DEPARTMENT OF
ECOLOGY
State of Washington

Ecotech Nephelometer Operating Procedure

Air Quality Program

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State of Washington
Department of Ecology
Air Quality Program

ECOTECH NEPHELOMETER OPERATING PROCEDURE

Prepared by: Puget Sound Clean Air Agency

March 2009

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INTRODUCTION

This document describes the Washington State Department of Ecology's procedures for sampling ambient air using the Ecotech M9003 portable nephelometer. The Ecotech M9003 and the upgraded version Ecotech M9003 Aurora instrument use the exact same measurement principles and thus are considered the same instrument. The Aurora model has a smaller physical footprint. This procedure covers both versions of the nephelometer. It is intended to be used together with the sampler specific information and instructions provided by the manufacturer. The manufacturer does have an operations manual and a service manual available for the nephelometer in addition to training manuals and periodic technical update memorandums. All Air Quality Program nephelometer station operators are expected to refer to this document if they operate the M9003 nephelometer. A picture of the nephelometer can be seen in figure 1.

Figure 1: Ecotech M9003 Nephelometer

Method of Operation

The M9003 nephelometer uses an LED array as the light source. Sample air is drawn by the pump in through the sample inlet into the measurement volume and exits through the sample outlet. Light from the light source illuminates the sample air in the measurement cell. Gaseous and particulate components of the sample air will cause the light to scatter.

The baffles inside the cell are positioned so that only light scattered inside a narrow cone reaches the photomultiplier tube and so that multiple scattered light is unlikely to reach the photomultiplier tube. The photomultiplier tube produces electrical signals proportional to the

intensity of the incident light. Hence the signal produced by the photomultiplier tube is proportional to the scattering coefficient of the sample air.

The light trap and other baffles eliminate unwanted reflections from the light source and scattered light off the non-detecting end of the cell. The cell interior and baffles are coated with a special matte finish black paint to reduce any internal reflections. Light scattered by the particles suspended in the air sample can now be quantified and registered on the display screen as inverse Mega-meters, or (Mm-1). 10 Mm-1 is equal to 1.0 e-5 bscat on the Ecotech nephelometer. A more comprehensive explanation of the operations of the M9003 nephelometer can be found in the manufacturer's documentation.

SITING REQUIREMENTS

The following siting requirements are for neighborhood scale monitoring stations.
Comprehensive siting requirements can be found in Title 40 CFR 58, Appendix E.
http://edocket.access.gpo.gov/cfr_2008/julqtr/pdf/40cfr58e.pdf

Basic Requirements

- The distance from the nearest traffic lane to the probe inlet is based on average daily traffic (ADT) counts. The probe inlet must be positioned a minimum of 10 meters from the nearest traffic lane per 1000 vehicles ADT and can be no less than 10 meters distance. Average daily traffic counts for most roadways in Washington can be found at http://www.wsdot.wa.gov/mapsdata/tdo/annualtrafficreport.htm

- To keep impacts from windblown dust to a minimum, probe inlets should not be located above barren ground and should be located at least one quarter mile from potential sources of dust.

- Avoid areas with excessive smoke from local combustion sources.

- There must be no obstructions that would limit the sampler's ability to collect aerosols representing the regional area.

- An open horizontal arc of at least 270^{O} must surround the sampler inlet with prevailing winds entering the arc. Any obstructions within this arc must be twice the distance from the sampler inlet as they are tall.

- The probe inlet must be located between 2 and 15 meters above ground level.

- The probe inlet must be at least 1 meter away from any supporting structure.

- The probe inlet must be at least 10 meters from the drip line of trees.

- It is recommended that the probe inlet not be positioned next to a wall. If there is no other option then the probe inlet must be at least 2 meters from the wall and have a minimum of 180^{O} of open sample pathway.

- The probe inlet should be greater than 100 meters from any residential/commercial wood burning device.

Other factors must be remembered when considering a location for installation. The operator's personal safety is an important consideration. It must be remembered that during times of inclement weather the site may still need to be accessed. Power and telephone line availability is a concern. Security of both the operator and the equipment can be an issue. Access to the site must be such that the operator has the ability to bring tools and supplies in and out. All sensitive electronic equipment must be kept in a temperature-controlled environment that isolates it from moisture and rapid temperature changes.

INSTALLATION

Equipment and Supplies

- M9003 Nephelometer
- PC data logger and communications equipment. The instrument can be connected via analog datalogger, but this is discouraged. See manufacturer's manual for more detail.
- Probe material and mounting hardware
- Appropriate span gas
- Pressure regulator to fit span gas tank
- Length of particulate filter, conditioning coil, and rotameter for connecting span gas regulator to nephelometer calibration connection

Perform visual inspection of components upon receipt of the nephelometer system. Notify the Repair and Calibration Lab if any equipment is missing or damaged. Proper installation of the sample probe is very important. Care must be exercised to eliminate the possibility of drawing in water or insects with the air sample. There is a sample head available from the manufacturer. It includes a bug screen. The probe material is anodized aluminum inlet tubing along with 3/8" plastic flexible tubing. Installation of the probe should be done with minimal bends and turns as to minimize particulate loss due to adhesion. Install the nephelometer in a secure, dry location within the shelter that will not be directly impacted by the flow of air from a heater or an air conditioner. A wall mount is available for this instrument from the manufacturer.

System Setup

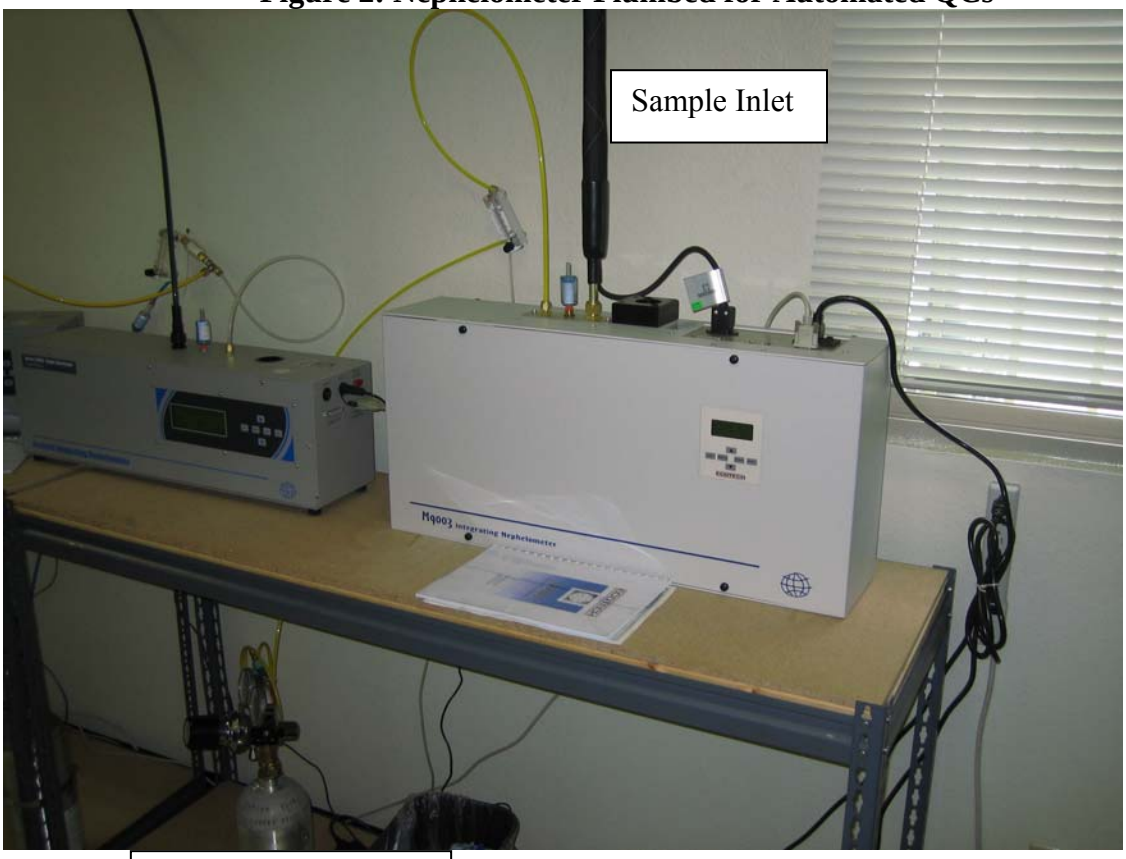
The Repair and Calibration Lab will have programmed the nephelometer according to its specific data collecting requirements. If it becomes necessary to change the programming of the nephelometer, contact the Repair and Calibration Lab. The Air Quality Program is currently using Envitech software installed on a computer as a data logger. This section will explain installing the nephelometer with the Envitech PC datalogger.

Connect a standard serial cable between the nephelometer serial output (RS232 Multi-Drop connection) and the computer's 8 port DB9M serial cable (octopus) to the cable that is factory marked with a number 1 (or another number based on the COM port used). The nephelometer analog output is not used for this application. Install the probe. All nephelometers include a heating chamber or heated probe that reduces the relative humidity of the sample before it enters the sample chamber. Only the factory designed heater should be used. The relative humidity sensor and heat controls are integrated into the nephelometer design.

Plumbing

The nephelometer has an integrated automatic QC system. See figure 2 for a picture.

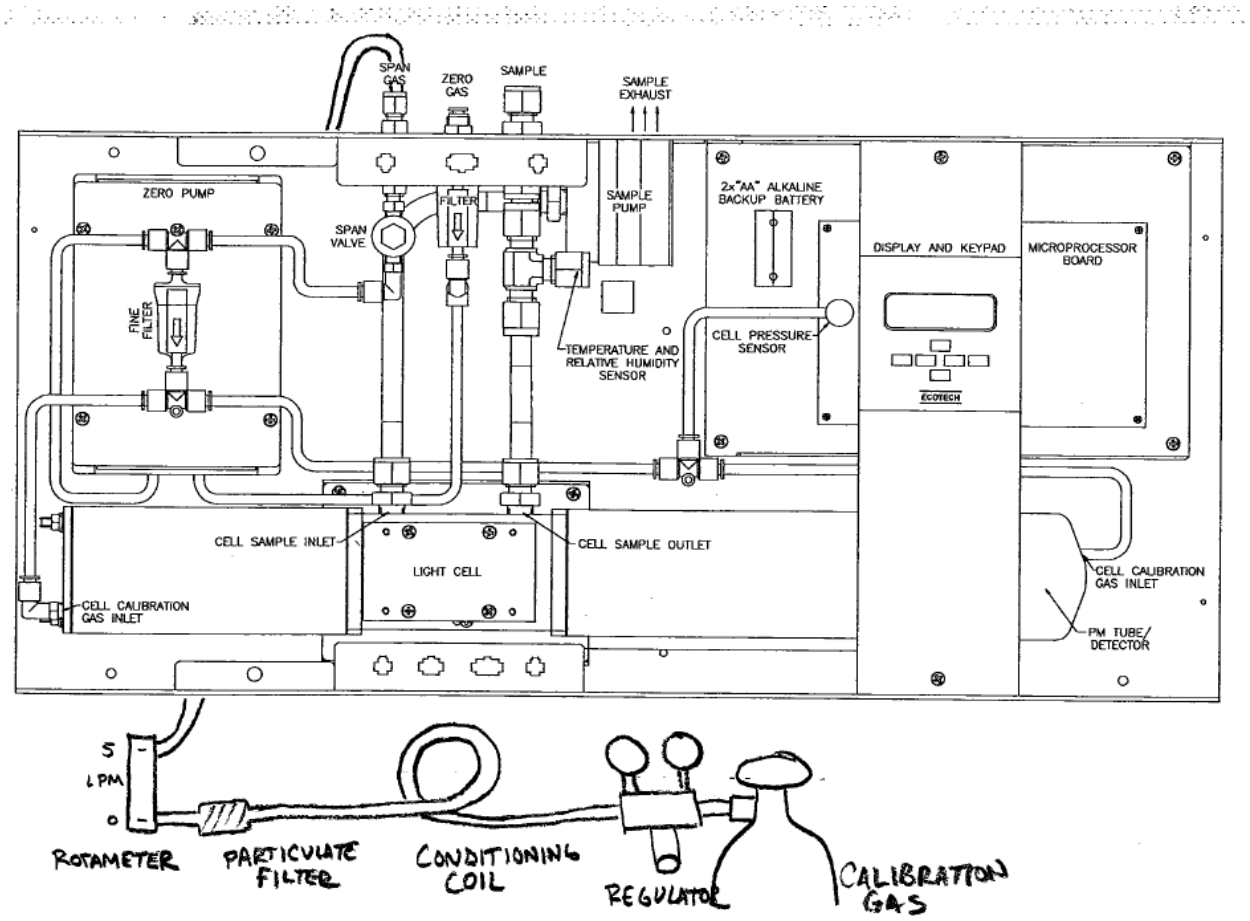
Figure 2: Nephelometer Plumbed for Automated QCs



Automated QC Nephelometers

All Ecotech nephelometers have an automated QC subsystem integrated into the design of the instrument. See figure 3 for a block diagram of the connections. To use the nephelometer automatic zero/span subsystem 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, using PFA grade Teflon tubing that is rated above 100 pounds per square inch that will not react with the span gas. This is the same material used as sample probe material for criteria gas pollutant samplers. Experience has shown that there must be a conditioning coil of at least 1 meter in length along with a particulate filter and a rotameter in series between the calibration gas regulator and the instrument's calibration gas inlet port. Install a particulate filter for the zero gas measurement.

Figure 3: Nephelometer Plumbed Block Diagram



STATION VISITS

Station visits and a quality control check are required once each calendar month for all nephelometer stations that are not equipped to perform QCs automatically. Stations that are equipped to perform automated quality control checks must be visited a minimum of once every 90 days. Document all site visit activities (QC results, site conditions, etc.) in the electronic site log. During every station visit it is highly recommended that the site operator visually inspect the probe inlet screen and funnel for damage and check the span gas supply.

QUALITY CONTROL CHECKS

Periodic two-point quality control checks are used to verify that the nephelometer and data collection system are operating correctly. Multi-point quality control checks are not required due to the M9003's proven linearity.

A quality control check consists of a check of the zero and a check of the span of the instrument. The operator must evaluate the automated processes and make a report via Envidas for Windows (EFW) Reporter electronic logbook as to the status of the instrument and data collection integrity. The calibration schedule can be controlled and monitored by the EFW software or the instrument itself. The operator is expected to observe proper system performance by checking calibration gas pressure, and diagnostics parameters and log the observations in Reporter if the zero and calibration check are within specifications. If the zero and calibration check are not within specifications, then the operator must take actions according to the flowchart discussed later in this section.

When the operator performs a full calibration of the instrument, the values displayed by the instrument are zero and span results given before the new calibration is mathematically calculated and set in the instrument memory. Therefore, after the operator performs the full calibration, the operator must subsequently perform a calibration check to ensure that the calibration conducted by the instrument will now yield accurate zero and span results. Full calibrations are only used when necessary, and there is not a required timeframe that the instrument needs full calibration. Automated Quality Control checks are normally conducted weekly.

Span Gas

Ecology's Air Quality Program uses a refrigerant, HFC-134a as the span gas. As noted in the manufacturer's documentation, there are other gases that are acceptable for use in the Ecotech M9003 nephelometer. The Puget Sound Clean Air Agency has chosen CO_2 to be the preferred calibration gas based on its light scattering coefficient, cost, availability and negligible impact on the environment. Use of an alternate span gas requires approval by the Quality Assurance Coordinator.

Quality Control Limits

If the zero point is less than ± 5.0 Mm-1 and the span point is within 10% of the calibration gas value set point then the nephelometer is operating within acceptable limits. 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 zero point is greater than or equal to plus or minus 3.0 Mm-1 or the span point is greater than or equal to 7% of the calibration gas value set point, a calibration of the nephelometer is highly recommended.

Figure 4: Control Limits

Quality Control Check	Action Level	Adjust bscat To
Zero Point	≥ ± 3.0 Mm-1	< ± 1.5 Mm-1
Span Point	≥ 7%	= 22.7 Mm-1 (CO_2) = 88.88 Mm-1 (R-134a)

Performing Automated Quality Control Checks using EFW as the Controlling Entity

Choosing to use EFW as the controlling entity for your automatic PC has advantages and disadvantages. One advantage of using EFW as the controlling entity is that the calibration check is based on the datalogger time, not the instrument time. This keeps the calibration data collection information in line with the instrument's output. Another advantage is that the operator can trigger an extra calibration remotely. If EFW is configured to use the DO command set as specified in the Operator's manual, the disadvantage of this command set is that the instrument will not capture the last span and zero check or stability information correctly because the DO command set only commands the valve operations, it does not set the instrument mode. If EFW is configured to use the **J command set as specified in the Operator's manual, then the instrument will capture the information correctly because this command set tells the instrument to go into the zero or span calibration mode, rather than simply commanding the valves to operate. Additionally, both the EFW channel and the instrument must use the same Module Address in order for the devices to communicate properly. The datalogger channel and the calibration sequence must be configured correctly. Figures 5-1, 5-2, and 5-3 show an example of a Channel and Calibration sequence that is configured to provide the automated zero and span check using EFW as the controlling entity. Note that in this case, the Address 3 is used in both the command line in the calibration sequence and in the Address under General Channel configuration. The instrument has been set to address 3 under the menu option: Serial IO > Module Addr (address for multidrop RS232 port: 0-7).

Figure 5-1: General Channel Configuration using EFW as the Controlling Entity

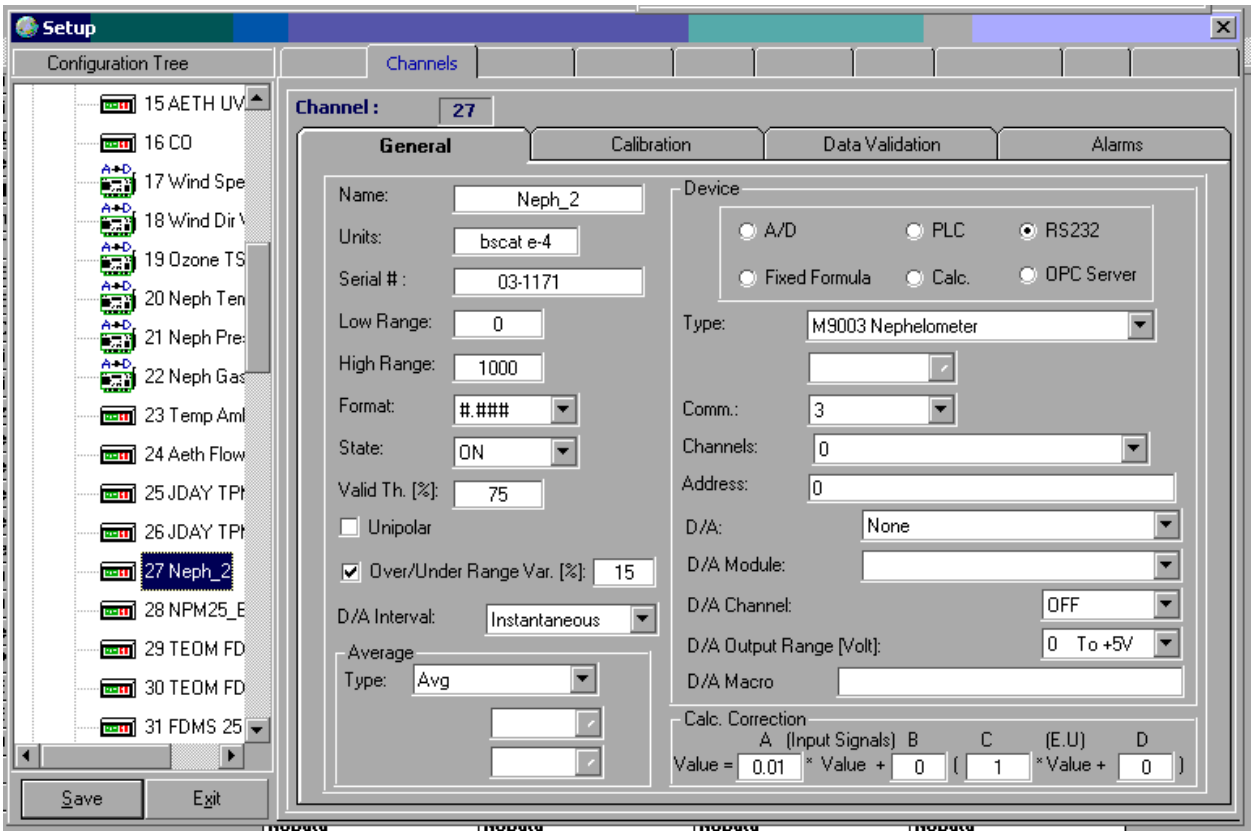


Figure 5-2: Calibration Channel Configuration using EFW as the Controlling Entity

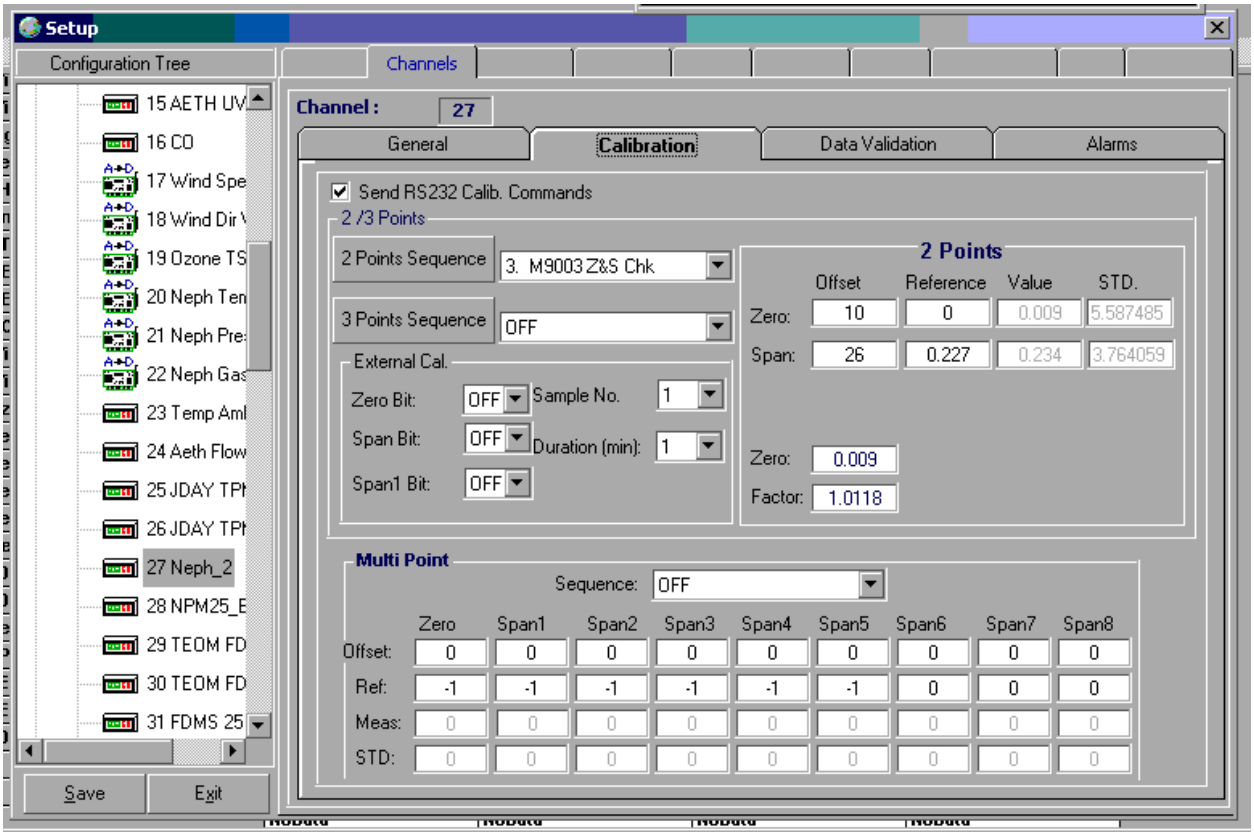
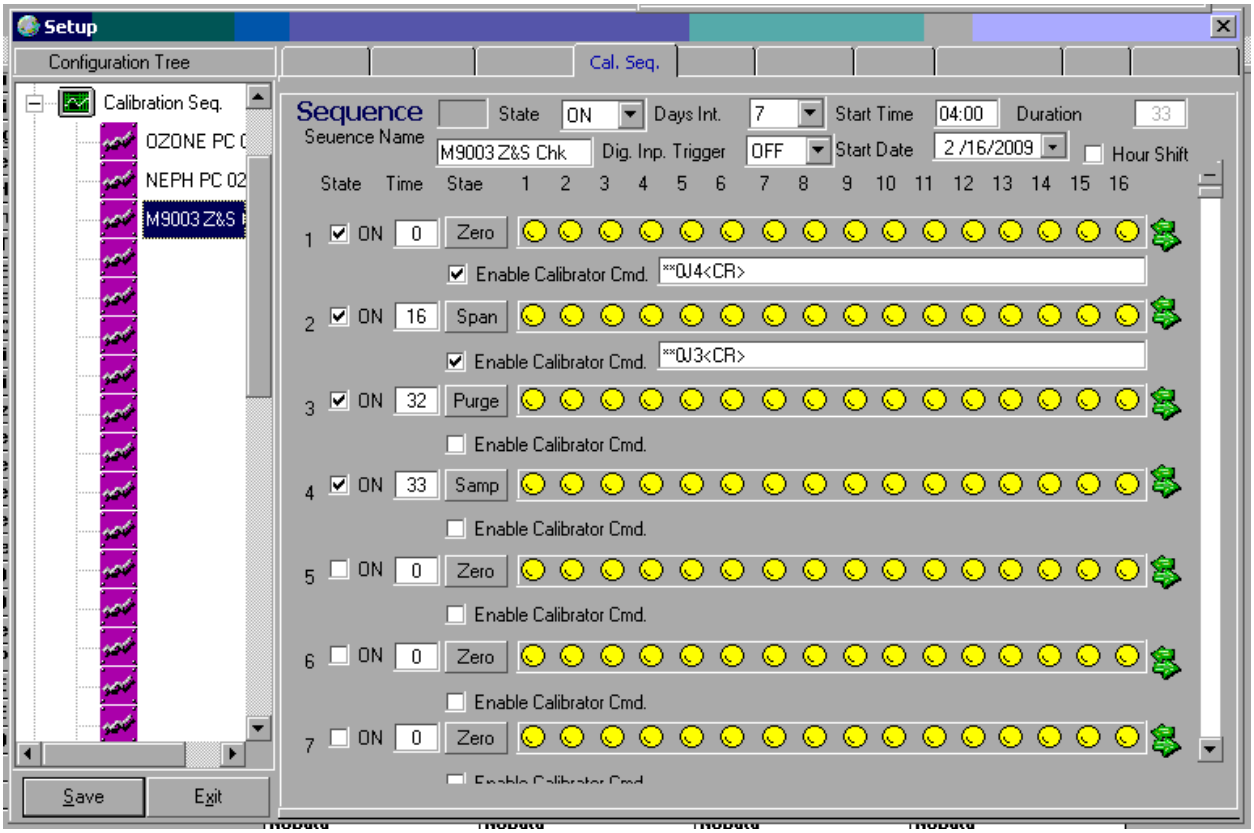


Figure 5-3: Calibration Sequence Configuration using EFW as the Controlling Entity



The operator must evaluate the Calibration Report screen to compare the results of the zero and calibration check to the standards used. The operator must use the limits established in the Quality Control Limits section in this manual to determine what actions may need to be taken for abnormal results. The formula to calculate percent difference is:

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

If adjustments are not necessary then the operator must log the results in the Reporter electronic log and submit the proper paperwork to the Quality Control section via normal monthly or quarterly reporting methods. If adjustments are necessary, follow the procedure under the section titled **CALIBRATION.**

Performing Automated Quality Control Checks using the Nephelometer as the Controlling Entity

If you choose to use the nephelometer as the controlling entity for your automatic PC, then you must be aware of certain facts. The advantage of using the nephelometer is that the nephelometer itself will trigger the actions for the zero and span. And the nephelometer will record the zero and span along with % stability parameters and wall value parameters that will be recorded in the instrument memory. The operator can either use the datalogger diagnostics report to collect this information, or can go to the instrument under Enter > Calibration > to find the last zero check, last span check, wall value and % stability statistics. The disadvantage of performing the check in this manner is that if the instrument and datalogger clocks deviate significantly, then you may get incorrectly calculated zero and span checks via the Reporter Calibration Report. A comparison between diagnostics report and calibration report can detect this. Another disadvantage is that the operator cannot trigger remote calibration checks.

Regardless, both the nephelometer and the EFW Channel must be configured correctly. Configure the nephelometer by entering these settings:
Enter > Calibration >

Auto Cal Intv = Weekly (normally performed on Monday at 0000).
AutoCal Type = Z&SChk
Cal min time = 15
Cal max time = 15
%Stability = 95

Configure the calibration sequence and the nephelometer datalogger channel by using the settings described in Figures 6-1, 6-2, and 6-3.

Figure 6-1: General Channel Configuration using the Nephelometer as the Controlling Entity

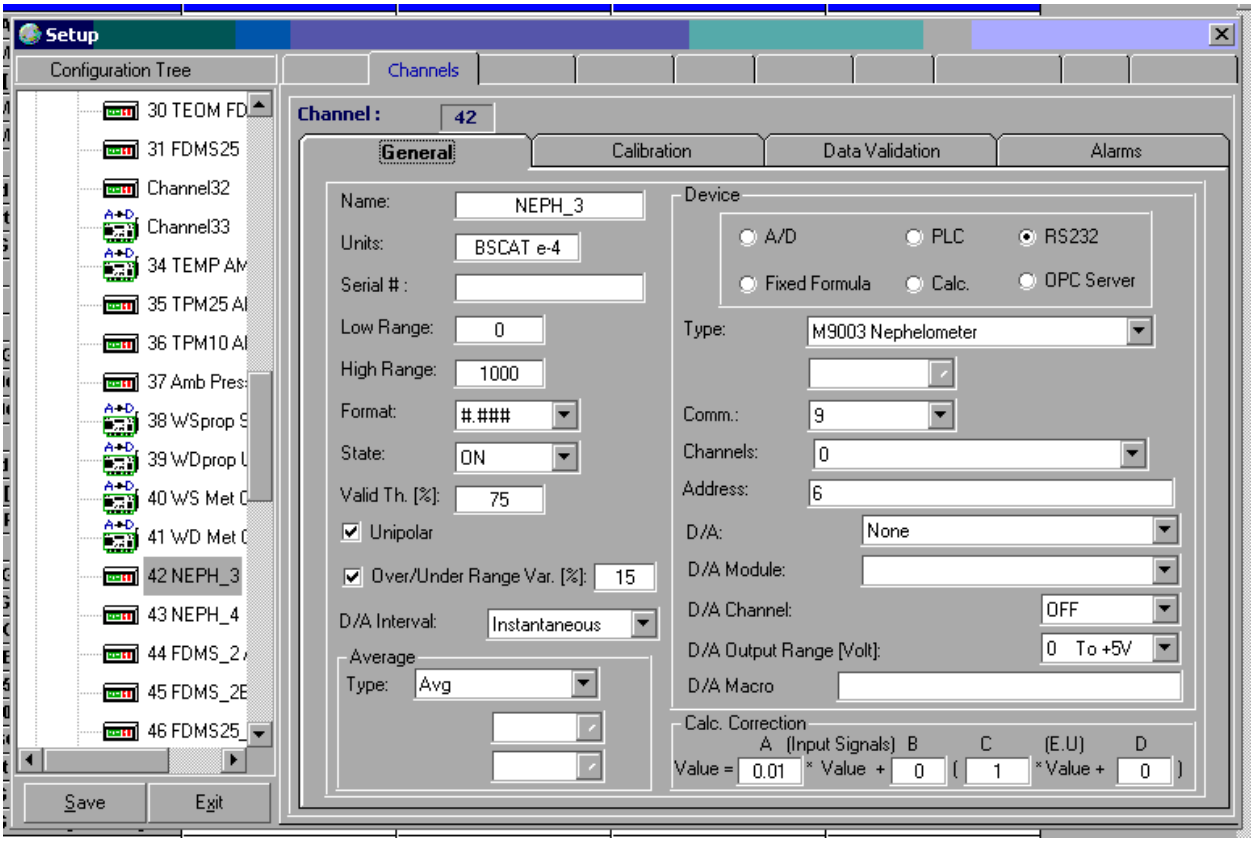


Figure 6-2: Calibration Channel Configuration using the Nephelometer as the Controlling Entity

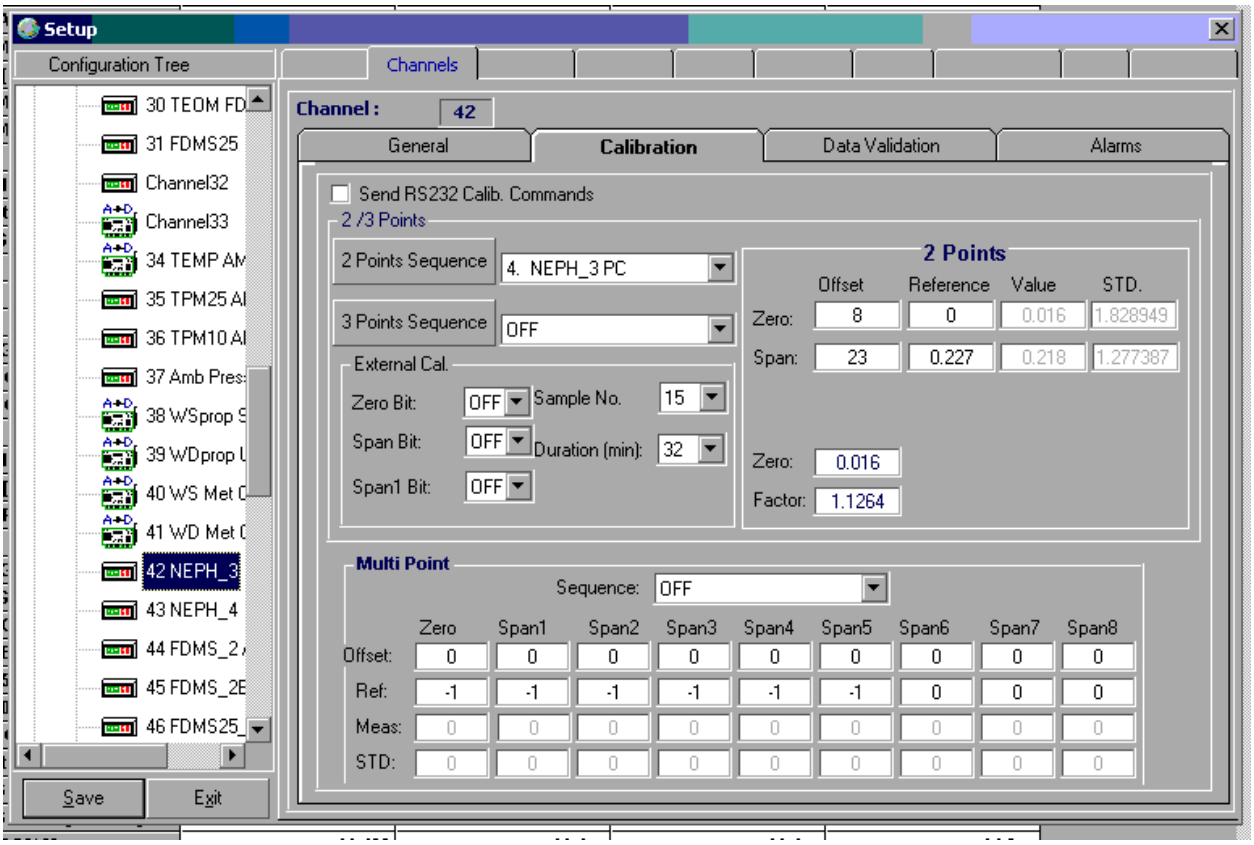
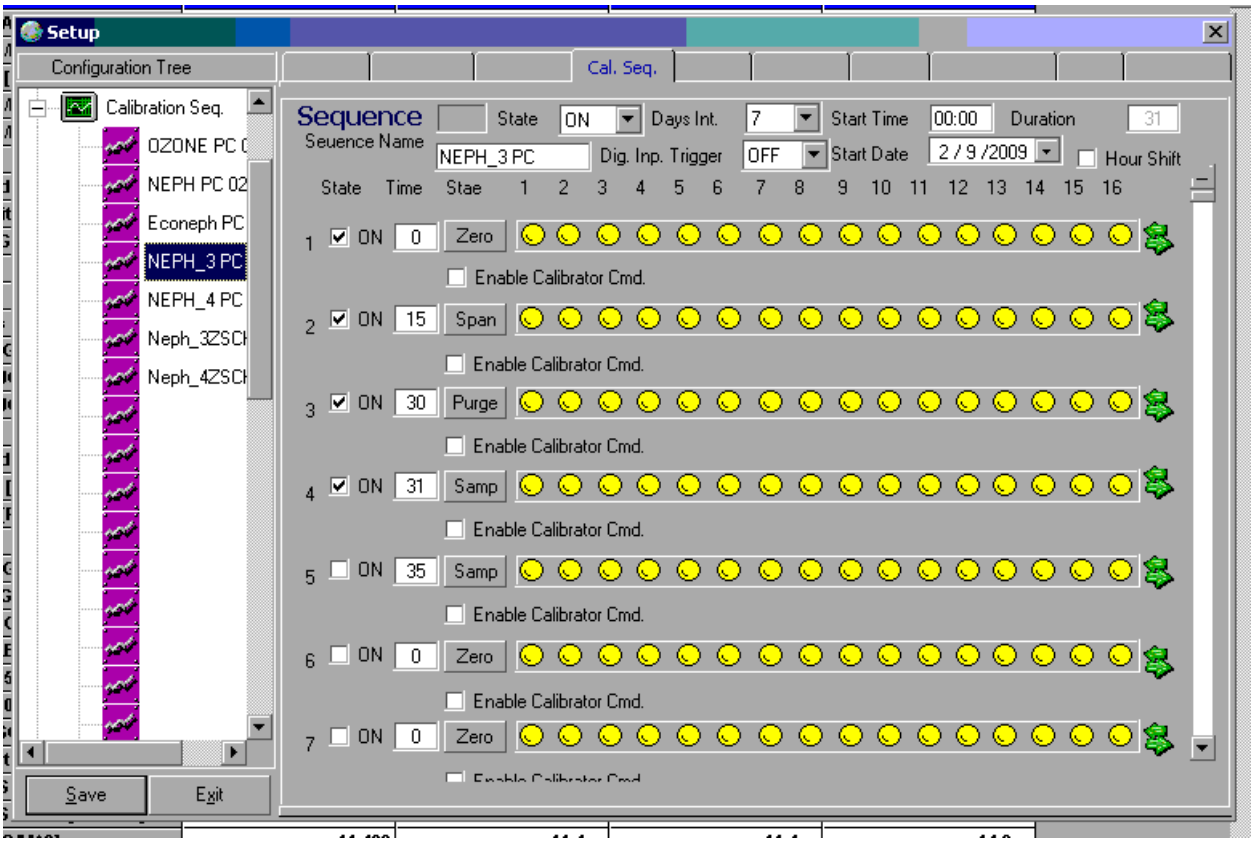


Figure 6-3: Calibration Sequence Configuration using the Nephelometer as the Controlling Entity



The operator must evaluate the Diagnostics report to find the screen to compare the results of the zero and calibration check to the standards used. The operator must use the limits established in the Quality Control Limits section in this manual to determine what actions may need to be taken for abnormal results. The formula to calculate percent difference is:

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

If adjustments are not necessary then the operator must log the results in the Reporter electronic log and submit the proper paperwork to the Quality Assurance Unit via normal monthly or quarterly reporting methods. If adjustments are necessary, follow the procedure under the section titled **CALIBRATION.**

CALIBRATION

Performing Calibrations

Make certain that data logging is disabled prior to performing any calibration procedures. A flowchart of the logic can be seen in figure 7.

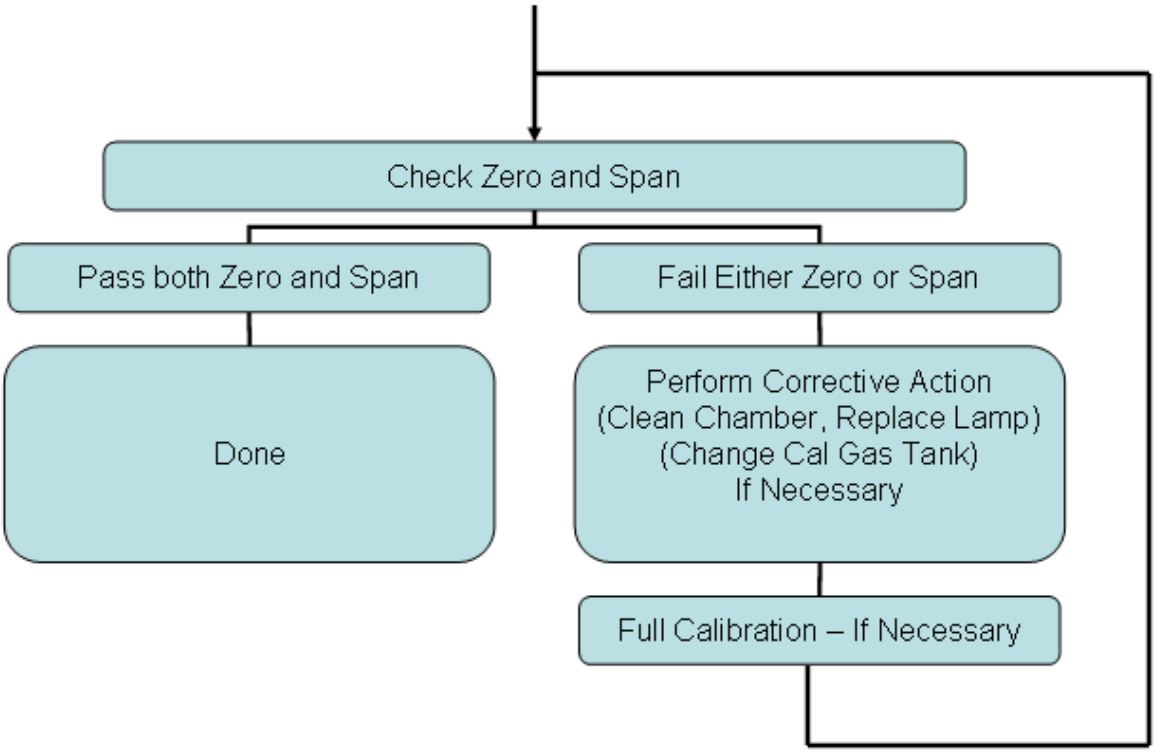
When the operator performs a full calibration of the instrument, the values displayed by the instrument are zero and span results given before the new calibration is mathematically calculated and set in the instrument memory. Therefore, after the operator performs the full calibration, the operator must subsequently perform a calibration check to ensure that the calibration conducted by the instrument will now yield accurate zero and span results. Full calibrations are only used when necessary, and there is not a required timeframe that the instrument needs calibration. Automated Quality Control Checks are normally conducted weekly.

To conduct the calibration, use the menu tree: Enter > Calibration > Do full cal.

To conduct the calibration check:

> For EFW as the controlling entity: Under EFW Utilities > Perform Extra Calibration > Ecotech Neph Z&S Check > Start. Record results from the Calibration report and then use the electronic log to log your results.
>
> For Instrument as the controlling entity: Enter > Calibration > Do zero chk. When the zero check is complete, do: Enter > Calibration > Do span chk. Use the instrument Last zero ck and Last span ck to record the results on your PC sheet and the electronic log.

Figure 7: QC Logic Flowchart



MAINTENANCE

Probe lines should be cleaned annually. The head and bug screen should be cleaned or replaced as needed by the site operator. The sample pump and zero pump will need replacement for preventative maintenance. If there is increased variability in the zero or span checks (for example, the % stability is below 95.0), or as needed, the operator must periodically clean the measurement chamber of the nephelometer. Instructions for this are found in the Service Manual. Materials needed include Q-tip sticks, forced air dusters, no-lint cloth. If the Shutter Count or Dark Count is abnormal, then the nephelometer may need service. Service and troubleshooting should be conducted by a trained technician, or by the manufacturer.

DATA DOCUMENTATION AND REPORTING

For sites equipped with a new server/logger and a Nephelometer Auto Zero/Span Module the Nephelometer Zero/Span Log will need to be filled out and sent to the QA staff for the 90 day visit. The Monthly Precision Check summary form will no longer be required.

For sites without a server or without the automatic zero and span features used, the required quality control check frequency remains once a month, not to exceed 30 days. The Monthly Precision Check Summary form and the Nephelometer Zero/Span Log will continue to be

required and must be submitted by the 10th of the month following the month during which the data was collected.

DATA VALIDATION

The Quality Assurance Unit is responsible for final data validation.

DATA QUALITY ASSESSMENT

For each calendar quarter and year, the Quality Assurance Unit will prepare a quality assessment report.

Data Completeness

Data completeness will be determined for each analyzer and expressed as a percentage. Percent valid data will be a gauge of the amount of valid data obtained compared to the amount expected under ideal conditions (24 hours per day, 365 days per year). Exceptions will be made for analyzers operating on a seasonal basis.

REFERENCES

1) "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I - Principles." EPA-600/9-76-005. December, 1984.

2) "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II - Ambient Air Specific Methods." EPA-600/4-77-027a. January, 1983.

3) Code of Federal Regulations, Title 40, Part 58 (40 CFR 58).

4) " Automated Method Data Documentation and Validation Procedures." March 2004.

5) "M9003 Nephelometer, Operation Manual", Ecotech, Version 3.00, May 2004.

6) “M9003 Nephelometer Service Manual”, Ecotech, Revision 1.1, October 2007

7) “Envidas for Windows”, Dr Das, fifth edition Rev 12.9, 02/2006

Ecotech Nephelometer QC Data Sheet

Station #: Date: _____

Location: Time: _____

Operator: _____

Sampler Serial #: _____ Current σ_{sp} _____

Time Check

Data Logger _____ Neph _____ Difference _____ min (Change if > 5 min)

Time reset to data logger time? Yes [ ] No [ ]

Last Span and Zero Check

Wall Signal _____

Last Zero Check _____ e^{-6} Last Zero Stability _____ %

Last Span Check _____ e^{-6} Last Span Stability _____ %

Diagnostics Parameters (Diagnostics assessment should include a look for abnormal values or trends)

RH Av _____ Dark Count Average _____

Shutter Count Average _____

Final Checks

Do the DCN & nephelometer values compare? [ ]
Is the DCN enabled? [ ]
Cal Gas Pressure – High side (>500psi). Low side (5-10psi)[ ]

Action and Failure Levels

Parameter	Action Level	Failure Level
SPAN STABILITY:	≤ 96.000% – recalibrate or fix	None
ZERO:	> ± 3.50e^{-6} – recalibrate or fix	> ± 5.00e^{-6}
SPAN:	≤ 21.57e^{-6} and ≥ 23.85e^{-6}	≤ 21.12e^{-6} and ≥ 24.30e^{-6}

Monthly Precision Check Summary

AIRS NUMBER: _____

PARAMETER: _____ **YEAR:** _____ **MONTH:** _____

STATE TAG OR ID #: _____

LOCATION: _____ **OPERATOR:** _____

DATE			ACTUAL CONC.	INDICATED CONC.	UNITS	*PASSED? Y or N	COMMENTS
Month	Day	Year					

*Shaded area to be completed by QA Personnel

PRECISION CHECK EQUIPMENT:

Gas Cylinder Serial #: _____

Calibrator Model: _____

Calibrator Serial #: _____

Permeation Tube #: _____

Decimal Placement:	
CO	2
SO2	3
NO2	3
O3	3
NEPH	3

COMMENTS: