAP flow being 1 lpmv.

4. Make a plot of the flow from your flow calibration device (true flow in slpm) on the y-axis and the PID flow value (lpmv) on the x-axis. An example calibration is shown in **Fig. C7**.

Calculation of Target Flow	
Flow Needed at Impactors (lpmv):	30
Flow at MFC (lpmv):	29
Temperature Assumption (K):	294
Pressure Assumption (mbar):	830
Target flow rate (slpm):	**22.07**

Calibration Data		
Set Point	PID Flow	True Flow (slpm)
35	35.23	23.008
32.3	32.55	21.287
30	30.23	19.948
28	28.23	18.726
25	25.24	16.871



Calculation of Set-Point for Flow	
Slope from Graph:	0.6108
Intercept from Graph:	1.4624
Flow set-point (lpmv):	**33.74**

Figure C7: An example work-up of the impactor box flow calibration.

5. Enter the new calibration in the configuration file. For the example above, the entry would be:

```
[instrument.X2.data.Q_Q11]
address = 0x34
type = "sample_flow"
description = "analyzer flow"
calibration = [1.46,0.61] # 20240412/ekb
```

The annotation should also be updated with the date of the most recent calibration and the initials of the person who performed it.

6. Use the linear equation to calculate the new flow setpoint (lpmv). Following the procedure in step #2 of this calibration, change the flow setpoint on the PID to the new calculated setpoint using the FORGE instrument menu.

CN box flow calibration and check

The NOAA GML CN Box has two flow procedures, the first is a flow calibration and the second is a sample flow check. Note that the flow measurements of the two procedures are different. These procedures will be the same regardless of the condensation nuclei (CN) or condensation particle counter (CPC) instrument being used in the CN box.

Sample and Drier Flow Calibration

Flow Measurement: Standard Liters per Minute (slpm)
Range of Flow Calibration Device: Low / Medium

Procedure:

1. Confirm the channels of the µMAC or CR1000 that are reporting the readout of the mass flow meters (MFM). You will need to look at the configuration file to determine the channel assignment for your station. Use the desktop icon labeled ‘Acquisition Configuration’ to open the configuration file. Scroll down until you see a set of lines that look like this:

```
[instrument.X1.data.Q_Q71]
channel = 12
description = "CPC flow"
calibration =  [0.1498,0.378] # 20231027/ekb
cut_size = false

[instrument.X1.data.Q_Q72]
channel = 14
description = "CPC drier flow"
calibration =  [0.0784,0.352] # 20231027/ekb
cut_size = false
```

   This section should be grouped with the other lines for the µMAC or CR1000. This shows the variable identifiers (Q_Q71 and Q_Q72), identifies the channels, describes what the variables are, and lists the calibration values. The calibration should be annotated with “#YYYYMMDD/nnn” where ‘YYYYMMDD’ is the year, month, and day of the calibration and ‘nnn’ is the initials of the person who did the calibration.

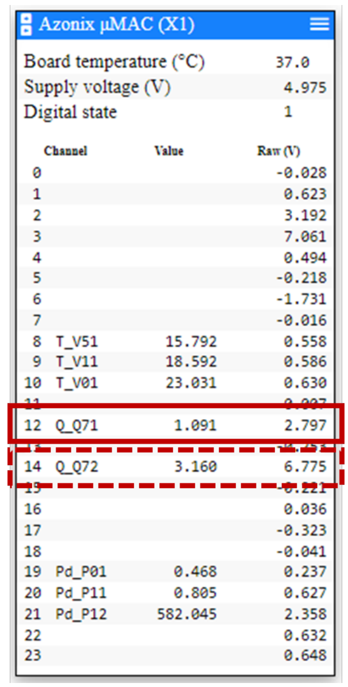


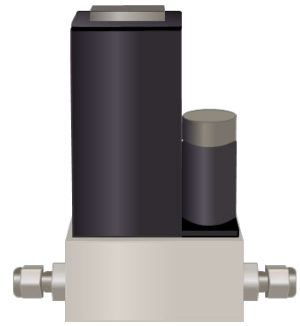
Figure C8: Example of a µMAC window and identification of the voltage readout of the two mass flow controllers for the CN Box.

2. Open the µMAC or CR1000 instrument window on the FORGE acquisition screen by clicking on the blue button for the instrument. This will bring up a screen showing the voltages for each channel (**Fig. C8**).

3. Identify the voltage readout of the mass flow controller for the CN/CPC flow (red solid box in **Fig. C8**), and the drier flow (red dashed box in **Fig. C8**).

4. Before you start the calibration, identify/confirm what kind of MFM your CN Box.

   • If you have *Brooks mass flow meters* (black and silver, ~5 inch tall, 1 inch wide, 3 inch deep, see image on right) then you can proceed with the calibrations without changing anything in the configuration file. Your final calibrations will be based on the measured flows, from the flow calibration device, and the voltage reported by the MFM, from the μMAC or CR1000 instrument window (under the 'Raw (V)' column).



   • If you have *TSI mass flow meters* (white or beige, 2 inch tall, 1 inch wide, 5 inch deep, see image on right) then you will first need to put the default calibration into the TSI flow meter module in the configuration file and restart acquisition so that the new calibration is applied. Your final calibrations will be based on the measured flows, from the flow calibration device, and the flow reported by the MFM, from the μMAC or CR1000 instrument window (under the 'Value' column).

5. To calibrate the CN/CPC instrument flow, connect your flow calibration device to the inlet of the CN/CPC instrument (where flow is controlled by a critical orifice).

6. Record the flow measured by the flow calibration device (slpm) and either the voltage or flow (depending on the type of MFM) reported by the "CPC flow" MFM (variable Q_Q71 on channel #12 in **Fig. C8**). Do this for when the flow is on and then turn the flow off and record those values. This will give you a two-point calibration for the flow (see **Fig. C9**).

   NOTE: The easiest way to turn the flow "off" is to disconnect the flow from the back of the instrument. Just don't forget to reconnect the flow afterwards.

7. To calibrate the drier flow, connect the flow calibration device to the inlet of the MFM for the drier flow (where flow is controlled by a homemade critical orifice).

8. Record the flow measured by the flow calibration device (slpm) and either the voltage or flow (depending on the type of MFM) reported by the "CPC drier flow" MFM (variable Q_Q72 on channel #14 in **Fig. C8**). Do this for when the flow is on and then turn the flow off and record those values. This will give you a two-point calibration for the flow.

9. Make a plot of the flow from your flow calibration device (true flow in slpm) on the y-axis and either the voltage or flow from the MFM (depending on the type of MFM) on the x-axis. An example calibration is shown in **Fig. C9**.

10. Enter the new calibration in the configuration file. For the example above, the entry for the CPC flow would be:

```
[instrument.X1.data.Q_Q71]
channel = 12
description = "CPC flow"
calibration =  [0.1541,0.3351] # 20240412/ekb
cut_size = false
```

For the CPC drier flow the entry would be:

```
[instrument.X1.data.Q_Q72]
channel = 14
description = "CPC drier flow"
calibration =  [0.0871,0.4536] # 20240412/ekb
cut_size = false
```

11. Restart the acquisition software for the changes to take effect.

Calibration Data	
CPC Flow (slpm)	Ch. 12 (V)
1.1521	2.978
0	-0.46
Drier Flow (slpm)	Ch. 14 (V)
3.156	6.766
0	-0.192

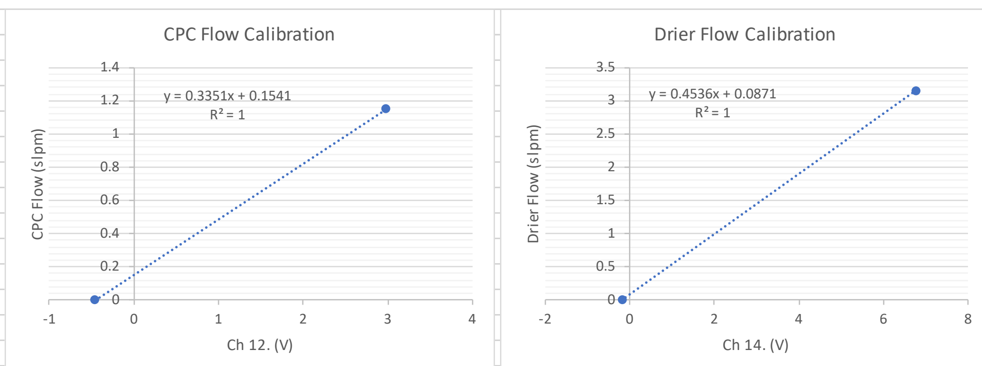


Figure C9: An example calibration for a CPC instrument flow and a CN box drier flow from a site using Brooks mass flow meters in the CN box.

Sample Flow Check

Flow Measurement: Volumetric Liters per Minute (lpmv)
Range of Flow Calibration Device: Low / Medium

<u>Procedure</u>:

1. Connect your flow calibration device to the inlet of the CN instrument.

2. Measure the flow at the inlet, and if needed convert the flow to units of cubic centimeters per second (cc/s). Some flowmeters will allow you to measure the flow in units of volumetric cc/s directly, however, if this is not possible you will need to convert lpmv to cc/s afterwards (1 cc = 1 mL).

3. Update the flow (in cc/s) in the configuration file. The flow should be put in the field for 'Q' in the instrument data lines. This will look like this:

   ```
   [instrument.N71]
   type = "tsi3760cpc"
   serial_port = "/dev/ttyUSB3"
   cut_size = false
   serial_number = 388
   [instrument.N71.data]
   Q = 1.536 # 20240412/ekb
   ```

   The annotation should also be updated with the date of the most recent calibration and the initials of the person who performed it.

Magic Flow Calibration Factor

Although there are differences between the flow configurations of the different Magic models, the flow measurement is the same. The Magic uses a pressure drop across an internal orifice to determine the flow of the instrument. Regardless of model, the main sample flow for the Magic should be ~0.3 L/min volumetric (lpmv). If the reported flow is not ~0.3 lpmv then you may need to update the flow calibration factor and the pump power to achieve the correct flow.

Checking the Flow Calibration Factor

Flow Measurement: Volumetric Liters per Minute (lpmv)
Range of Flow Calibration Device: Low / Medium

<u>Procedure</u>:

1. First, open the instrument parameters in the FORGE acquisition screen by opening the instrument menu and selecting 'Set Parameters' (first two steps in **Fig. C10**), a window should open showing the current instrument settings. Note the current flow calibration factor ('qcf' in **Fig. C10**), and make sure it is in the range reported (**Table C1**).

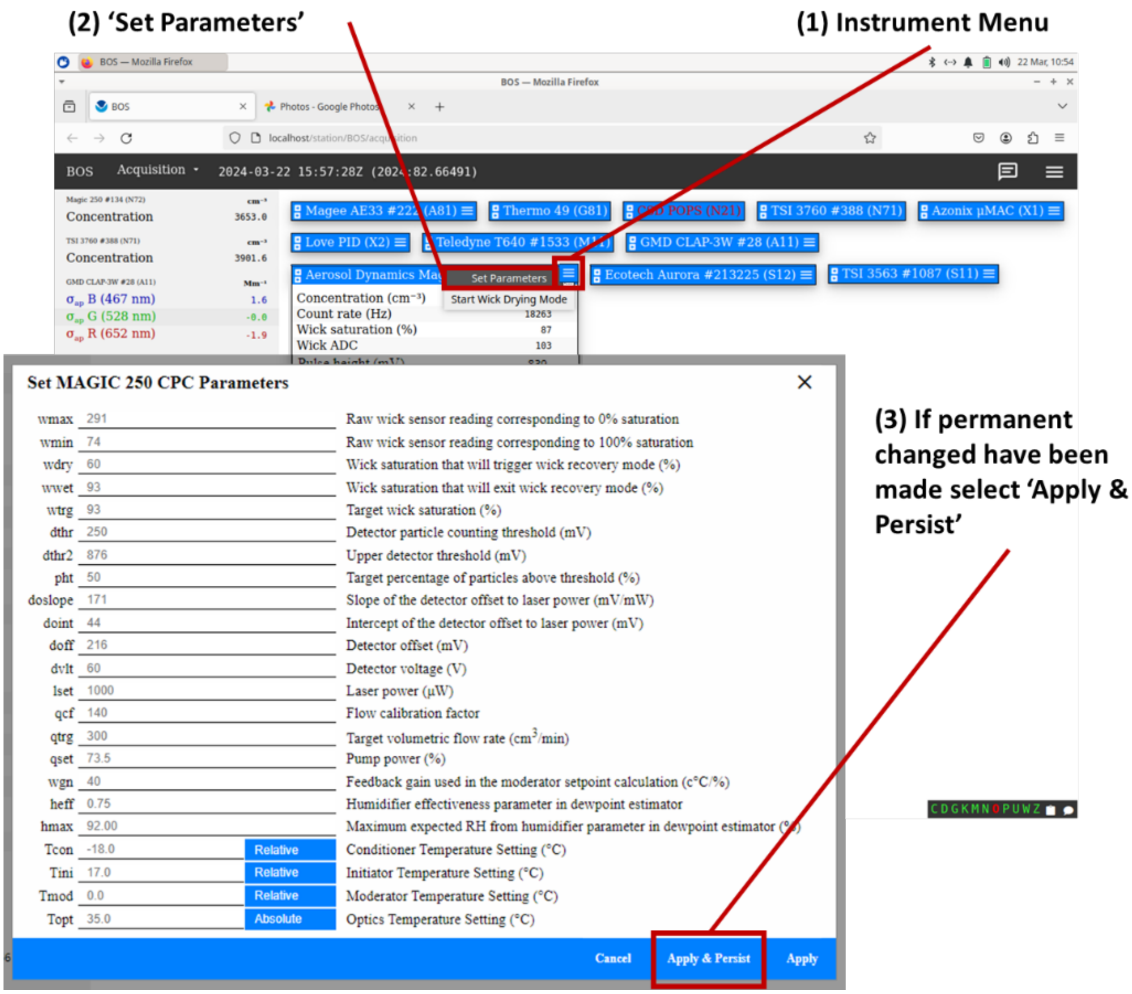


Figure C10: Steps for checking the Magic CPC variable setpoints using the FORGE acquisition interface.

Table C1: List of the flow scale / calibration factor identifiers and ranges for the different Magic models.

Model #	**200P**	**200 & 210**	**250**
Variable	`fsf`	`qcf`	`qcf`
Range or approx. value	~128	$40 \leq N \leq 255$	$1 \leq N \leq 255$
Description	Flow scale factor	Flow calibration factor	Flow calibration factor

2. While the instrument is running attach your external flow meter to the inlet of the Magic. Make sure the flow being measured is volumetric, not standard.

   If you have a 210 model you will need to disconnect the 'transport flow', which is a clip-lok port on the bottom of the instrument. This is the only model with an auxiliary flow of 0.1 lpmv through this line. Once it is detached your target flow will be 0.3 lpmv, just like the other Magic models.

3. Record both the measured flow and the flow reported on the FORGE instrument screen. There are two fields on the Magic instrument screen for flow: 'flow' and 'display flow'. In most cases the two numbers will be the same, but if they are not - take the number from the 'display flow' field.
4. Once you have these numbers use the following formula to calculate the new flow calibration factor:

$$qcf_{new} = qcf_{old} \times \left(q_{real} \,/\, q_{display}\right)$$

   In this equation qcf_{old} is the number you recorded in step #2 of these directions, q_{real} is the flow that you measured, and $q_{display}$ is the flow that the instrument is reporting. For example, if the initial qcf value of an instrument was 122, and the flow was measured to be 0.250 lpmv but the instrument displayed a flow of 0.300 lpmv, then the new flow scale/ calibration value would be:

$$qcf_{new} = 122 \times (0.250\, lpmv \,/\, 0.300\, lpmv) = 102$$

5. Once you have the new scale/ calibration factor set this in the instrument configuration. Follow the steps from step #1 (Fig. C10) to open the parameters menu, click on the field next to variable, type the new value, and select 'Apply & Persist'.

   <u>NOTE:</u> 'Apply & Persist' will make sure the variable changes remain even if the instrument is restarted – it is the equivalent of save

6. Measure the flow again and make sure that the measured flow and the flow displayed on the instrument now match within ±3%.

   If you are working with a 210, make sure to plug the 'transport flow' back in on the bottom of the instrument when you are done!

Changing the Flow on the Magic

If you follow the steps above, and the flow is still not at ~0.3 lpmv then you may need to adjust the flow set point. This should not have to be done often, if you notice that flow is dropping consistently than this may be a sign of a dying pump. For this adjustment it can be helpful to have an external flow meter to confirm the actual flow while you are changing the pump set point. Note that there are two sets of procedures for the different models of the Magic CPC.

Flow Measurement: Volumetric Liters per Minute (lpmv)
Range of Flow Calibration Device: Low / Medium

<u>Procedure for Magic 210, 200, & 200P</u>:

1. Follow the steps from above to open the instrument parameters in the FORGE acquisition screen (**Fig. C10**). Note what the pump set point is (‘qset’ in **Fig. C10**).

2. To decrease the flow, set the pump set point lower and to increase flow increase the pump set point. To change the values follow the steps from **Fig. C10** to open the parameters menu, click on the field next to variable, type the new value, and select ‘Apply & Persist’.

3. Check that the instrument reported flow is now ~0.3 lpmv, and if using an external flow meter check that the actual flow matches the reported flow. If the flow still is not where it should be, repeat the steps above until the desired flow is achieved.

   <u>NOTE:</u> For these Magic CPC models, qset is initially set to ~150. The maximum set point is 255 (**Table C2**). If you need to set qset to ≥ 242 to achieve the correct flow then you may have a pump problem.

<u>Procedure for Magic 250:</u>

The Magic 250 is slightly different because it has a flow control built in. When the flow control is enabled during normal operation you will not be able to change the pump set point. Changing these settings for the 250 is therefore only recommended if you are seeing strange fluctuations or trends in the instrument flow that indicate pump or flow control problems.

1. Follow the steps from above to open the instrument parameters in the FORGE acquisition screen (**Fig. C10**). Note what the pump set point is (‘qset’ in **Fig. C10**), and set the target flow rate variable to zero (‘qtrg’ in **Fig. C10**). In this case select ‘Apply’ and not ‘Apply & Persist’, as we want to make sure the flow control is not permanently disabled.

2. Once flow control is off, you can change the pump set point to some new value. The maximum set point for the Magic 250 is 100 (**Table C2**).

3. Check that the instrument reported flow is now ~0.3 lpmv, and if using an external flow meter check that the actual flow matches the reported flow. If the flow still is not where it should be, repeat the steps above until the desired flow is achieved.

   <u>NOTE</u>: If you need an N ≥ 95 (pump at 95% power) to achieve the correct flow then you likely have a pump problem. However, if N < 95 and setting the pump power manually produces a stable flow of ~0.3 lpm then you may have issues with the flow controller.

Table C2: List of the pump setpoint variables with ranges for the different Magic models.

Model #	**200P**	**200 & 210**	**250**
Variable	`ppw`	`qset`	`qset`
Range	$0 \leq N \leq 255$	$0 \leq N \leq 255$	$0 \leq N \leq 100$
Description	Pump pulse width. Instruments are usually set to 200 – 220, with 255 setting the pump to it maximum.	Flow set point. This setting has arbitrary units. Instruments are usually set to ~150.	Pump power %

* Note that for the 250, `qset` cannot be changed while the flow control is active.

CLAP Flow Calibration

There are two calibrations for the CLAP in the configuration file. The entry for the CLAP in the configuration file will look like this:

```
[instrument.A11]
type = "clap"
serial_port = "/dev/ttyUSB4"
advance_transmittance = [0.3, 0.5, 0.3]
spot = [19.67, 20.17, 20.23, 20.50, 19.88, 20.05, 19.80, 19.50]
hardware_flow_calibration = [-0.65311, 0.69929, -0.19473, 0.04253] #
20200129/pjs@GML
[instrument.A11.data.Q]
scale = 0.995 # 20231027/ekb
```

The first is a polynomial fit of flow to voltage done at NOAA, listed as the 'hardware_flow_calibration' in the configuration file. The actual flow calibration for the CLAP is complicated – please talk to a NOAA scientist if you think this is needed. The second flow calibration is a tweak to the flow calibration to account for departure of the polynomial fit from the desired flow rate, listed as the 'scale' in the configuration file. The tweak value in configuration file is the ratio of the measured flow, using a BIOS flow meter, to the CLAP reported flow. To get this number, follow the procedure below.

Flow Measurement: Standard Liters per Minute (slpm)
Range of Flow Calibration Device: Low / Medium

Procedure:

1. Change the 'scale' value in the configuration file to 1.0 (i.e. no scaling will now be applied to the flow), and restart the acquisition system to apply the new scale value.

2. Calculate the desired operating flow for the CLAP at your site. The desired instrument flow is 1 lpmv. This is done to keep the face velocity across the filter consistent across the NOAA network. However, the instrument is calibrated in slpm. The flow setpoint will need to be calculated:

$$Q_{Target} = 1.0\ lpmv * \left(\frac{P_{site}}{1013.25}\right) * \left(\frac{273.15}{T_{site}}\right)$$

   Q_{Target} – the flow (slpm) that you are trying to achieve.
   P_{site} – approximate pressure at the site in mbar
   T_{site} – approximate temperature at the site in Kelvin

3. Set the CLAP flow to the desired operating flow using the valve on front of the CLAP, and measure the flow at the inlet of the CLAP.

4. Record the measured flow and the flow reported on the instrument menu on the FORGE acquisition screen. Calculate the new scale value:

$$scale = Q_{measured}/Q_{reported}$$

   If the value is 1.1 < scale < 0.9, then a new calibration may be needed. Please contact a NOAA scientist.

5. Update the 'scale' value in the configuration file, and restart the acquisition system for it to take effect.

Calibration of the μMAC and CR1000 Pressure Sensors

On the back of the μMAC and CR1000 boxes there are an array of pressure sensors that need to be calibrated over two different pressure ranges: 0-10 psi and 0-8" H_2O. Two different calibration pressure ranges are needed due to the various pressure differentials (dP) that are monitored using the μMAC or CR1000 boxes. **Table C1** lists the various dP values monitored at NFAN sites, their typical maximum values for various units, and their required calibration ranges. Not all of the pressure sensors are used but calibration data is collected over both ranges for all four sensors. This is done so that we can easily change which pressure sensors are being used in the event that a sensor fails.

Table C1: Monitored dP values, their typical maximum values for various units, and their required calibration ranges.

Monitored dP	Maximum dP Values* hPa	psi	Inches H_2O	Appropriate Calibration Range
Filter Rack dP	150	1.5	60	0 – 2 psi
Nephelometer Impactor dP	15	0.15	6	0 – 8 inches H2O
System/CN Vacuum dP	600	6	240	0 – 10 psi

* Conversion Values: 1 hPa = 0.01 psi; 1 hPa = 0.40 in. H2O

For a μMAC, the pressure sensors correspond to channels #20 - #23 in the instrument window on the FORGE acquisition screen (even though they are numbered 1-4 on the box itself). For a CR1000 the pressure sensors correspond to channels #13 - #16 in the instrument window (they are numbered according to their channel on the box). See **Fig. C1X** for schematics of the two boxes, with the pressure sensors indicated by red boxes.

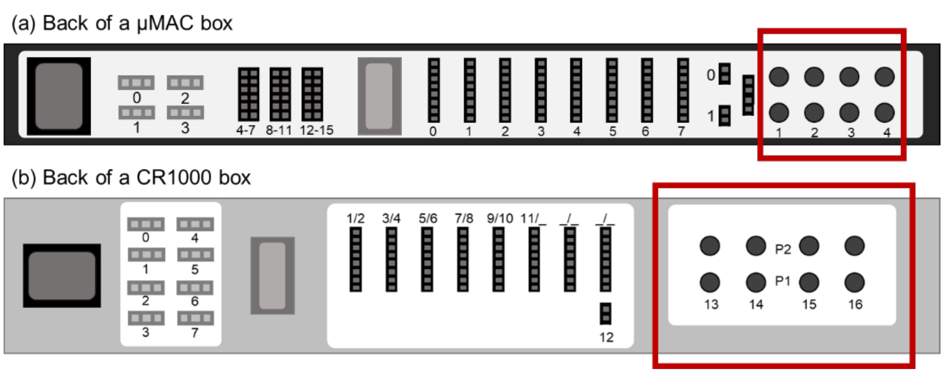


Figure C1X: Location of the pressure sensor array on the backs of both a (a) μMAC and (b) CR1000 box. The array of sensors is highlighted using red boxes.

<u>Tools Needed for Calibration</u>:

- Magnehelic vacuum gauge (0 – 15 inches H_2O)
- Magnehelic vacuum gauge (0 – 10 psi)
- Manifold for pressure sensor calibration: tubing, tee fittings, and plugs as needed
- Handheld vacuum pump
- Tape and markers for labeling the tubing currently attached to the pressure sensors

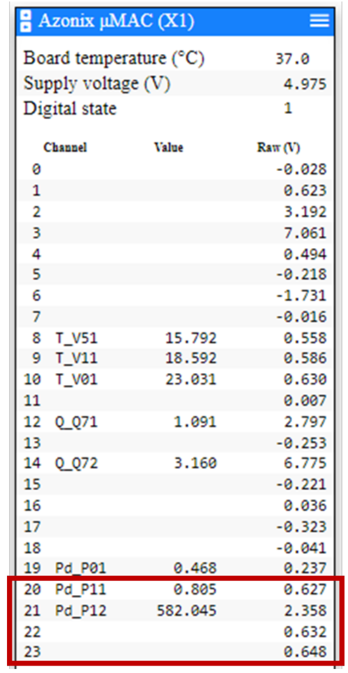
Procedure:

1. Take a look at the back of the µMAC or CR1000, note which ports / channels are currently being used and by what. If you are unsure about which channels correspond to which variables, check the configuration file and µMAC or CR1000 instrument window. These are sample lines from a site using a µMAC:

```
[instrument.X1.data.Pd_P11]
channel = 20
description = "impactor pressure drop"
calibration =  [-204.49,326.52] # 20231027/ekb
cut_size = false

[instrument.X1.data.Pd_P12]
channel = 21
description = "system vac"
calibration =  [-212.3,336.34] # 20231027/ekb
cut_size = false
```

This section should be grouped with the other lines for the µMAC or CR1000. The configuration file lines above indicate that the impactor pressure drop is being measured by channel #20 (pressure sensor #1 on µMAC) and the system vacuum is being measured by channel #21 (pressure sensor #2 on the µMAC). This is confirmed on the instrument screen (**Fig. C1X**) which shows only channels #20 and #21 giving pressure readings. These channels are also labeled with the variable IDs (Pd_P11 & Pd_P12), which are in the section headers of the configuration file lines corresponding to each variable.



Azonix µMAC (X1)

Board temperature (°C)	37.0
Supply voltage (V)	4.975
Digital state	1

Channel		Value	Raw (V)
0			-0.028
1			0.623
2			3.192
3			7.061
4			0.494
5			-0.218
6			-1.731
7			-0.016
8	T_V51	15.792	0.558
9	T_V11	18.592	0.586
10	T_V01	23.031	0.630
11			0.007
12	Q_Q71	1.091	2.797
13			-0.253
14	Q_Q72	3.160	6.775
15			-0.221
16			0.036
17			-0.323
18			-0.041
19	Pd_P01	0.468	0.237
20	Pd_P11	0.805	0.627
21	Pd_P12	582.045	2.358
22			0.632
23			0.648

Figure C1X: Example of a µMAC window and identification of the pressure sensors readings.

2. Label all tubing then disconnect it from the pressure sensors.

3. Assemble the pressure calibration manifold, and attach it to the µMAC or CR1000 sensor array. The manifold should connect the handheld vacuum pump to the magnehelic vacuum gauge, with a tee connection between them that goes to the pressure sensor (**Fig. C1X**). Note that two pressure sensors can be calibrated at the same time if an additional tee fitting is used (**Fig. C1X**).

   NOTE: You will need to place the magnehelic vacuum gauge on a surface where it can be made to sit upright – the flat back should not be on a horizontal surface and the face of the gauge should face a wall and not the ceiling. If it is not oriented correctly the pressure readings will be inaccurate.

4. Take the first reading without any pressure applied, record the dP and voltage reported in the µMAC or CR1000 instrument window.

5. Change the pressure using the handheld vacuum pump. For the calibration over 0 – 8 inches H_2O, steps of ~2 inches H_2O are recommended to achieve a 5-point calibration. For the calibration over 0 – 10 psi, steps of ~2 psi are recommended to achieve a 6-point calibration. At each pressure record the dP and voltage reported in the µMAC or CR1000 instrument window.

   NOTE: If the pressure value on the magnehelic drifts lower which you are trying to take a reading then there is a leak in pressure calibration manifold which you will need to fix before moving forward with the calibration.

6. Use the recorded pressure and voltage readings to make a calibration for the pressure sensors. An example calibration for both the 0 – 8 inches H_2O and 0 – 10 psi pressure range are shown in **Fig. C1X** and **Fig. C1X** respectively. The pressures all need to be converted to units of hPa for the calibration, the conversion can be doing using the following relationship:

$$1 \text{ hPa} = 0.0145 \text{ psi} = 0.401 \text{ in. } H_2O$$

7. Enter the new calibration in the configuration file. The entry for the channel #20 calibration from the example show would be:

```
[instrument.X1.data.Pd_P11]
channel = 20
description = “impactor pressure drop”
calibration =  [-204.62,327.62] # 20240412/ekb
cut_size = false
```

8. Restart the acquisition software for the changes to take effect.

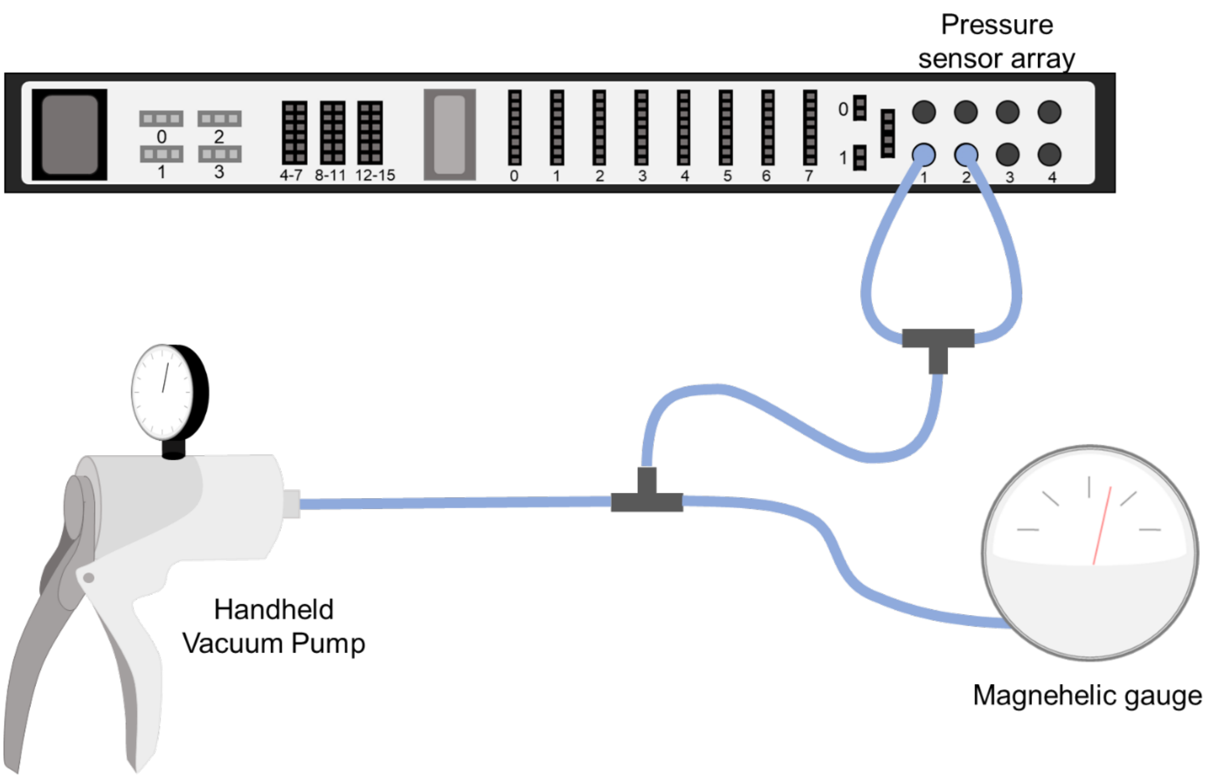
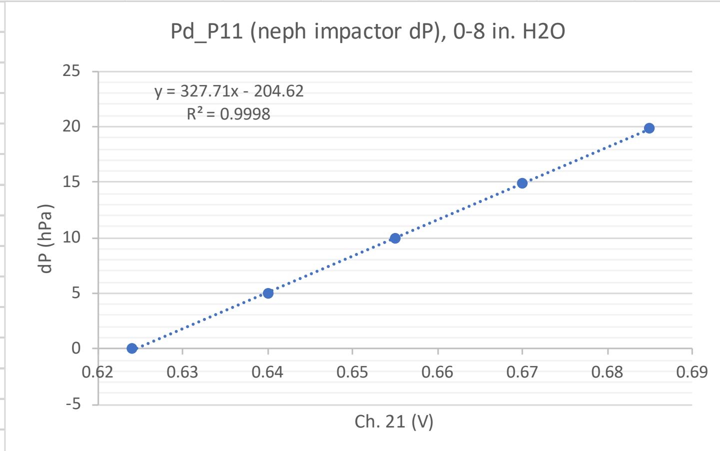


Figure C1X: Schematic of an example set-up for calibration of a µMAC’s pressure sensors. In this figure both pressure sensors #1 and #2 are being calibrated at the same time.

Neph Impactor (Ch. 20)		
dP (in H2O)	dP (hPa)	Voltage
0	0	0.624
2	4.982	0.64
4	9.964	0.655
6	14.946	0.67
8	19.928	0.685



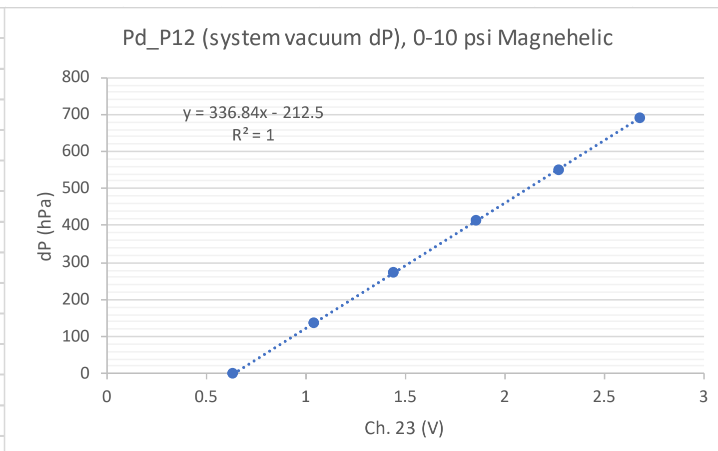
Auxilary Port #1 (Ch. 21)		
dP (in H2O)	dP (hPa)	Voltage
0	0	0.628
2	4.982	0.644
4	9.964	0.659
6	14.946	0.674
8	19.928	0.689

Auxilary Port #2 (Ch. 22)		
dP (in H2O)	dP (hPa)	Voltage
0	0	0.632
2	4.982	0.647
4	9.964	0.662
6	14.946	0.676
8	19.928	0.692

Auxilary Port #3 (Ch. 23)		
dP (in H2O)	dP (hPa)	Voltage
0	0	0.649
2	4.982	0.664
4	9.964	0.679
6	14.946	0.693
8	19.928	0.71

Figure C1X: An example calibration for an array of μMAC pressure sensors over the 0 – 8 inches H_2O pressure range. A calibration curve is only shown for the first μMAC pressure sensor (channel #20) as this is the sensor used for the impactor (see configuration file lines and Fig. C11 above).

System Vacuum (Ch. 21)		
dP (psi)	dP (hPa)	Voltage
0	0	0.633
2	137.896	1.043
4	275.792	1.441
6	413.688	1.859
8	551.584	2.273
10	689.48	2.677



Auxilary Port #1 (Ch. 20)		
dP (psi)	dP (hPa)	Voltage
0	0	0.624
2	137.896	1.038
4	275.792	1.431
6	413.688	1.847
8	551.584	2.285
10	689.48	2.69

Auxilary Port #2 (Ch. 22)		
dP (psi)	dP (hPa)	Voltage
0	0	0.631
2	137.896	1.04
4	275.792	1.433
6	413.688	1.839
8	551.584	2.275
10	689.48	2.706

Auxilary Port #3 (Ch. 23)		
dP (psi)	dP (hPa)	Voltage
0	0	0.649
2	137.896	1.056
4	275.792	1.456
6	413.688	1.856
8	551.584	2.299
10	689.48	2.713

Figure C1X: An example calibration for an array of μMAC pressure sensors over the 0 – 10 psi pressure range. A calibration curve is only shown for the second μMAC pressure sensor (channel #21) as this is the sensor used for the system vacuum (see configuration file lines and Fig. C11 above).

Nephelometer Span check and Calibration

Calibration and Span check Set-up

In order to preform a span check or calibration, the instrument must be supplied with a high span gas (at NFAN sites CO_2 is used).

Span checks

A span gas check is used to evaluate the performance of a nephelometer and assess the accuracy of the calibration. In a span gas check the scattering coefficients of a low span gas (typically filtered air) and a high span gas (for example, CO_2) are measured under instrument conditions of temperature and pressure. The results are used to derive the measured scattering coefficient of CO_2 under conditions of standard temperature and pressure (STP; 273.15K and 1013.25 mb). The measured value of scattering by pure CO_2 is compared with the published value for each measurement wavelength. The mean "error" in the CO_2 measurement (i.e., the difference from the CO_2 target value), calculated from each of the six nephelometer channels (three wavelengths each with a total and hemispheric backscatter measurement) should be within a few percent, with no individual channel's error being larger than 10%. If the compiled error is > 5%, this indicates either an instrument problem or a poor calibration. The following instructions will outline how to perform a calibration on both the TSI integrating nephelometer and the Ecotech Aurora 3000 nephelometer, both of which are used at NFAN sites.

Appendix D: System Cleaning and Part Replacement Procedures

Cleaning the Pitot Tube in the Pump Box

A pitot tube is a piece of equipment that determines fluid flow velocity by measuring the difference in total and static pressure. There is a pitot tube in the pump box, housed in an acrylic tube (see Fig. C1)

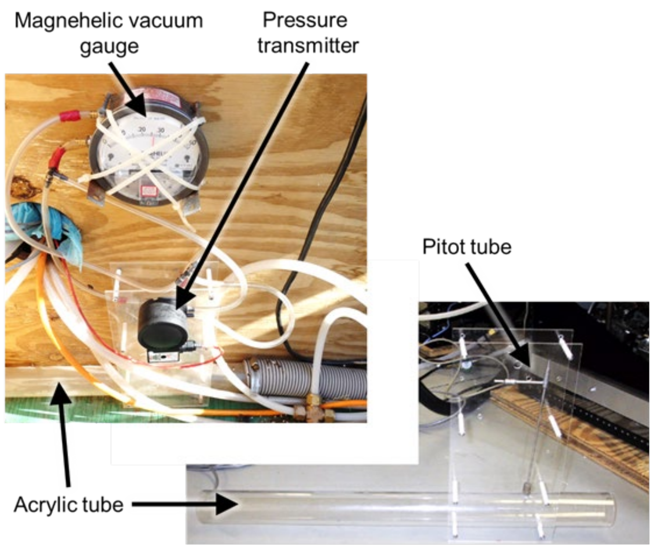


Figure D1: Pictures of an actual site set up showing the acrylic tube and the pitot tube nested inside along with the associated plumbing inside the pump box.

Tools needed: 3/8” wrench, 7/16” wrench, alcohol, chem wipe tissue, small wire, water

Procedure:

1. Remove tubing from top (if not labeled, you may want to mark which tube goes to which pitot tube port (High (H) or Low (L)).
2. Carefully remove pitot tube assembly from pumpbox. You’ll need to detach both ends of acrylic tube from flexible 2” tubing.
3. Remove clear plastic rectangular cover so you can access pitot tube – you may be able to undo the bottom 4 screws/spacers and then pull the pitot tube and acrylic tube down and out of the rectangular cover.
4. Using a 3/8” wrench, loosen the top nut so the pitot tube is loose in the Swagelok fitting.
5. Using a 7/16” wrench, ***very very carefully*** remove the pitot tube from the acrylic tube. It is very easy to crack the acrylic tube around the threaded hole that the pitot tube sits in – you don’t want to do that.
6. Clean acrylic tube with water and dry with tissue
7. Clean pitot tube first with water, then with alcohol. You can use a small piece of wire to try to clean the holes if it seems needed (**See schematic of the tip of the pitot tube, Fig. C1**)
8. Reassemble

Carbon Vane Pump Maintenance

Cleaning the Impactors

TSI Nephelometer

Cleaning the light trap

<u>Tools needed:</u> Phillips head screwdriver (one with a thin handle), 7/16" wrench, alcohol, compressed air (optional but useful), chem wipe tissue

<u>To Clean the Light Trap</u>:

1. Place the Nephelometer on its side and use thick packing foam or a stack of binders to prop the end up

2. Remove the 3 screws that attach the neph body to the lip on the base (**Figure DX**)

3. Loosen the nut on the bottom of the internal HEPA filter (**Figure DX**)

4. Slide base away from neph body being careful to not scrape the light trap on the walls inside as the light trap column is attached to the base (**Figure DX**)

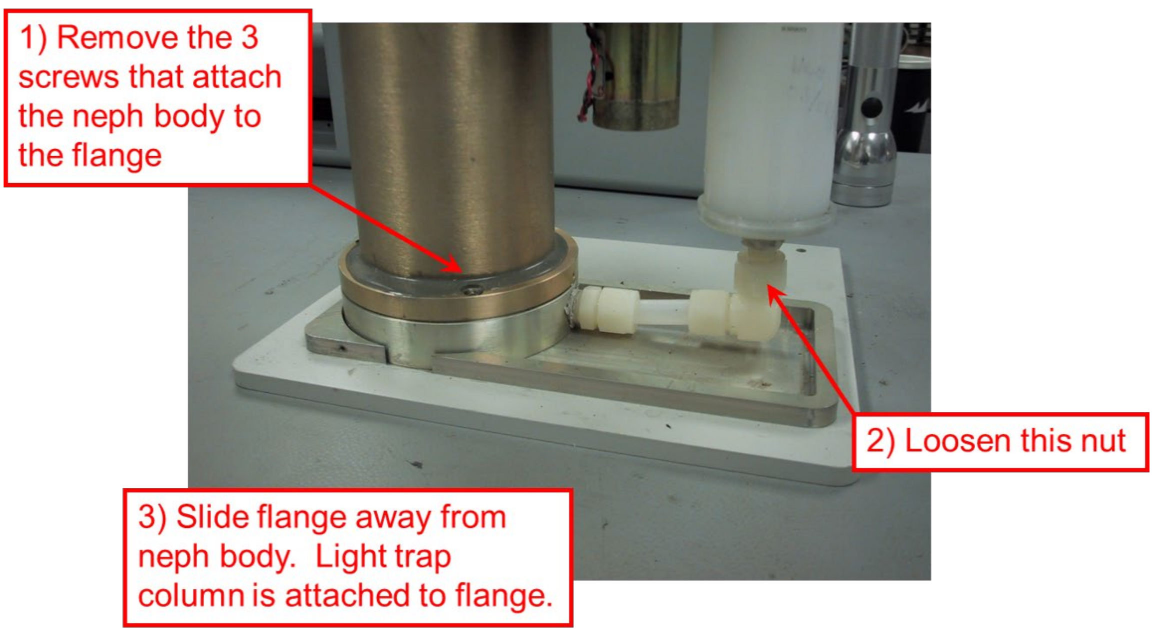


Figure 6.1: Opening Nephelometer to Remove Light Trap Column, steps 2-4 of cleaning the light trap on the Nephelometer.

5. Open the light trap column by removing the two nuts at the top of the column. Be careful not to strip the mat black paint of the pieces and make sure to lay pieces out as you take them off so as not to lose or misarrange pieces when reassembling (**Figure DX**)

6. Remove the light trap column by lifting it straight up – be ***very very carful*** as there are two sections to the column and sometimes they can get stuck together and make it seem like one piece

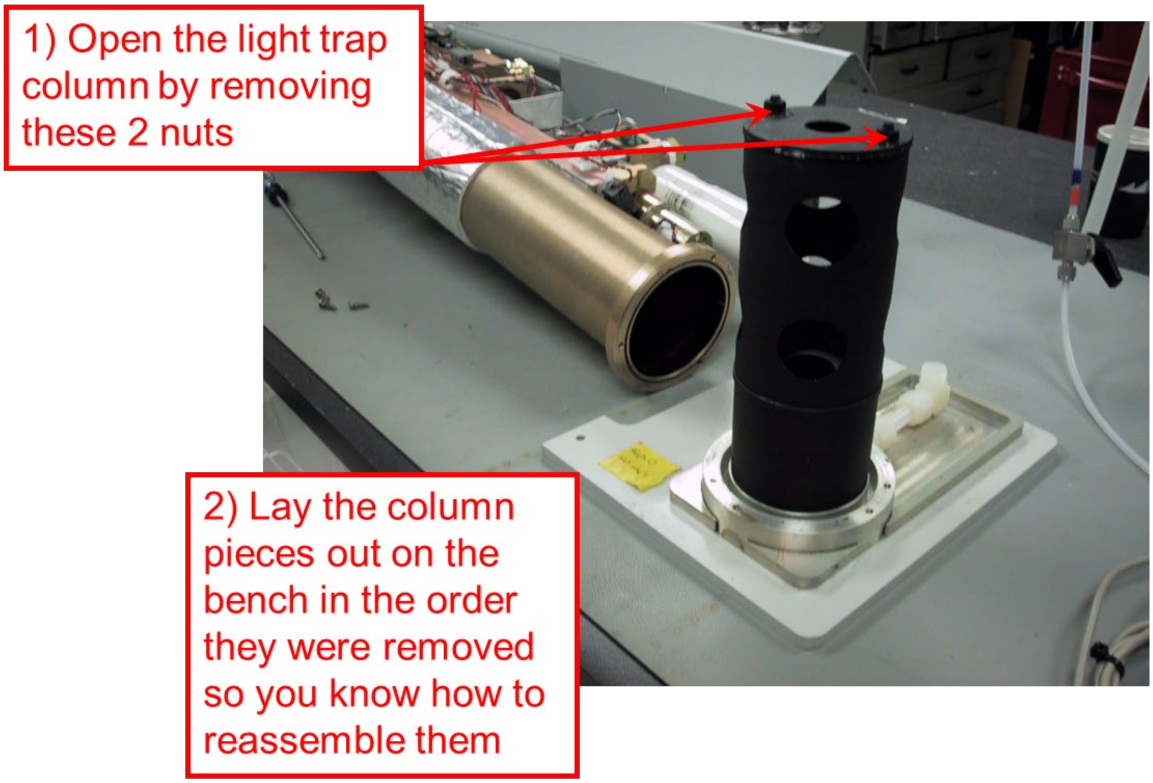


Figure 6.2: Light Trap Column, step 5 of cleaning the light trap on the Nephelometer

7. Visually inspect the light trap for dirt, then clean the trap gently with a chem wipe and alcohol or with some compressed air (**Figure DX**)

Figure DX: Example of Dirty Light Trap for step 7.

8. Once the light trap is clean you can reassemble it the way it was before (**Figure 6.4**).

   <u>NOTES</u>:
   - There is black felt on one side of the light trap column and the mirror at the bottom should be facing it when it is reassembled
   - If any of the black paint was scratched during the cleaning, patch it if you have the black paint with you
   - Make sure the o-ring on the Nephelometer body remains in the groove during reassembly

9. Once the light trap has been put back together, carefully re-insert it into the bottom of the Nephelometer and attach the three screws that hold the pieces together. It's a good idea to do a leak check on the instrument after this cleaning has been done

Figure 6.4: Column Reassembled for step 8 in the cleaning.

Replacing the bulb