SOP #2

Site Selection, Installation, and Maintenance Protocols

Table of Contents

Site Selection, Installation, and Maintenance Procedures

1.0 PURPOSE

The purpose of this Standard Operating procedure (SOP) is to provide consistency for the selection and installation of all SPARTAN sampling sites. It will also provide instruction on the maintenance of the SPARTAN sampling site once installed.

REVISION HISTORY			
Revision No.	Change Description	Date	Authorization
1.0		June 1, 2015	Crystal Weagle

2.0 SITE SELECTION

SPARTAN sites are to be collocated with CIMEL sunphotometers at existing AERONET sites when possible. However, the following variables must still be considered when selecting the specific location for the sampling station:

a. Representativeness of area-wide air quality
b. Security
c. Electrical Power

2.1 Representative of area-wide air quality

The site should be in a location that is representative of regional air quality. This means that the site should not be located within less than 2 km of a pollution point source that includes, but is not limited to, power plants and factories. As well, the site should not be within 500 meters of major roads/highways. Heavily used dirt roads that can produce dust unusual for the region should also be avoided.

The site should be at least 5 meters away from other structures or surfaces such that airflow is unimpeded from all directions. The top of such structures within 100 meters should not have any more than a 30º angle from the sampler inlet (see Figure 1). Sites can be either located at ground level or on the rooftop of a building no more than 5 stories (~15m) high. To remain representative, if a site is located on a rooftop it needs to be placed away from vents, cooling towers, and other ventilation equipment such as motors, and air intakes. Ultimately, the sampling stations are placed according to exposure to regional air quality.

2.2 Security

It is critical that the sampling station is in a location such that unauthorized persons cannot get access to the instruments. If the sampling station is located next to an existing AERONET site security measures should have previously been implemented. If not, it is important to guarantee security before receiving the sampling instrumentation. This means that if the best location is found at ground level, appropriate security measures must be taken such as fencing, lights, etc. If the use of such security measures is not feasible, the sampling station should be located on a low-rise rooftop that provides adequate security.

2.3 Electrical requirements

To guarantee that there is sufficient power at the site, there should be at least a 1.0 Amp, 220 (or 110) V line available on site. For sites where this is not possible, or are on intermittent power grids, it is necessary to have a back-up battery and solar panel available. For further information regarding the solar panel and battery backup please see Section 4.3.

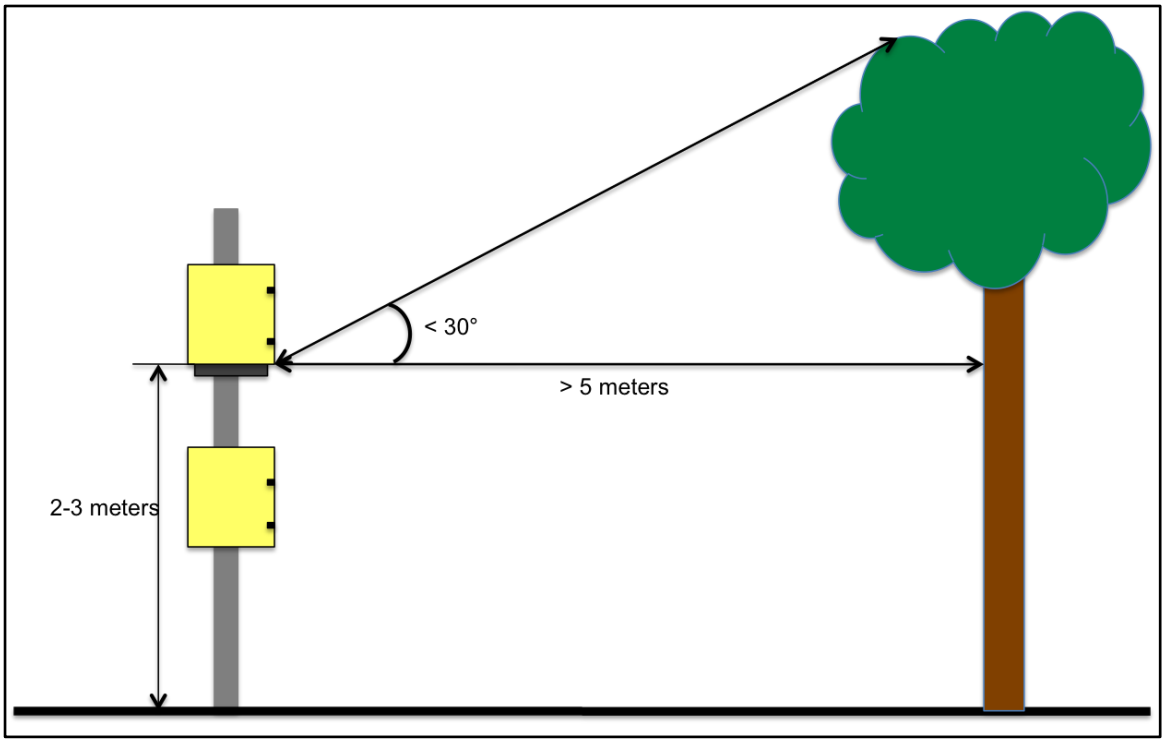


Figure 1: Illustration of SPARTAN sampler set-up (tree is used as an example, this could be a wall or any other tall object).

Please note that these criteria are not absolute, a site location that falls slightly outside the criteria may be the best choice. Any significant variances from the criteria should be well documented and reviewed before site installation.

3.0 SITE INSTALLATION

The general approach employed is to minimize travel time as well as the cost of shipping equipment while increasing the efficiency of site installation. Therefore, it is important that the site is prepared for installation before the sampling equipment and site manager from Dalhousie is due to arrive.

3.1 Equipment and materials required for the installation of the sampling stations include:

- ☐ Pole 3 to 4 m in length and between 4 and 6 cm in diameter
- ☐ Extension cords (if necessary)
- ☐ Weather/radiation shield that is silver or white in color with dimensions of at least 6 cm deep x 8 cm wide x 14 cm long, such as an aluminum cover (or plastic container) shown in Figure 2

3.2 Pre-installation activities

- ☐ Arrange appropriate site security if not already done so
- ☐ Ensure that electrical requirements of the site have been met
- ☐ Obtain supplies listed above
- ☐ Pole required for mounting the samplers must be secured and therefore should be stable to avoid vibration and shifting after installation. It should also be able to withstand extreme weather events.

3.3 Instrumentation Checklist

Upon receiving SPARTAN instrumentation it is important to make sure you have received all parts and accessories needed to proceed with installation of the sampling station. If you are missing any of the items on the following list, please contact the appropriate site manager at Dalhousie University either at crystal.weagle@dal.ca or graydon.snider@dal.ca.

- ☐ Sampling case 1 (electronics)
- ☐ Sampling case 2
- ☐ Sampling station pump and corresponding case (attached to the bottom of control box case)
- ☐ Nephelometer
- ☐ 3 pre-loaded cartridges
- ☐ External flow adapter

- ☐ External rotameter and tubing
- ☐ Vacuum grease
- ☐ 3 log sheets (one per cartridge) + extras
- ☐ Kim-wipes (small)
- ☐ Power cables

3.4 Installation of filter-based sampler to support structure

The sampling case that contains the 8 sampling inlets must be positioned at least 2 meters above ground height. Even if the site is located on a rooftop the height requirement of 2 meters from the roof surface needs to be observed. This allows for proper mixing of air and reduces sampling of emissions directly from the roof/ground. Please refer back to Figure 1 for an illustration.

The sampler has a metal bar attached to the back of each case; use this to attach the sampler to the pre-assembled pole with the provided hose clamps (Figure 3). It may also be effective to use a durable strap (e.g. cloth or zip-tie) to provide extra support for the sampler. Utilization of the strap may be especially important if a pole of appropriate diameter (Section 3.1) was unable to be located. After the samplers are secure attach the weather/radiation shields. Please refer back to Figure 2 for an example of the final set-up of the SPARTAN filter-based sampler.

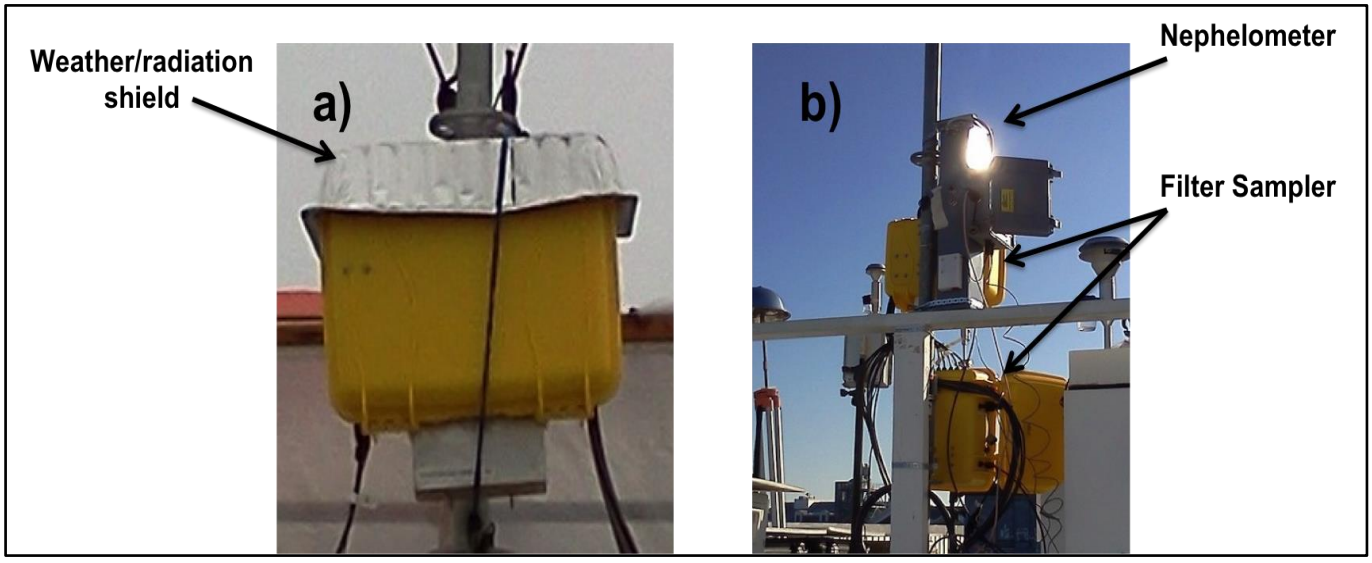


Figure 2: a) Example of weather/radiation shield. b) Positioning of the filter sampler and nephelometer on the same pole.

3.5 Installation of the nephelometer to the support structure

The same height restrictions apply to the nephelometer as that for the filter-based sampling cases. The nephelometer can be bolted to a wooden platform or also attached to a pole using the provided hose clamps. It is important that the inlet and outlet are situated such that they cannot be blocked in the case of a snow, sand, or water. The nephelometer can be attached to the same pole as the filter-based sampler, however, it is important to ensure that the nephelometer outlet is situated away from the inlet valves of the filter-based sampler and vice versa. Please refer to Figure 2 for an example illustration of the final set up of the SPARTAN filter-based sampler and nephelometer.

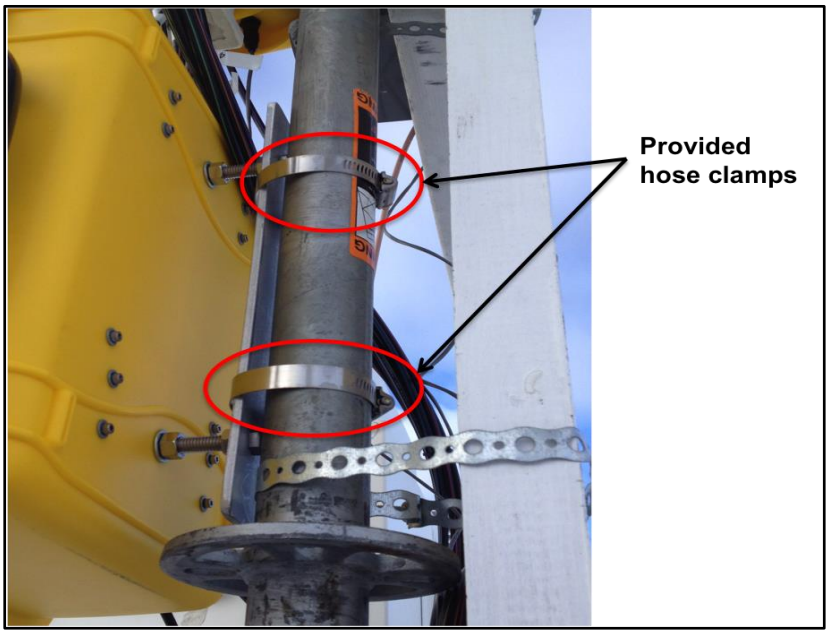


Figure 3: Example of using the metal bar on the back of the sampler cases to attach to a preassembled pole using the provided hose clamps.

4.0 SAMPLING PROCEDURE

The filter cartridge to be inserted in the filter-based sampling case contains 8 filter slots, each of which contains a Teflon filter. The first 6 of 8 filters collect $PM_{2.5}$ the 7th filter is a travelling blank and the 8th filter collects PM_{10} for the entire cartridge cycle.

At sites with an ambient coarse particulate matter (PM_{coarse}) concentration **less than 28 µg/m^3** each sampled filter combination actively samples for a total of 48 hours starting at 06:00 hours local time and with the following duty cycle:

Day	Start Time	End Time
1	06:00	12:00
2	09:00	15:00
3	12:00	18:00

4	15:00	21:00
5	18:00	00:00
6	21:00	03:00
7	No Sampling	No Sampling
8	00:00	06:00
9	03:00	09:00

The above duty cycles describe sampling only for $PM_{2.5}$, it should thus be noted that the duty cycle of the 8th filter collecting PM_{10} is 54 days. Thus it samples for 1 hour each day after the $PM_{2.5}$ sampling for the duration of the cartridge to give 48 hours of sampling time over the cartridge lifetime.

At sites with an ambient PM_{coarse} concentration **greater than 28 µg/m³** a duty cycle framework will be used. This means that instead of sampling the full 3 hours the sampler will run for a fraction of this time that is calculated specifically for each site to avoid filter clogging. The fraction of time sampled within the framework stated above is inversely proportional to the mean annual $PM_{2.5}$ concentration at each site. In general, the number of minutes sampled within the framework (maximum being 160 minutes, minimum being 16 minutes) is calculated using Equation 1:

$$\%\ \text{Duty} \approx \begin{cases} 100\% & \langle PM_{coarse} \rangle \leq 28\ \mu g\ m^{-3} \\ \frac{160\ \mu g}{[\langle PM_{coarse} \rangle + 2\sigma] \cdot V_{samp}} \cdot 100\% & \langle PM_{coarse} \rangle > 28\ \mu g\ m^{-3} \end{cases} \quad \textbf{Eq. 1}$$

where $<PM_{coarse}> + 2\sigma$ is the upper limit coarse aerosol concentration for 95% of the 9-day sampling periods and V_{samp} is the volume of air passing through the filter in 24 hours (5.76 m³ for 24 hours at 4 lpm).

After the number of minutes to be sampled is calculated, the appropriate duty cycle to be programmed into the instrument will be provided to each site upon start-up. Given the 9-day sampling procedure, each cartridge can remain and operate unattended in the field for a total of 63 days. The collocated nephelometer will remain in the field along with the filter-based sampler and sample for 24 hours a day, 7 days a week. For further information on programming the SPARTAN filter-based sampler and nephelometer please see Sections 4.1 and 4.2, respectively.

Note: The % duty can be modified at any time if it is found that it is either too strict or too relaxed for the sampling sites. Site operators will be notified if a change is necessary.

4.1 Programming the SPARTAN filter-based sampler

Upon receiving and setting up the instrument it is important that the instruments are programmed correctly with local date/time, etc. To begin this programming please enter the "Menu" and select "Next" until the "System Settings" screen is displayed; press "Go". The time to be programmed is local date/time and is on a 24-hour clock.

After successfully programming the instrument with local settings, proceed with programming the sampling procedure (outlined by Dalhousie University site managers as this can vary from site to site). A quick description of the elements that contribute to programming the sampling procedure are listed below:

1. **Start Time** – local time when sampling will begin.
   Note: Sampling will start the next time this hour occurs (e.g. If it is currently 13:00 on July 22 and the sampler is programmed to start at 09:00, it will start sampling at 09:00 on July 23. However, if it is 08:00 on July 22, the sampler will start at 09:00 on July 22)
2. **Period** – amount of time a particular filter will be used. At the beginning of each new period, a new filter will start sampling; this proceeds progressively from filter 1 through 7.
3. **Duration** – within a given period, the duration determines how long each filter will actively be sampled on (must be equal to or less than the Period).
4. **Duty Duration** – determines the duty cycle duration. For example, if the duty duration is set at one hour, the system will be 'on' for the **duty percentage** of time during that one hour and 'off' for the remainder of that hour.
5. **Duty Period** – percentage of time that the system is 'on' during the duty duration (must be equal to or less than Duty Duration).
6. **Short Duration** – duration within the duty duration
7. **Short Period** – period within the short duration

4.1.1 Information to be programmed into the SPARTAN instrument

The following information is to be used specifically for sampling with the duty cycle stated in Section 4.0 for sites with an ambient PM_{coarse} concentration **of 28 µg/m³ or less**. The information below is to be programmed into the sampler exactly as shown below.

Start Time: 06:00

Period: 09/00:00:00 (9 days)

Duration: 09/00:00:00 (9 days)

Duty Period: 001/03:00:00 (1 day, 3 hours)

Duty Duration: 000/06:00:00 *

Short Period: 000/00:00:00

Short Duration: 000/00:00:00

***For sites with an ambient PM_{coarse} concentration **greater than 28 µg/m³** the start time, period, duration, duty period, and short period all remain the same as shown above. **The only element of the programmed information that changes is the duty duration.** Upon installation of a new site, the duty duration and short duration to be programed in the sampler will be provided by the SPARTAN site manager.

Given that no problems arise, each cartridge will remain in the field for 63 days.

4.2 Programming the SPARTAN nephelometer

To start the nephelometer, flip the switch inside the attached case to the 'ON' position. Once the nephelometer is started it will run continuously and record both forward and back scattering data every 15 seconds for the following wavelengths: 455 nm (blue), 530 nm (green), and 630 nm (red). To stop sampling, simply flip the switch inside the attached case to the 'OFF' position.

4.3 Solar panel and battery backup

For areas on an intermittent power grid or with no available power, a backup battery and solar panel (for charging) are essential for operation. The sampling station will run on AC power as long as it is available. If AC shuts off the sampler will automatically change to battery power given that it is connected and switched ON. There is no specific programming necessary when the sampler is hooked up to battery power, only simple variations using the ON/OFF switches in the electronics case.

1. No battery/solar panel: "AC Mains" switch should be in the 'ON' position and the "Battery" switch in the 'OFF' position.
2. No available AC power: "AC Mains" switch should be in the 'OFF' position and the "Battery" switch in the 'ON' position.
3. AC available with battery backup: both switches need to be in the 'ON' position.

If your site requires battery backup further instruction regarding obtaining and installing the battery and solar panel will be provided.

5.0 INSTALLING/CHANGING FILTER CARTRIDGES

As stated in Section 4.1.1, each cartridge can remain in the field for 54 days, after such time the full cartridge will need to be replaced with a new one before the scheduled start time. Measuring start/end flows, are important factors in sampling. Instruction on how to measure the start and end flows is outlined in Section 5.1.

To install new cartridges (skip to step 6 for first cartridge install) or replace full cartridges, please follow the procedure outlined below:

1. **Before removing the full cartridge it is important to measure the end flows of each valve and record the values on the log sheet received with the cartridge.** An example log sheet can be found in Figure 6 in Section 6.2.
2. Lift the two red clamps on either side of the cartridge slot and remove the full cartridge.
3. Place the full cartridge inside 3 sealed plastic bags and write "SAMPLED' using a permanent marker on the outermost bag.
4. Remove the memory card for the full cartridge and place inside the bag containing the cartridge
5. Place the new cartridge in the cartridge slot under the valve inlets (**Error! R eference source not found.**4), making sure that the gaskets on either side are not impeding flow and are creating a seal.
6. Secure the cartridge into place by pushing the two red clamps on either side of the cartridge down tightly (Figure 5).

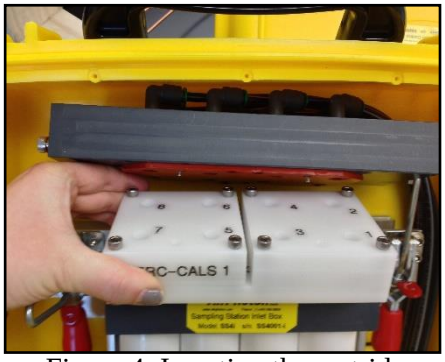


Figure 4: Inserting the cartridge into the sampling station - numbers 1, 3, 5, and 7 should be facing outward

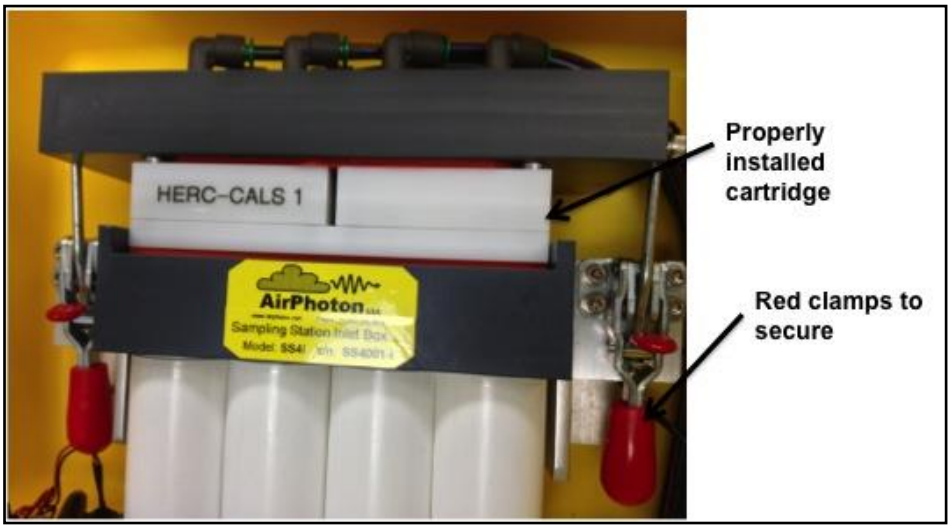


Figure 5: Example of a properly installed cartridge

7. Insert the memory card for the new cartridge in the memory card slot. Make sure that the cartridge and memory card numbers are the same (e.g. 5001). It is important to insert the memory cards while the sampling station is OFF.
8. Double check that the sampling settings are the same as those outlined in Section
9. Fill out the first page of log sheet for the new cartridge.
10. Measure the start flows for the new cartridge (adjust the external flow to 5.0 +/- 0.2 lpm using the flow control knob but adjust **valve 1 only**; however all valves 1 through 6 must have the flow measured) and record on the second page of the log sheet. More explicit instructions are provided on page 12 and are also included in the provided folder containing the log sheets.
    For valve 8, which samples PM_{10} the required flow-rate to obtain this size-cut with the cyclone inlet is 1.5 lpm. Adjust the external flow to this value using **valve 2. Note: There is a lag between the flow reported by the instrument and the actual flow. When adjusting the flow be patient and wait for the flow reading to update. Flow can be adjusted to 5.0 lpm using the external rotameter, and then one can wait until the reported flow is adjusted before recording the values.**

5.1 Measuring start/end flow rates

Measuring the flow rates before and after sampling is a means of verifying the flow rates reported/recorded by the instrument.

- Unscrew the screws securing the cyclone inlet to the top of the sampling inlet tube. Remove the cyclone inlet and set aside.
- Place the black adapter attached to the end of the flow meter over the top of the exposed end of the sampling inlet, pushing down to ensure a tight seal.
- On the station control panel select “system settings” > “pneumatics test” and then turn the vacuum pump on.

- Toggle the controls until the first filter tube is selected on the screen.
- Using **valve A** adjust the knob until the exterior flowrate (measured by the flowmeter) reports a value of 5.0 lpm. Record the associated interior flow rate. Note: if the interior and exterior flow rates do not agree with each other to within (+/- 0.5 lpm) remove the cartridge and adjust gaskets to ensure a tight seal is obtained. If flow problems persist, contact your SPARTAN representative for help with troubleshooting.
- Skip to the filter tube 2 and record the interior and exterior flow-rates on the log sheet. It is important **not** to adjust valve A as this will affect the flows for filter 1. Just record the values observed. If the flow rate is not within 0.5 lpm of 5 lpm, proceed with the troubleshooting outlined in the previous step.
- Continue for filters 3-6 as described above.
- On filter tube 8 use **valve B** to adjust the exterior flow rate to 1.5 lpm. Record the interior and exterior flow rates on the log sheet.

After inserting the new cartridge into the filter sampler, the start flows need to be measured and recorded on the log sheet (Section 6.2). An example of how to read the Omega rotameter received with the sampling station is shown below in Figure 6. It is equally important to measure and record the end flows before removing the sampled cartridge.

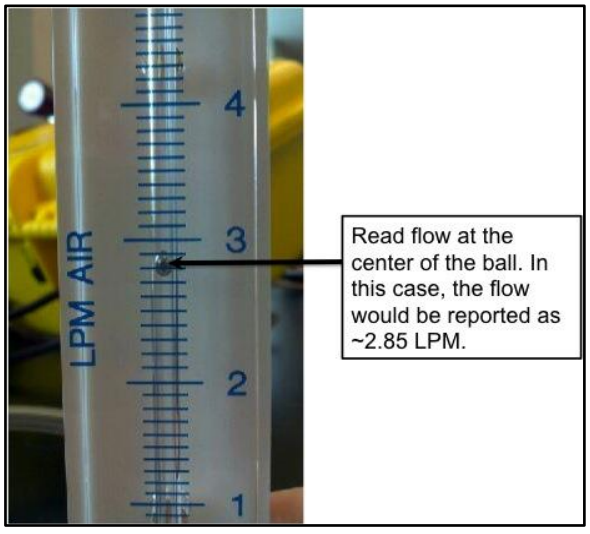


Figure 6: How to read the Omega Rotameter

How to measure START and END flows (see SPARTAN Sampling Log Sheet)

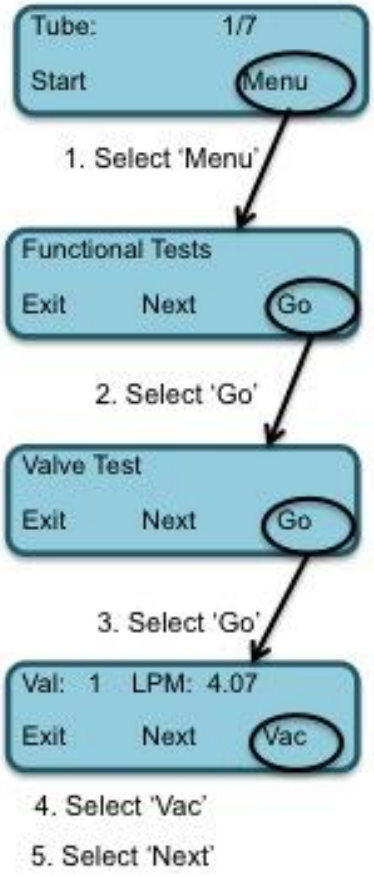
1. Select 'Menu' to see your options.

2. Press 'Next' until you see 'Functional Tests', then press 'Go'.

3. Press 'Next' until you see 'Valve Test', then press 'Go'.

4. Press 'Vac' to turn on the pump – you should now hear the pump on. Using the flow control knob, adjust the flow as close as possible to 4.00 (± 0.2) **FOR VALVE 1 ONLY** – do not manually adjust the flow using the flow control knob after doing so for valve 1 (Flow should only be adjusted when Start flows are being recorded – do not try to adjust the flow for the End flow measurement, simply read the value reported).
   a) Record the internal flow value on the log sheet under 'Internal Flow (lpm)'
   b) Record the the external flow value on the log sheet under 'External Flowmeter (lpm)'.

5. Move to the next valve by pressing 'Next' and continue to record the internal and external flow measurements on the log sheet for each valve.



6.0 DOWNLOADING DATA AND RECORDING INFORMATION

6.1 Downloading data from the instruments

The nephelometer and the filter-based system use a memory card (found in the electronics case) to record data collected during sampling. **These data are extremely important and must be handled with care**.

At a minimum, the nephelometer data should be downloaded when a new cartridge is installed, when a full cartridge is removed, and at an approximate midpoint between cartridge installation and removal. However, downloading nephelometer data on a bi-weekly basis ensures that data can be sent to Dalhousie University easily. **Be sure to turn off the nephelometer BEFORE removing the memory card** and do not turn the nephelometer back on until the memory card has been reinserted**.** Download the data by inserting the memory card into the appropriate slot in a computer. To access the data, open the file that reads "INXXXX" (XXXX = sampling station number). The data will be in a CSV file (.csv format).

Data can be sent to the SPARTAN site manager by email or through a file sharing system such as Dropbox or Google Drive. The method of sharing data with the site manager is based on what works best for the on-site operators. Files larger than 25 MB are too large to send by email, and the nephelometer produces approximately 10 MB of data per week. Please keep this figure in mind when considering the method of file sharing as well as how often the site operators plan to download data.

After downloading the nephelometer data, place the memory card back in the appropriate slot and turn the nephelometer back on. **Do not send the nephelometer memory card to Dalhousie University and do not clear the memory card until instructed** by a site organizer from Dalhousie University.

As with the nephelometer, the memory cards remain with the sampling station until instructed by the site manager or the memory card is no longer usable. It is very important to **turn off the sampling station before removing the memory card**. Memory card data is shared with the site manager at the end of each sampled cartridge and can be erased from the memory card once it has been safely copied. When a cartridge is installed it is important to program the instrument with the memory card number found on the memory card itself, which is the same as the cartridge number. For example, if the cartridge is BDDU-005, program the memory card as "005".

6.2 Recording information on the log sheet

Keeping accurate records of flow measurements, weather conditions, and programmed information for each cartridge is crucial to identifying potential issues in collected data. When a new pre-loaded cartridge is received a log sheet for that specific cartridge will accompany it. The log sheet will include the labels pertaining to the filters inside the cartridge slots (1 through 8). When installing the cartridge all of the information on the first page (e.g. weather conditions, programmed information, etc.) as well as the start flows must be recorded. **Before removing the cartridge** after the sampling period, the end flows must be measured and recorded on the log sheet. The log sheet is then returned to Dalhousie University along with the sampled cartridge. Please make a copy for your own records. An example of a completed log sheet is shown in Figure 8 in the Appendix.

7.0 STORAGE AND SHIPMENT OF FILTER CARTRIDGES

After a cartridge is finished sampling it is to be returned to Dalhousie University within three business days. While awaiting shipment the filter cartridge can be stored under ambient conditions; no cold storage is necessary. Methods of shipment vary from site to site and will be discussed/communicated with you upon site start-up by a site manager. If you have questions, please email either Crystal.Weagle@dal.ca

APPENDIX – EXAMPLE OF COMPLETED SPARTAN SAMPLING LOG SHEET

SPARTAN Sampling Log Sheet

Date of cartridge installation (month/day/year): 01/25/2013
SPARTAN Instrument #: 4001 **Cartridge #:** 4003

Local Conditions
Location: Dalhousie (DAL) Local time (hh:mm): 07:35 UTC time (hh:mm): 10:35
Local air temperature (°C): 13°C
Relative Humidity (%): 65%
Weather conditions: Overcast & windy (no rain)

Programmed Sampling Settings
(✓ Automatic or ( ) Manual mode
Sampling Start Date (month/day/year): 01/25/2013 Sampling Start Time (hh:mm): 09:00
Sampling End date (month/day/year): 03/28/2013 Sampling End Time (hh:mm): 09:00
Period (days/hours:minutes:seconds): 009/00:00:00
Duration (days/hours:minutes:seconds): 009/00:00:00
Duty Duration (days/hours/minutes/seconds): 001/02:40:00
Duty Percentage (%): 10 %

1

	Labels		Start Flows		End Flows	
Valve Number	Fine	Coarse	Internal Measurement	External Measurement	Internal Measurement	External Measurement
1	12081-CH-TSI-01	12089-CH-TSI-01	4.02	3.95	3.97	3.96
2	12082-CH-TSI-02	12090-CH-TSI-02	4.02	3.96	3.98	3.96
3	12083-CH-TSI-03	12091-CH-TSI-03	4.03	3.96	3.98	3.97
4	12084-CH-TSI-04	12092-CH-TSI-04	4.01	3.93	4.02	3.94
5	12085-CH-TSI-05	12093-CH-TSI-05	3.99	3.92	3.99	3.96
6	12086-CH-TSI-06	12094-CH-TSI-06	4.02	4.01	3.97	3.92
7	12087-CH-TSI-07	12095-CH-TSI-07	4.01	4.00	3.99	3.93
8	12088-CH-TSI-08	12096-CH-TSI-08	Blank	Blank	Blank	Blank

Comments:
- When start flows were measured the instrument was reporting a flow of 0.06 lpm when the pump was off.

2