



M903 Nephelometer Operating Procedure

For the

Air Quality Program

Washington State Department of Ecology
Olympia, Washington

May 2023, Publication 01-02-001

Publication Information

This document is available on the Department of Ecology's website at:
<https://apps.ecology.wa.gov/publications/summarypages/0102001.html>

Contact Information

Air Quality Program

P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6800

Website¹: [Washington State Department of Ecology](http://www.ecology.wa.gov)

ADA Accessibility

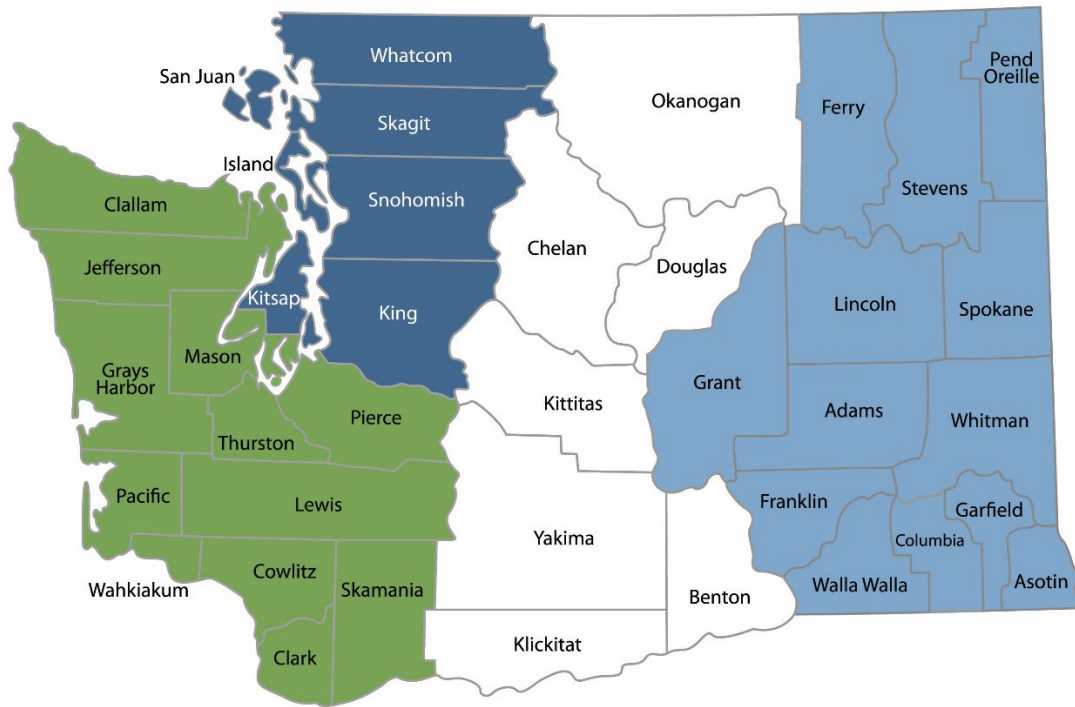
The Department of Ecology is committed to providing people with disabilities access to information and services by meeting or exceeding the requirements of the Americans with Disabilities Act (ADA), Section 504 and 508 of the Rehabilitation Act, and Washington State Policy #188.

To request an ADA accommodation, contact Ecology by phone at 360-407-6800 or email at melanie.forster@ecy.wa.gov. For Washington Relay Service or TTY call 711 or 877-833-6341. Visit Ecology's website for more information.

¹ www.ecology.wa.gov/contact

Department of Ecology's Regional Offices

Map of Counties Served



Southwest Region
360-407-6300

Northwest Region
206-594-0000

Central Region
509-575-2490

Eastern Region
509-329-3400

Region	Counties served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	P.O. Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	P.O. Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 West Alder Street Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 North Monroe Spokane, WA 99205	509-329-3400
Headquarters	Statewide	P.O. Box 46700 Olympia, WA 98504	360-407-6000

M903 Nephelometer Operating Procedure

Air Quality Program
Washington State Department of Ecology
Olympia, WA

May 2023 | Publication 01-02-001



Approved by:

Signature: _____ Date: _____
Rob Dengel, Air Quality Deputy Program Manager

Signature: _____ Date: _____
Sean Lundblad, Technical Services Section Manager

Signature: _____ Date: _____
Jill Schulte, Air Monitoring Coordinator

Signature: _____ Date: _____
Scott Dubble, NWRO/SWRO & Air Quality Operations Unit Supervisor

Signature: _____ Date: _____
Eric Beamesderfer, Air Quality Program Quality Assurance Coordinator

Signatures are not available on the Internet version

Table of Contents

List of Figures and Tables	7
Figures	7
Tables	7
Acknowledgements	Error! Bookmark not defined.
Introduction	8
Principles of Operation	9
Using nephelometers to monitor fine particle pollution in Washington State	10
Equipment and Supplies	11
Installation	12
Siting	12
Installation	13
Quality Control and Maintenance	21
Automated quality control checks	21
Site visits and operator initiated quality control checks	21
Data Validation, Data Completeness, and Quality Assurance.....	28
References	29
Appendix A – M903 Nephelometer Quality Control Check Form.....	30

List of Figures and Tables

Figures

Figure 1. M903 nephelometer	8
Figure 2. Schematics of the M903 nephelometer	9
Figure 3. M903 nephelometer plumbed to auto zero/span module	15
Figure 4. M903 nephelometer plumbed to auto zero/span module, rear view	16
Figure 5. Screenshot of Envidas Ultimate channel configuration – Bscat	17
Figure 6. Screenshot of Envidas Ultimate main calibration configuration – Calibrations.....	18
Figure 7. Screenshot of Envidas Ultimate settings for 2-point relay commands - Neph	19
Figure 8. Screenshot of Envidas Ultimate 2-point configuration - Calib Neph 2pt	20
Figure 9. Screenshot of NPM25 configuration	21
Figure 10. M903 nephelometer location of operational switches	22

Tables

Table 1. Summary of M903 nephelometer equipment and supplies.....	11
Table 2: Summary of M903 nephelometer neighborhood scale siting criteria	12
Table 3. Summary of M903 operating screens.....	23
Table 4. Summary of control limits	24

Introduction

This document describes the Washington State Department of Ecology's standard operating procedure (SOP) for sampling ambient air using an M903 nephelometer (Figure 1). This SOP should be used together with the instruction manual provided by the manufacturer. All Washington Network nephelometer station operators are expected to follow the SOP contained in this document.



Figure 1. M903 nephelometer

Principles of Operation

The attenuation of light through the atmosphere can be described by the Beer-Lambert law. This law states that the rate of decrease in the intensity of a ray of light per change in space is proportional to the initial ray intensity times the extinction coefficient. In the real atmosphere this extinction coefficient can be separated into four components: (1) scattering by particles, (2) scattering by gases, (3) absorption by particles, and (4) absorption by gases. The M903 nephelometer measures the scattering extinction coefficient by particles.

The principle of operation for the M903 nephelometer is standard configuration integrating nephelometry. This instrument measures the particle back scattering extinction coefficient of light (bscat) by aerosols. This measurement is accomplished by performing a geometrical integration of light scattered within a sample volume illuminated with a diffuse light source oriented orthogonally to the detector. This technique provides a direct measurement of the bscat of an aerosol sample independent of the physical and chemical compositions.

Figure 2 is a schematic of the detection axis of the M903. The M903 is a cylinder with a photomultiplier tube (PMT) detector on one end and a light trap on the other end. The sample volume and flash lamp are positioned axially $\sim 2/3$ of the path length away from the detector. An internal chopper is mounted at the interface between the sample volume and the apertures along the detector side of the cylinder. The sample inlet is located on the light trap side of the sample volume and the sample outlet is located just past the chopper on the detector side.

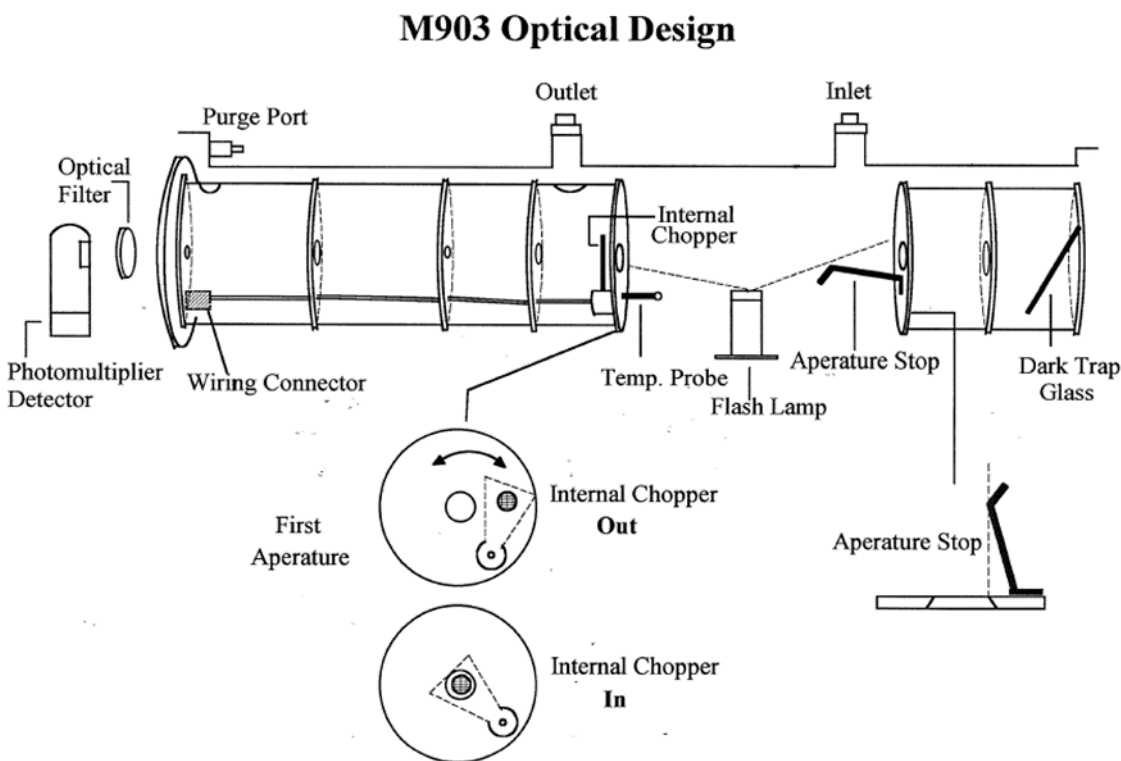


Figure 2. Schematics of the M903 nephelometer

During operation the M903 pulls ambient aerosol into the sample volume. The aerosol is then illuminated with a flash lamp where it scatters light in all directions. However, integrating nephelometry requires detection of light scattered orthogonally in to a well-defined solid angle. Three design features ensure that only light scattered in to the solid angle reaches the detector. First, all surfaces are coated with ultra-flat black matte paint to reduce reflection of light.

Second, a series of apertures installed along the axis of the cylinder from the sample volume to the PMT define the solid angle by allowing a physical path from sample volume to the detector.

Third, light scattered away from the PMT is trapped by a dark glass trap. In addition, the nephelometer must account for background noise from the PMT. To do this, the M903 has a chopper that can move between the “in” and “out” positions. When the chopper is in the “in” position, it establishes a zero reference value for the PMT. The PMT is blocked from influence of the light source and the output is from background noise only. The M903 then moves the chopper into the “out” position, where the PMT is subjected to photons scattered from the light source, which is the signal value. The zero reference value signal is then subtracted from the signal value to give the signal from scattered light free from detector background noise.

Isolation of the bscat signal requires one more step because the nephelometer is sensitive to both the scattering of light by particles and gases. Removal of the signal from light scattered by gases is accomplished by the introduction of particle free air into the nephelometer. This value is called the zero and is subtracted from an ambient signal to give the scattering from particles alone or bscat. This number is what registers on the display screen as bscat. Further and more comprehensive explanations of the operations of the M903 nephelometer can be found in the manufacturer’s documentation.

Using nephelometers to monitor fine particle pollution in Washington State

The Washington State Department of Ecology uses these M903 nephelometers to report concentrations of particulate matter with an aerodynamic diameter of 2.5 microns or less (PM_{2.5}) at over 50 locations throughout Washington State.

Nephelometers measure the back scattering of light (bscat) and are therefore not a direct measurement of particulate matter. They are not suitable for Federal Reference or Equivalent Methods (FRM/FEM) for PM_{2.5} monitoring. However, Ecology implements EPA guidance for mathematically relating (correlating) bscat to PM_{2.5} concentrations from an FRM/FEM PM_{2.5} instrument via site-specific relationships. In order to establish a correlation, Ecology requires each nephelometer to FRM/FEM relationship to have a coefficient of determination (r^2) of 0.85 or above. When the 0.85 criteria are met, the resulting slope and intercept equation is applied to the nephelometer bscat data via a calculated channel on the data logger to produce FRM-based estimates of PM_{2.5} concentrations. Utilizing this method at over 50 sites across the state, Ecology and its partners maximize spatial coverage of PM_{2.5} monitoring and are able to provide near real-time estimates of fine particle pollution via Ecology’s Washington Air Quality Advisory (WAQA) and EPA’s AirNOW websites.

Nephelometers are an excellent tool for reporting near real-time PM_{2.5} concentrations at sites with pollution levels below the National Ambient Air Quality Standards (NAAQS). However, because nephelometers are not an FRM/FEM for PM_{2.5} monitoring, the resulting PM_{2.5} data cannot be used to demonstrate compliance with the NAAQS. For this reason, when pollution levels routinely exceed 80% of the NAAQS, FRM/FEM monitoring is established.

Equipment and Supplies

Nephelometers within the Washington Network are used primarily to obtain estimates of PM_{2.5} due to their relative affordability and demonstrated strong correlation between 24-hour bscat readings and 24-hour concentrations from collocated FRM/FEM PM_{2.5} monitors. Proper siting is essential to ensure that data collected are representative at the appropriate scale. The majority of PM_{2.5} monitoring within the Washington Network is conducted at the neighborhood scale (0.5 – 4 km), in order to better understand air pollution across a fairly large area with relatively consistent geography and land use. Siting criteria for neighborhood-scale PM_{2.5} monitoring sites are described extensively in 40 CFR Part 58, Appendices D and E; the primary considerations are summarized in Table 1 below. Operators of sites at other monitoring scales (e.g., microscale, regional scale, etc.) should consult Appendices D and E for siting requirements.

Table 1. Summary of M903 nephelometer equipment and supplies

Category	Equipment	Purchase Schedule
Hardware	M903 Nephelometer w/heater and controller	Once
	PC data logger and communications equipment	Once
	Pressure Regulator, 2-stage, to fit span gas Tank	Once
	Mounting Hardware	Once
	Auto-calibration module	Once
	Sample pump or fan	Once-pump, as needed-fan
Diagnostic Tools	NIST-traceable thermometer	Once
	Handheld barometer/altimeter	Once
Spare Parts	Filters (Span/CO ₂ & Zero)	As needed
	CO ₂ Span Gas	As needed, typically annually
	Tubing and associated fittings	As needed
	Flashlamp Bulbs	As needed
	Probe Material – Tygon or equivalent	As needed
	Funnel	As needed
	Fine Mesh Screen	As needed
	Pump rebuild kit	Annually

Installation

Siting

Proper siting ensures that data collected are representative of the area defined by the monitoring objective. As mentioned previously, nephelometers within the Washington Network are used to estimate near real-time PM_{2.5} concentrations. For these reasons, the CFR siting criteria for PM_{2.5} is followed when choosing nephelometer monitoring locations. These criteria are described extensively in 40 CFR Part 58, Appendix E. The vast majority of PM_{2.5} monitors in the Washington Network are sited to represent air quality conditions on a neighborhood scale. Table 4-1 summarizes neighborhood-scale siting criteria.

Table 2: Summary of M903 nephelometer neighborhood scale siting criteria

Parameter	Category	Siting Requirement
Inlet Height	General	2-15 m above ground
	On rooftop	2 m above roof
	Collocated samplers	Within 1 vertical m of each other
Inlet Radius Clearance	General	≥ 1 m radius clearance
	Near small obstructions (fences, walls, etc.)	≥ 2 m with a minimum of 180 degrees of open sample pathway
	Near large obstructions (buildings, sound walls, billboards, etc.)	Distance ≥ 2x height of obstruction
	Near overhanging trees	≥ 10 m from tree drip line
	Arc of air flow	Unrestricted 270° arc that includes prevailing direction of high concentrations
Nearby Air Sources	General	As far away as possible from vents
	Near any residential/commercial wood burning device	≥ 100 m away
Distance from Roadways	< 1,000 vehicles per day*	≥ 10 m from nearest traffic lane
	Elevated roadway (> 25 m high)	≥ 25 m away
	Unpaved roads	As far away as possible

* Average daily traffic counts for most roadways in Washington can be found at <http://www.wsdot.wa.gov/mapsdata/travel/annualtrafficreport.htm>.

Other factors must be taken into account when considering a location for installation:

- The operator's personal safety is an important consideration. Remember that the operator may need to access the site during times of inclement weather.
- Power and telemetry connection (cell modem reception, DSL, or other wired internet connection) or telephone line must be available.
- The M903 nephelometer must be installed in a dry, environmentally-controlled location. Walk-in shelters, mobile trailers, and environmentally-controlled mini-enclosures are suitable enclosures for the M903 nephelometer.
- Site security.

Installation

Upon receipt of the nephelometer from Ecology, visually inspect it to ensure that all components listed in the manual are included. Notify the Calibration & Repair Lab if any equipment is missing or damaged. For additional installation instruction, follow the detailed instructions found in the manufacturer's manual for the M903 nephelometer.

Proper installation of the sample line is very important. A site operator should install the inlet such that it prevents entry of water or insects within the air sample. To accomplish this, install a funnel and fine mesh screen around the inlet. The funnel prevents water from entering the sample line, while the mesh screen prevents the entry of insects. Sample lines are made of flexible, Tygon tube with a 3/8" inside diameter and 5/8" outside diameter. The length of sample inlet required for the site will determine which flow device should be used. Sample lines greater than 10 m, but not more than 15 m require the use of a pump, whereas sample lines less than 10 m use a fan. Installation of the line should be done with minimal bends and turns as to minimize particulate loss due to impaction. Install the nephelometer in a location within the shelter away from the direct flow of air from a heater or an air conditioner.

System setup

The Calibration & Repair Lab will have programmed the nephelometer according to its specific data collecting requirements. If it becomes necessary to change the programming of the nephelometer, contact the Calibration & Repair Lab.

All Ecology M903 nephelometers include a heating chamber that reduces the relative humidity of the sample before it enters the sample chamber. This heating chamber connects to a heater control box. The heater control box is connected to the nephelometer via a Molex™ plug that is located on the left side of the nephelometer just below the serial output connector. The heater requires the use of a relative humidity (RH) sensor that is positioned between the heater and the input port of the nephelometer. The RH sensor plugs into the ¼" phone jack on the left side of the nephelometer. There is one more Molex™ connector on the nephelometer that connects to the fan that draws the sample into the nephelometer. The two Molex™ connectors are different so the connections can't be reversed. Plug the power supply into the nephelometer before supplying 120 VAC to the power supply and the heater control box.

Plumbing

Nephelometer stations require the installation of an automated nephelometer zero/span module. See Figure 3 and Figure 4 for pictures of the connections. Connect the end of the sample probe to the barbed fitting that protrudes out of the upper left of the zero/span module when facing the front of the zero/span module. Connect the barbed fitting on the upper right of the zero/span module into the PVC stub that extends from the heater element. This should require some effort and may be accomplished by slightly twisting the tubing as you apply a light force. This PVC stub is made from common ½" schedule 40 PVC. Older nephelometers are equipped with ½" schedule 20 PVC stubs for use between the heater element and the RH sensor. If the sample probe fits loosely into the stub the location of these stubs is reversed. Connect the lower right barbed fitting of the zero/span module to the output sample port of the nephelometer. Connect the bottom barbed fitting of the uppermost solenoid valve of the zero/span module to a 0.45 µm filter. Make certain that the arrow on the filter that indicates the direction of flow is pointing toward the solenoid valve. Connect the lower barbed fitting of the middle solenoid valve to the fan or input of the vacuum pump. All of these connections are made with the same type of tubing used for the sample probe.

To use the nephelometer automatic zero/span module it is necessary to use a span gas supply with regulated output pressure. Connect the regulator's output port to the input side of the zero/span module's gas solenoid valve. Use PFA grade Teflon tubing that is rated above 100 pounds per square inch. This is the same material used as sample probe material for criteria gas pollutant samplers. Contact the Calibration & Repair Lab for assistance if needed.

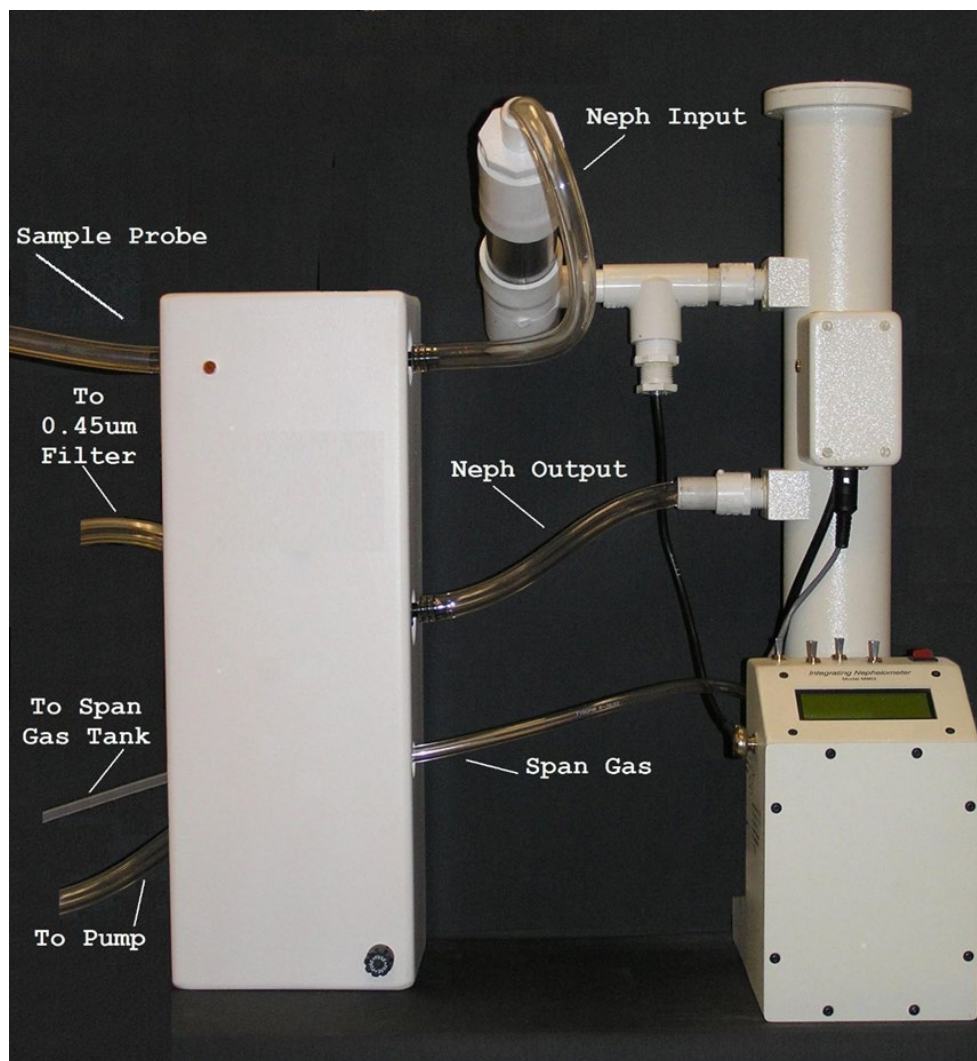


Figure 3. M903 nephelometer plumbed to auto zero/span module

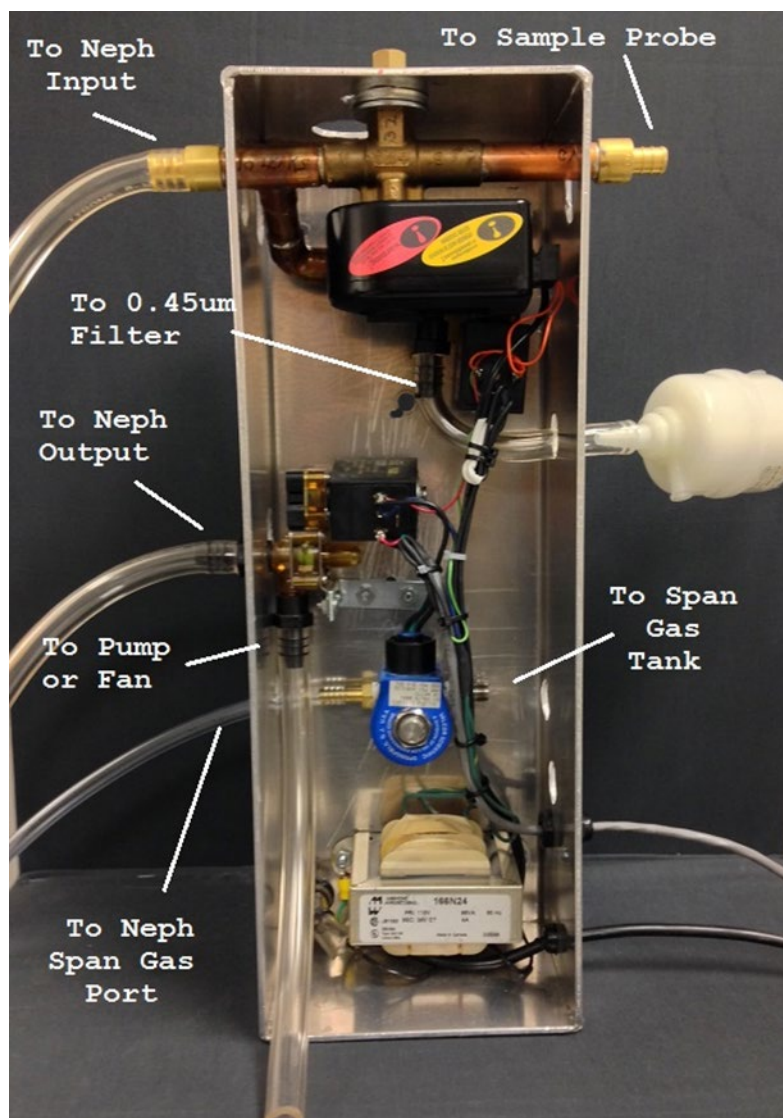


Figure 4. M903 nephelometer plumbed to auto zero/span module, rear view

Envidas Ultimate data logger configuration

Envidas Ultimate data loggers are used exclusively throughout the Washington Network. This section explains the installation and configuration of the M903 nephelometer with the Envidas Ultimate logger.

The Air Quality Program's (AQP) IT Unit programs the Envidas Ultimate data logger with the Washington Network standard configuration for the M903 nephelometer. The operator should verify that the data logger configurations are correct prior to any data collection. The information and screen shots below reflect the correct logger configuration. If there are problems establishing serial communications between the M903 and the data logger or with the logger configuration, contact the telecommunications specialist in the IT Unit.

The data logger channel configuration for the M903 nephelometer is as follows:

BSCAT_R – raw bscat values.

NPM25_R – a calculated channel used to estimate near real-time PM2.5 concentrations (turn on this channel only if the site has an acceptable PM2.5 site-specific correlation).

NephPress_R – internal nephelometer pressure needed to calculate gas value.

NephTemp_R – internal nephelometer temperature needed to calculate gas value.

NephGas_R – calculated channel for reference gas used as an assessment or “actual” value in quality control checks.

The following screen shots show the proper configuration for the most critical data channels and 2-point quality control checks.

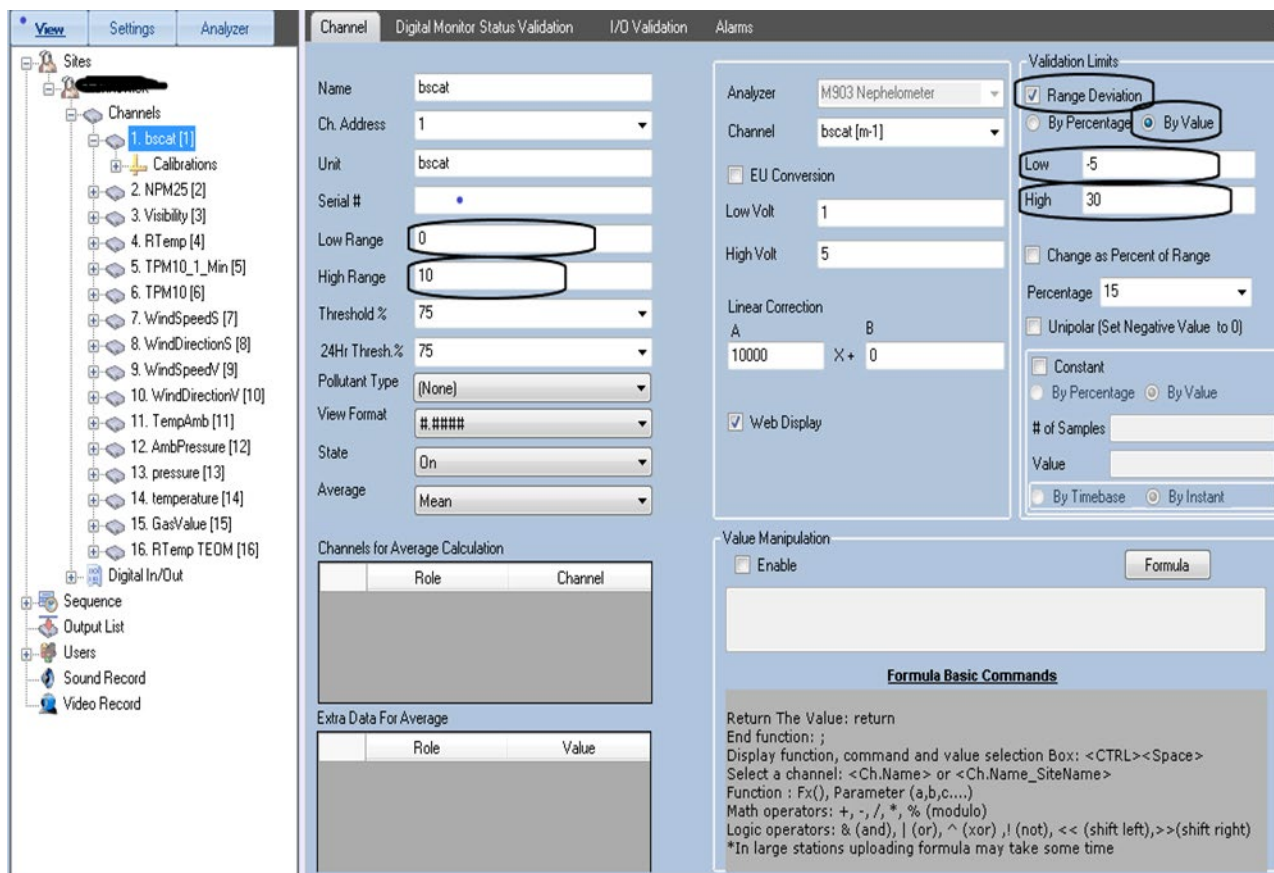


Figure 5. Screenshot of Envidas Ultimate channel configuration – Bscat

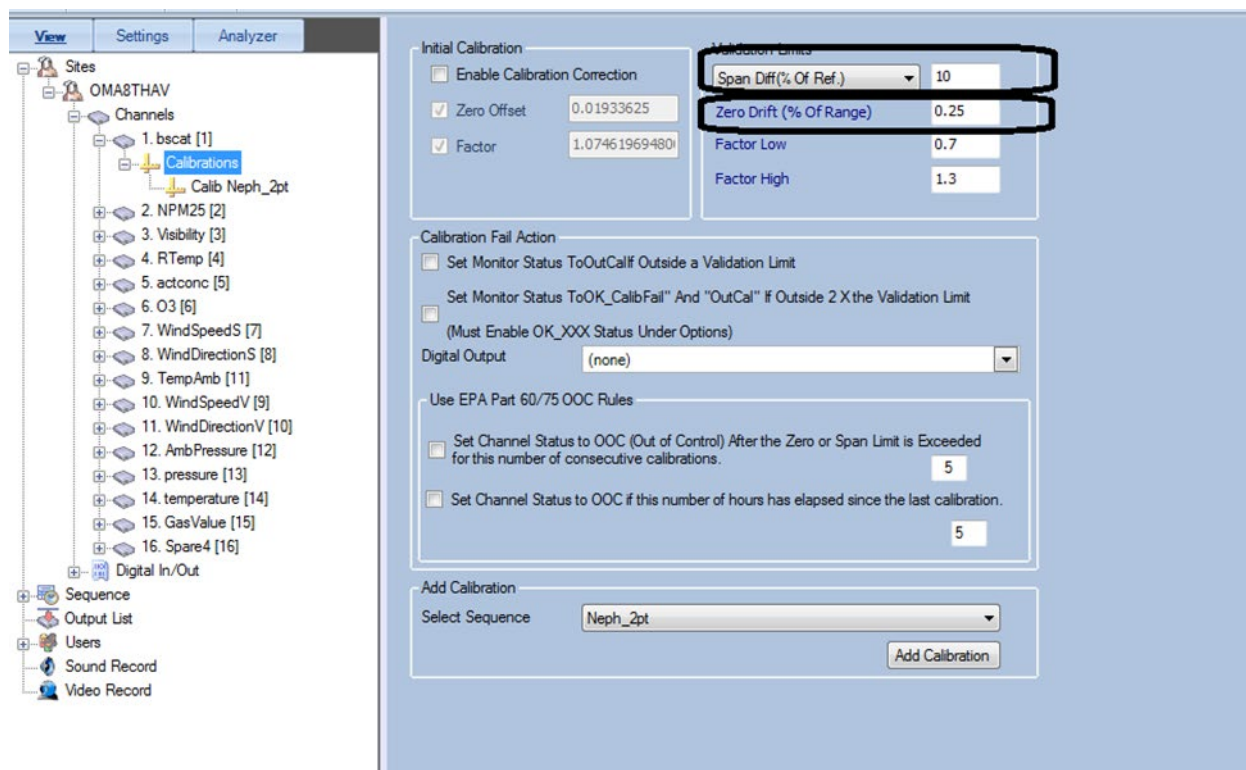


Figure 6. Screenshot of Envidas Ultimate main calibration configuration – Calibrations

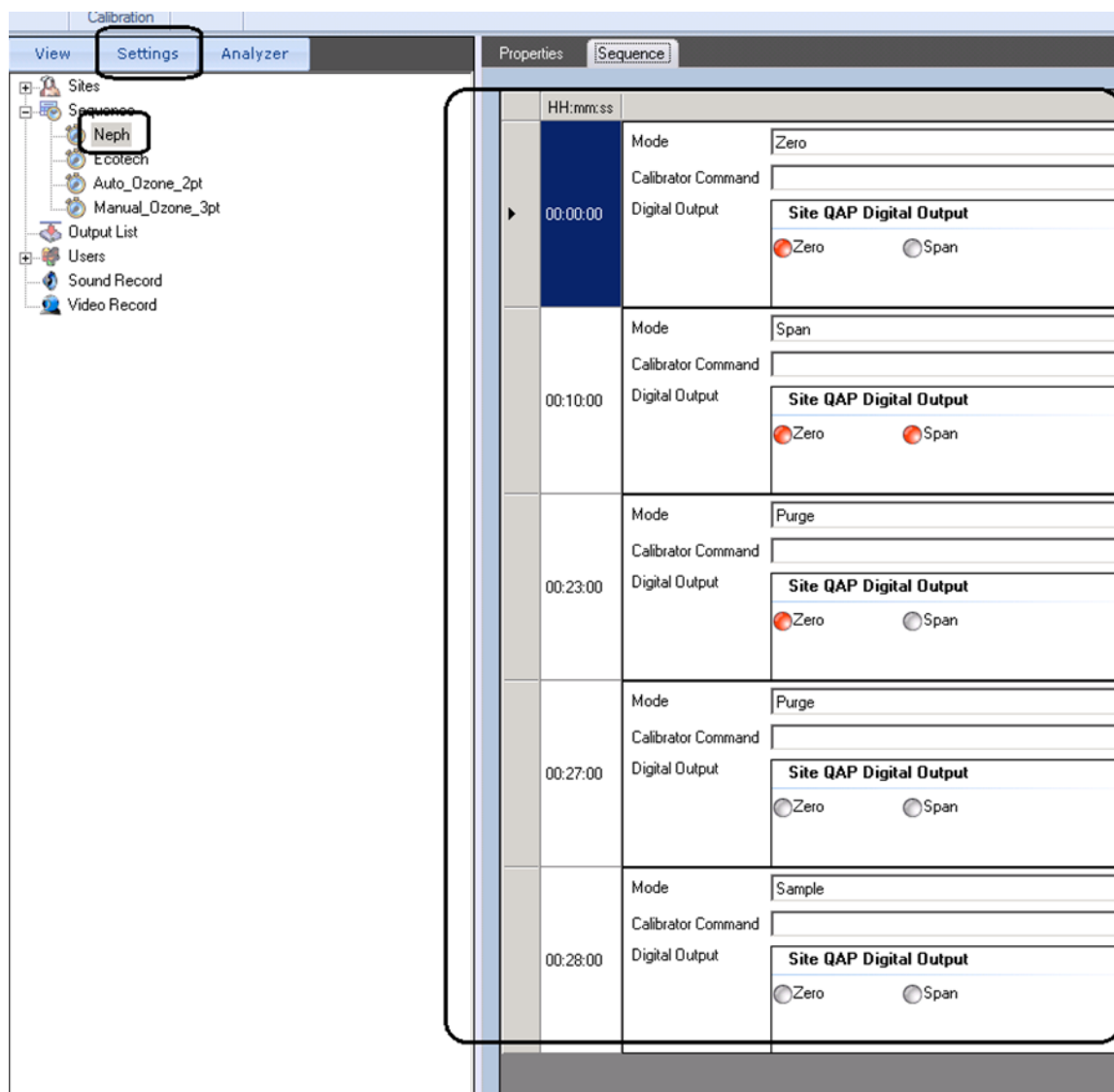


Figure 7. Screenshot of Envidas Ultimate settings for 2-point relay commands - Neph

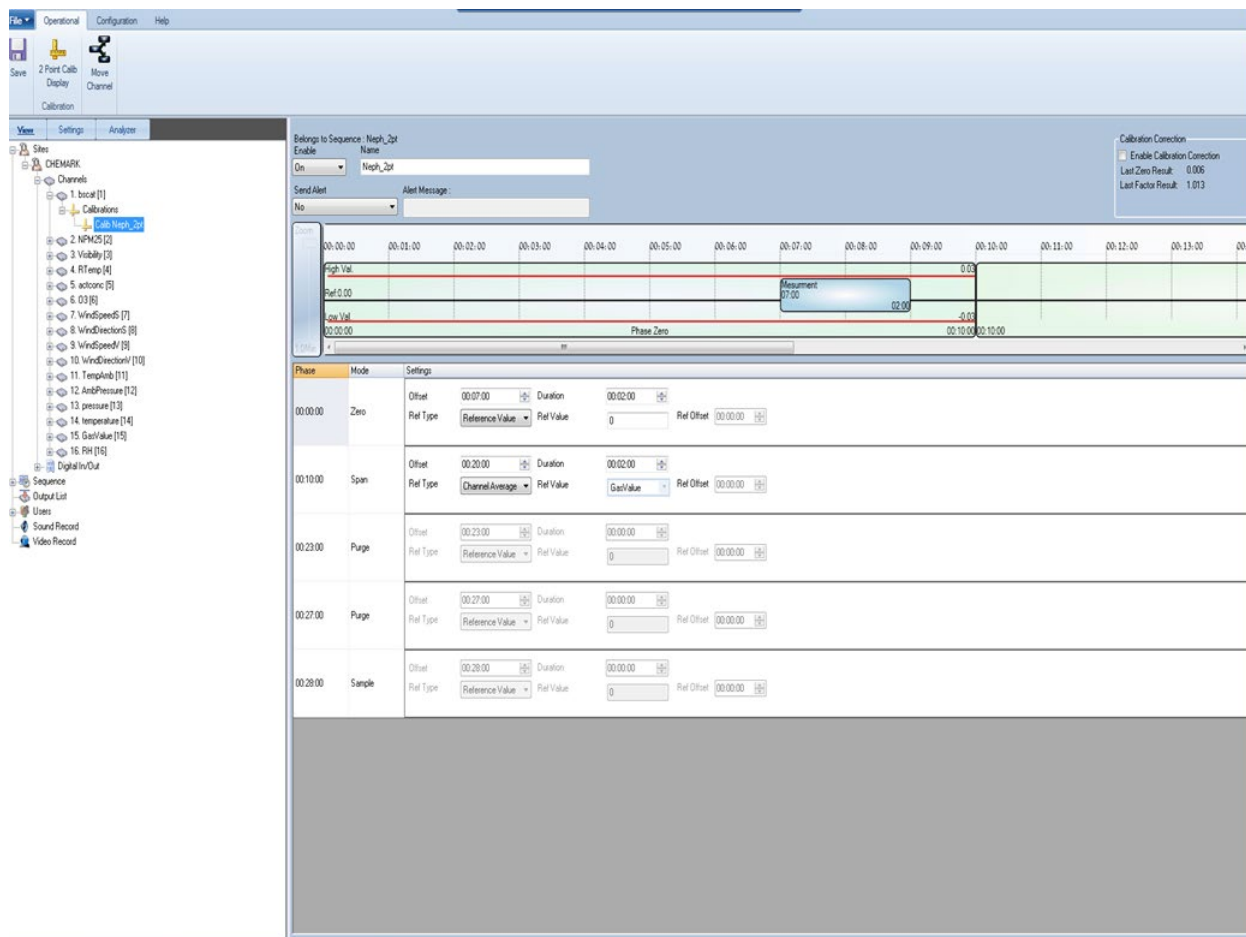


Figure 8. Screenshot of Envidas Ultimate 2-point configuration - Calib Neph 2pt

Upon site installation, operators should check the site-specific NPM2.5 correlation on the data logger to ensure that it is enabled and correct. Contact Quality Assurance staff to obtain the correct correlations. See Figure 9 for an example of the NPM2.5 configuration screen.

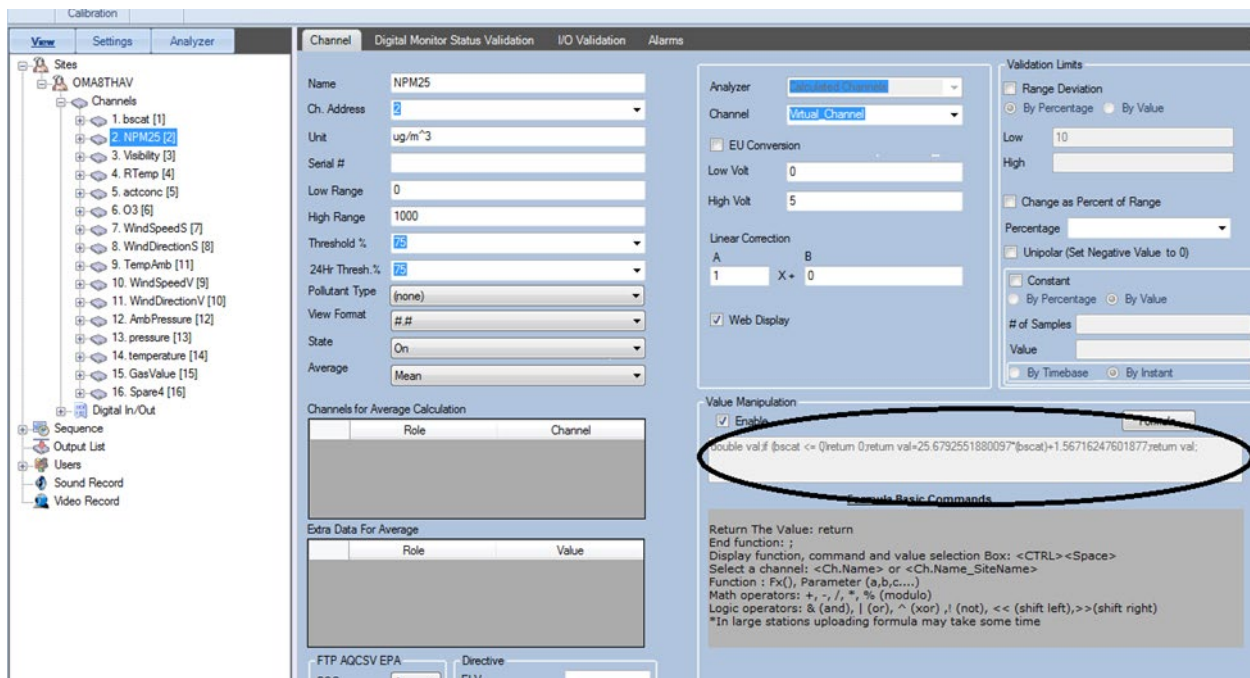


Figure 9. Screenshot of NPM25 configuration

Quality Control and Maintenance

Periodic, two-point quality control (QC) checks are used to verify that the nephelometer and data collection system are operating correctly. Multi-point QC checks are not required due to the M903's proven linearity.

Automated quality control checks

Automated QC checks occur via preprogrammed sequences at 14-day intervals, occurring every other Monday morning, typically between the hours of 0200 and 0500 PST. The QC checks are set to initiate at 46 minutes after the hour, so they complete at 14 minutes after the following hour to minimize data loss and meet the 75% data completeness measurement quality objectives (MQO) for both hours affected. They last 28 minutes in duration and consist of a zero, span, and purge phase. The data logger calculates pass/fail results and telemeters those results to a central server in Lacey. Following auto-QCs on Monday mornings, station operators shall review calibration results via EnvistaARM or onsite via the logger to ensure that nephelometers are within calibration and to prevent data loss.

Site visits and operator initiated quality control checks

Station visits and an extra 2-point QC check initiated by the operator via the Envistas Ultimate software are required at a minimum of once every 90 days. During site visits, operators are to record all activities (e.g., maintenance, QC results, unusual or notable site conditions, etc.) in

the electronic site log in Ultimate Reporter and record all QC results on the current version of the Nephelometer QC Check Form spreadsheet (Appendix 8-1). Operates must also email an electronic copy of the Nephelometer Quality Control Check Form to the QA Coordinator no later than 10 days following the QC check.

During every station visit operators should visually inspect the probe inlet screen, funnel, and tubing for damage, ensure no obvious leaks or loose tubing, and check the span gas supply. Once tank pressure drops below 500 psi, tank replacement may need to be scheduled on or before the next scheduled QC visit.

There are 5 switches located on top of the nephelometer: one power switch and 4 operational switches. The four operational switches, from left to right are labeled Display, Item, Parameter and Reset. There are 9 different screens available on the liquid crystal display (LCD) that can be accessed by toggling the display switch. Each screen has been assigned a number. Briefly toggling the Display switch towards the front of the nephelometer changes the LCD display to screen 1. Continually toggling the Display switch will cycle the display through all 9 screens, from screen 0 to screen 8 and back to screen 0. See Figure 10 below for the location of the switches and Table 3 for a description of the operating screens.



Figure 10. M903 nephelometer location of operational switches

Table 3. Summary of M903 operating screens

Screen	Operation
0	Manufacturer's firmware version identification screen
1	Default screen that displays current date and time, bscat value, and data logging/flashlamp mode.
2	Used to adjust the nephelometer's data logging and flashlamp mode.
3	Used to adjust the zero-reference point. Set Zero should match value from most recent as left QC.
4	Used to adjust the span reference point. This number should match value from most recent QC.
5	Used to adjust the high voltage that operates the photomultiplier tube and shouldn't ever need adjustment in the field.
6	Displays the sample temperature, sample pressure and sample relative humidity and is used to adjust the air Rayleigh scatter ratio which should not be changed.
7	Used to adjust the Rgas ratio and shouldn't need adjustment. Rgas ratio is 00261 for CO ₂ .
8	Used to set the baud rate of the communications port and needs to correspond to the baud rate that is set within the Envivas software. In most cases this will be 9600 baud.

Span Gas

Ecology's Air Quality Program uses carbon dioxide (CO₂) as the span gas. As noted in the manufacturer's documentation, there are four more gases that are acceptable for use in the M903 nephelometer. The AQP chose CO₂ based on its cost, availability, and lower greenhouse gas footprint compared to the other acceptable gases. The calibration gas to air Rayleigh ratio to enter in the M903 Rgas field is 00261.

Quality control acceptance limits and action levels

The M903 nephelometer is operating within acceptable limits when the absolute value of the zero point is less than 0.25E-5 m⁻¹ and the span point is less than $\pm 10\%$ of the gas value. However, allowing the nephelometer to operate close to these limits is not recommended. Action levels have been established to alert the station operator of the need for an adjustment. If the absolute value of the zero point is greater than $\pm 0.15\text{E-}5$, or the span point is greater than $\pm 7\%$ of the gas value, action must be taken to prevent exceeding the acceptance limits. The action limit exceedance should be verified with an additional QC. Diagnostic data should be reviewed and the cause determined, and the cause should be corrected through maintenance or calibration of the nephelometer. Often a trending change in response at the zero or span points over the course of several QC checks indicates a gradual accumulation of particles in the nephelometer that can be corrected through recalibration until the wall value exceeds 80% after which additional maintenance must be performed. Table 4 summarizes these limits.

Table 4. Summary of control limits

Quality Control Check	Acceptance Level	Action Level	Adjust bscat To
Zero Point	$< 0.25\text{E-}5 \text{ m}^{-1}$	$> 0.15\text{E-}5 \text{ m}^{-1}$	$0.00\text{E-}5 \text{ m}^{-1}$ (Screen 3)
Span Point	$< 10\%$	$> 7\%$	= gas (Screen 4)
Wall Value		$> 80\%$	
Flashlamp Value	30K – 60K	Values outside acceptance level	

Performing quality control checks at nephelometer stations

During the course of the QC check, operators must refrain from making any calibrations or adjustments until after the QC check is complete. This is known as an “as-found QC”. After significant maintenance or if the instrument was recalibrated, operators must perform another full QC, called an “as-left” QC. Both the as found and as left QC check forms must be submitted to the QA Coordinator within 10 days.

The Nephelometer Quality Control Check form is a spreadsheet arranged into 5 sections. Sections 1 and 2 describe operating conditions on arrival and should be filled in prior to making any changes. Section 3 is to be filled in with values obtained during the Span phase of the QC check. Section 4 is filled out after the quality control sequence is complete with the results obtained from the Calibration Report in Envidas Ultimate Reporter. Section 5 includes a Results field that is automatically populated with a Pass or Fail once the QC check is finished and also includes a Comments field.

Begin filling in the Nephelometer Quality Control Check form with the station AQS ID number and name, date, nephelometer model, serial and state equipment tag numbers, operator’s name and QC start time. On the Nephelometer QC Check Form enter the corresponding values from the nephelometer for screens 1, 3, 4, 5, 6 and 7 using the Display switch to cycle through the screens.

Using the Envidas Ultimate Viewer Software, follow the instructions below to initiate a QC sequence and complete the QC check of the M903 nephelometer. Note: Where practical, initiating the sequence at 46 minutes after the hour may help to minimize data loss if no additional maintenance is needed.

Operator initiated M903 nephelometer 2-point quality control check:

1. Initiate a sequence: From the Envidas Ultimate Viewer, select Operational tab > Sequence > Neph_2pt from the drop down menu.
2. Click the Initiate Sequence button found on bottom left corner of the Neph_2pt window. This will start an extra calibration check. The data will be flagged during the calibration so disabling the data logger is not necessary.
3. After initiating the sequence, you should hear a click from the nephelometer auto zero/span module. This is a solenoid valve energizing as the system enters the zero-

point calibration check phase. Verify the bscat channel flag has changed to Zero and the bscat value starts to decline.

4. There will be another click in 10 minutes indicating that the system has now entered into the span point calibration check phase. Verify the bscat channel flag has changed to Span and the bscat value has started to rise.
5. Wait ten minutes for the nephelometer to stabilize and record the CO2 tank and the regulated delivery pressures from the tank gauges and the sample pressure, also record the temperature and relative humidity from screen 6 of the nephelometer on the log sheet. You are on screen 6 if you see “Air Rayleigh” in the upper left corner of the display. Verify the RH declines as tank CO2 replaces ambient air in the system.
6. At the end of the span point calibration check phase, another click will be heard as the system enters the zero-air purge phase. The last click signals the start of ambient air purge phase. One minute later, the QC Check sequence will be complete, and the channel status flag should return to OK.
7. To view your results, open Envidas Ultimate Reporter > Operational > Calibration.
8. Click on “bscat” only > select “daily” with today’s date > highlight “Report Type: as Calib_2Points” > select OK.
9. On the Nephelometer Quality Control Check Form, record the measurements from the calibration report of the ZMeas (measured bscat of zero air E-4), the SMeas (measured bscat of CO2 span gas E-4), SRef (the expected value of CO2 E-4) and verify the Sdiff field auto populated on the form matches the calibration report SDiff (%ReF) (the % difference between the measured span bscat and expected span bscat). See Table 5-2 to determine whether or not an adjustment is necessary. To calculate the percent difference, use the following formula:

$$\left(\frac{\text{indicated value (bscat)} - \text{actual value (gas)}}{\text{actual value (gas)}} \right) * 100$$

10. Evaluate the results against the acceptance and action limits in Section 5.2.2 to determine if a calibration adjustment is necessary. Record the QC Stop Time on the Nephelometer Quality Control Check Form and review the form for accuracy and completeness. Email an electronic copy of the form to the Quality Assurance Coordinator no later than 10 days following the site visit.

If calibration adjustments are necessary, complete the as-found QC form and follow the procedure under the Calibration section.

Calibration

If an adjustment to the M903 nephelometer calibration is necessary, follow the instructions below to recalibrate the instrument. NOTE: Calibration adjustments are to be performed only after the initial (“as-found”) QC check has been completed and documented. In the following steps, with the item switch held to the Slow position, each click of the Parameter switch in either the Raise or Lower direction will typically adjust the resultant bscat value by approximately $0.03 \times 10^{-5} \text{ m}^{-1}$ when adjusting ZERO, and adjust the resultant Span percent difference value by approximately 1% when adjusting SPAN.

M903 nephelometer calibration procedure:

To adjust the ZERO:

1. On the nephelometer, toggle the Display Switch until screen 3 is displayed. You are on the correct screen if you see set ZERO in the upper right corner of the display.
2. From the Envidas Ultimate Viewer, select Operational tab > Phase From Sequence > Neph2pt.
3. In the Phase drop down menu on the bottom left corner of the pop-up window, select ZERO > START to initiate a Zero Phase. After starting the zero phase, there will be a loud click from the Auto Zero/Span Module. Wait 5 minutes into the zero cycle to view the bscat value on the display screen 3.
4. To adjust the bscat as close to zero as possible, hold the **Item Switch** on **Slow**, toggle the **Parameter Switch** towards **Lower** to raise the bscat or towards **Raise** to lower the bscat value to $0.00 \times 10^{-5} \text{ m}^{-1}$. The Parameter toggle can be used without holding the Item toggle on Slow to achieve smaller increments to the set ZERO number. If you adjust past your target bscat value of $0.00 \times 10^{-5} \text{ m}^{-1}$, you can refer to the original set ZERO number recorded on your QC form prior to adjustment. The bscat value will fluctuate as the integrator average stabilizes, so wait until the value stabilizes around your $0.00 \times 10^{-5} \text{ m}^{-1}$ target before stopping.
5. Click Stop once you have completed your adjustment and verify the bscat channel flag returns to OK and the bscat value rises to ambient conditions.
6. If also adjusting the SPAN, follow the procedure below. When all adjustments are complete, perform an “as left” QC Check as described in section 5.2.3 and document the results on a Nephelometer QC Check form, appending the as left designation to the file name. Email an electronic copy of the form to the Quality Assurance Coordinator no later than 10 days following the site visit.

To adjust the SPAN

1. On the nephelometer, toggle the Display Switch to screen 4. You are on the correct screen if you see set SPAN in the upper right corner of the display.
2. From the Envidas Ultimate Viewer, select Operational tab > Phase From Sequence > Neph2pt.
3. In the Phase drop down menu on the bottom left corner of the pop-up window, select SPAN > START to initiate a Span Phase. When the Span Phase is initiated, there will be a

loud click from the Auto Zero/Span Module. Wait 8 to 10 minutes into the Span cycle to allow the response to stabilize and view the bscat value on display screen 4.

4. While holding the **Item Switch** on **Slow**, toggle the **Parameter Switch** towards **Lower** to lower the bscat or towards **Raise** to raise the bscat value to the Reference Gas value shown as “gas =” on screen 4. The bscat value will fluctuate as the integrator average stabilizes, so wait until the value stabilizes around your Reference Gas target before stopping.
5. Click Stop once you have completed your adjustment and verify the bscat channel flag returns to OK and the bscat value rises to ambient conditions.
6. If also adjusting the ZERO, follow the procedure above. When all adjustments are complete, perform an “as left” QC Check as described in section 5.2.3 and document the results on a Nephelometer QC Check form, appending the as left designation to the file name. Email an electronic copy of the form to the Quality Assurance Coordinator no later than 10 days following the site visit.

NOTE: Prior to adopting Envidas Ultimate, operators were instructed to adjust the zero point to 0.15E-5 to avoid negative bscat values. This offset is no longer necessary. Negative bscat values can now be accounted for in the NPM25 equation in Envidas Ultimate. Operators should adjust the zero point as close to 0.00E-5 as possible with no offset.

Following an adjustment to either the zero or span point, the other point should be checked and not just assumed to have remained within acceptable limits. If it is necessary to revert back to the settings prior to the calibration, this can easily be done by referring to the log sheet. The set SPAN value on screen 4 and the set ZERO value on screen 3 are index values. Simply use the Item and Parameter switches to adjust these values back to what they were during the last quality control check and start the calibration procedure over. In the event of an accidental adjustment while the wrong screen is displayed, the same is true for all set values.

Guidance on Performing QC checks during smoky conditions

During wildfire season, which typically runs June – September, smoke can intrude into the nephelometer causing failing QCs. If this happens, it will be up to the operator to determine that there is smoke in the air and that the nephelometer **should not** be calibrated during the smoky period. Instead, wait until the smoke clears and then then run another QC check. If it passes, no action is needed. If it fails, the instrument is out of calibration and needs adjusting.

Maintenance

Sample pumps should be rebuilt and probe lines should be cleaned or replaced annually. The funnel and bug screen should be replaced as needed by the site operator. When the wall value reaches 80% it indicates that the nephelometer needs service. If the flashlamp value is outside the range of 30K to 60K, then the flashlamp should be adjusted or replaced. Small leaks in the

system can cause zero check bscat values to rise during high ambient particulate concentrations such as caused by wildfires, and any indicated leaks should be investigated and corrected prior to exceeding acceptance limits. If the site operator does not feel confident in performing these operations, contact the Calibration & Repair Lab and make arrangements to have the instrument serviced.

Data Validation, Data Completeness, and Quality Assurance

All Nephelometer Quality Control Check forms must be sent to the Quality Assurance Coordinator no later than 10 days following the site visit.

Preliminary data validation is the operator's responsibility. Preliminary data validation includes, but is not limited to:

- Reviewing results of onsite QC Checks.
- Reviewing auto-QC results on Monday mornings and comparing to past results.
- Using the EnvistaARM to review collected data for reasonability and comparability with other area monitors.
- Sending the QA Coordinator an email identifying any invalid data so that it can be removed from the dataset during final level data validation.

The Quality Assurance unit is responsible for final data validation. Data validity is evaluated using a number of criteria, including comparability to other area monitors and results of quality control checks.

References

- "Automated Method Data Documentation and Validation Procedures." October 2009.
Code of Federal Regulations, Title 40, Part 58 (40 CFR 58).
- "Envidas Ultimate", Continuous Emission, Air and Water Quality Monitoring System, Rev 1.2.15
February 2015, Envitech Ltd.
- "Operation Procedures M903 Nephelometer", Radiance Research, Version 2.37.20DE.
- "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I – A Field Guide to Environmental Quality Assurance." EPA-600/R-94/038a. April, 1994.
- "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II – Ambient Air Quality Monitoring Program." EPA-454/B-17-001. January 2017.

Appendix A – M903 Nephelometer Quality Control Check Form

Form revised 08082019

AQS No. _____
 Location _____
 Model No. _____
 Serial No. _____
 State Tag No. _____

Date _____
 Operator _____
 QC Start Time _____ PST
 QC StopTime _____ PST

Values upon Arrival

Screen 1	bscat	e-05
----------	-------	------

Screen 3	Set ZERO	
----------	----------	--

Screen 4	Gas	
	Wall	
	(< 80%)	%
Set SPAN		

Screen 5	High voltage	
	Flashlamp	
	(30K - 60K)	
	Dark Lamp	

Screen 6	Rsc:	
	P	
	T	
	RH	

Screen 7	Set Rgas	
----------	----------	--

Values during Span

CO2 Tank	Tank pressure	psi
	Delivery pressure	psi

Screen 6	P	
	T	
	RH	

Calibration Report Results

Read from Calibration Report	ZMeas	e-04
	SRef	e-04
	SMeas	e-04

SDiff(%REF) (< 10%)	
---------------------	--

QC Result:

Comments: