Gaseous Pollutant Monitoring Standard Operating Procedure (CO, SO_2, NO_X, NO_Y, NO_2)

By

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For the

Air Quality Program

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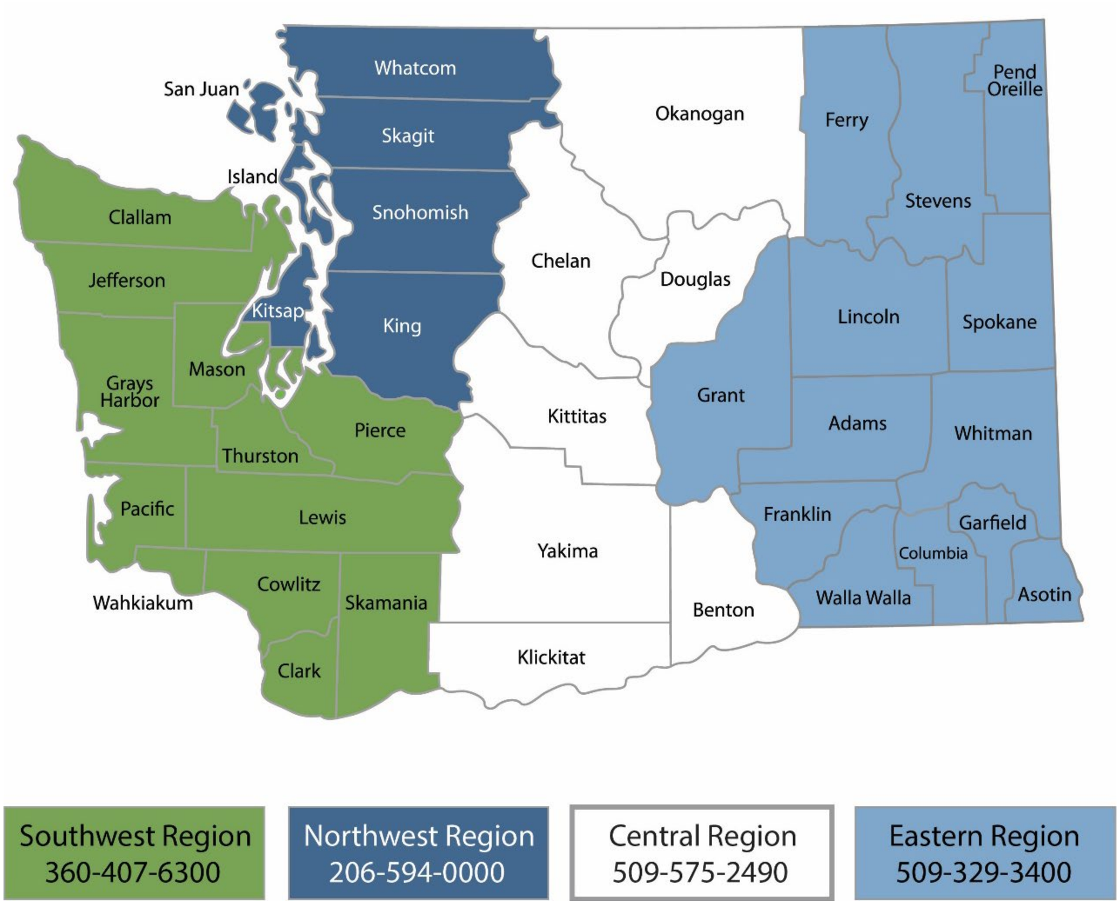
Map of Counties Served



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Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
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Air Quality Program
Washington State Department of Ecology
Olympia, WA

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Revision Date	Revision Number	Summary of changes	Revised sections	Revised by
10/31/24	1.0	First tracked version		Nicholas Mendes
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Definitions and Acronyms

AQS	Air Quality System
CFR	Code of Federal Regulations
CO	Carbon monoxide
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
In-Hg	Inches of mercury
lpm	Liters per minute
MDL	Method detection limit
MFC	Mass flow controller
NAAQS	National Ambient Air Quality Standards
NCore	National Core Monitoring Network
NIST	National Institute of Standards and Testing
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
NO_Y	Reactive nitrogen
PMT	Photo multiplier tube
ppb	Parts per billion
ppm	Parts per million
psig	Pounds per square inch, gauge
QA	Quality assurance
QAP	Quality Assurance Plan
QC	Quality control
sccm	Standard cubic centimeters per minute
SLAMS	State and Local Air Monitoring Stations
Slpm	Standard liters per minute
SO_2	Sulfur dioxide
SOP	Standard Operating Procedure
SPMS	Special Purpose Monitoring Stations
STP	Standard Temperature and Pressure (25°C and 760 mmHg)
Washington Network	Washington State Ambient Air Monitoring Network

1. Overview

1.1. Purpose and scope

This document describes Ecology's procedures for monitoring the gaseous pollutants sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_X and NO_Y), and nitrogen dioxide (NO_2). Monitoring these pollutants in the Washington State Ambient Air Monitoring Network (Washington Network) must be conducted in accordance with these procedures. They are intended to be used with the model-specific information and instructions provided by the equipment manufacturer as well as with Ecology's Quality Assurance Plan (QAP).

This SOP covers the installation, operation, quality control, maintenance, and data acquisition for both trace- and ambient- (non-trace) level gaseous analyzers. Where procedures differ between trace- and ambient-level instruments, it is noted in the text. This SOP applies to the analyzers manufactured by Teledyne Advanced Pollution Instrumentation (Teledyne API) listed in Table 1-1. All instruments that measure EPA criteria air pollutants (SO_2, CO, and NO_2) are either Federal Reference Method (FRM) or Federal Equivalent Method (FEM) designated monitors. NO, NO_X and NO_Y are not criteria pollutants and do not have FRM or FEMs. Monitoring sites are required to be equipped with the appropriate calibration equipment for trace- or ambient-level monitoring as listed in Table 1-1.

Table 1-1: Supported analyzers and required calibration equipment

Equipment Type	Pollutant	Trace-Level Equipment	Ambient-Level Equipment	Designation
Analyzer	SO_2	100EU, T100U	100E, T100	FEM
	CO	300EU, T300U	300E, T300	FRM
	$NO/NO_X/NO_2$	200EU, T200U	200E, T200	FRM for NO_2*
	NO/NO_Y	T200U-NO_Y	--	--
	NO_2	T500U	--	FEM
Calibrator	All**	700EU, T700U***	700E, T700	--
Zero Air Supply	All	701H	701	--

* The 200EU and T200U $NO/NO_X/NO_2$ analyzers are FRM designated only for NO_2.

** Calibrators used for NO_X and NO_Y monitoring must be equipped with an ozone generator module. See Chapter 6 for additional information on calibration requirements.

*** Trace-level CO and SO_2 monitors can be calibrated with standard 700E or T700 calibrators as long as they are equipped with a low-flow (0-10 sccm) mass flow controller (MFC). Trace level calibrators are only required for trace-level NO_X and NO_Y monitoring.

All monitoring sites must be equipped with cylinders of compressed EPA Protocol gas traceable to either a National Institute of Standards and Technology (NIST) Traceable Reference Material or NIST-certified Gas Manufacturer's Internal Standard. Cylinder certification cannot be expired.

Chapter 2 describes the general guidelines for installing gaseous pollutant monitoring sites.

Chapter 3 provides guidelines for maintenance and operation of the calibration system.

Guidelines for maintenance and operation of analyzers specific to each gas species are covered in Chapters 4-7.

1.1.1. Data quality objectives

Ecology and its partners collect gaseous pollutant data at a variety of sites, including State and Local Monitoring Stations (SLAMS), urban and rural National Core (NCore) stations, near-road monitoring sites, Photochemical Assessment Monitoring Stations (PAMS), and Special Purpose Monitoring (SPM) stations.

The data quality objectives (DQOs) for gaseous pollutant monitoring in the Washington Network are to collect valid, complete data that can be used to determine:

- attainment with primary and secondary NAAQS for SO_2, CO, and NO_2;
- representative levels of gaseous pollutant concentrations in populated areas;
- background concentrations of gaseous pollutants in rural areas;
- maximum concentrations of NO_X and CO in the urban near-road environment; and
- peak SO_2 concentrations near emissions sources.

1.1.2. Health and safety

Working with compressed gases presents a number of potential health and safety hazards to monitoring personnel. Compressed gases are stored at high pressures, typically up to 2000 psi. A cylinder's valve can readily snap off when impacted, rendering the cylinder a powerful projectile with enough force to damage buildings, walls, and workers. Even if it's not projectile, when the pressure inside a cylinder is released in a confined space it will displace the available oxygen and create a suffocation hazard. Staff must be thoroughly trained in transporting and handling compressed gas cylinders and working with two-stage regulators before using a compressed gas calibration system.

In addition to the general risks of pressurized cylinders, each gas species carries specific exposure risks:

- SO_2 is a colorless, corrosive, nonflammable gas with a strong odor. Inhalation exposure can cause respiratory irritation, asthma, and pulmonary edema at high concentrations.
- NO is a colorless gas with a sweet odor. It readily converts to NO_2 in air. Exposure to oxides of nitrogen can cause respiratory irritation, damage to the pulmonary system and cardiovascular stress.
- CO is a colorless, odorless, tasteless gas that displaces oxygen in blood when inhaled. Exposure to high concentrations deprives vital organs of oxygen and can cause chest pain or tightness, headache, fatigue, dizziness, and suffocation.

The following basic precautions should be taken while working in an environment with compressed gases:

- Never lift a gas cylinder by the valve or the attached regulator. Always lift a cylinder by the body.
- Cylinders must always be secured in transport and transported with safety caps installed. Five-pound CO_2 cylinders, usually associated with Nephelometers, do not require safety caps.
- When not in use, cylinders must be stored and secured in an upright position.
- As with cylinders in storage, cylinders with regulators attached must be secured to walls or tables in an upright position using chains, straps, clamps or other appropriate devices.
- When installing regulators, all threaded connection points should be checked with a liquid leak detector (such as Snoop®).
- Analyzers and calibrators must always be vented and exhausted outside the monitoring station.

If monitoring staff working with compressed gases experience any symptoms of harmful inhalation exposure, such as shortness of breath, light-headedness, headaches, dizziness, or respiratory irritation, they should leave the room immediately and alert their supervisor.

The following precautions should also be taken when working with monitoring equipment:

- Instruments should be disconnected from all power sources prior to maintenance requiring exposure to internal circuits when possible.
- Workers should wear an anti-static wrist strap if working near electrical circuit boards. Static discharge from the body can damage circuits even if not working directly on electrical components.

2. Site Installation and Maintenance

2.1. Introduction

This chapter covers the general guidelines for installation and maintenance of gaseous pollutant monitoring sites. This chapter applies to all gaseous pollutant monitoring sites and should be referenced in conjunction with Chapters 3-7.

2.2. Installation procedure

2.2.1. Siting

Siting criteria

Siting requirements for gaseous pollutant analyzers vary by gas species and monitoring objective. Operators should refer to Chapters 4–7 and 40 CFR Part 58 Appendix E for requirements specific to the monitoring objective, including horizontal and vertical placement and spacing from minor sources, obstructions, trees, and roadways.

In general, probes must be located at least one horizontal and one vertical meter away from any supporting structure such as a wall. If a probe is located near a building or wall, it must have unrestricted airflow in a 180° arc facing upwind in the dominant wind direction during the season of highest expected concentrations. If there are any obstructions nearby, the distance between the obstruction and the probe must be at least twice the height of the obstruction minus the height of the probe. Probes should be located at least 10 meters outside the drip line of trees.

Shelter conditions

Gaseous pollutant analyzers must be installed in clean, dry, temperature-controlled shelters with ample and reliable 110-120 VAC power. Shelters must be installed in a secure location safely accessible by monitoring staff. Shelters must be equipped with adequate HVAC systems to maintain room temperatures between 20 and 30° C year-round. Shelter temperature must also be thermostat-controlled such that the standard deviation of daily room temperature over 24 hours is no more than 2.1°C. Analyzers must not be positioned directly under the output vent of the air conditioner.

2.2.2. Installation

2.2.2.1. Probe configuration for a single gaseous analyzer

Gaseous pollutant monitoring sites contain a system of linked equipment to collect, analyze, calibrate, record and store ambient pollutant concentration and calibration data. To the extent possible, this system must be configured as shown in Figure 2-1. Both the analyzer and calibrator are connected to the data logger serially with a 9-pin cable. Cylinder gas and zero air are fed into the calibrator, which outputs calibration gas to a tee fitting at the probe tip outside the station.

One end of the tee is open to ambient air and the other is attached to the analyzer inlet. This dual probe configuration allows the calibration gas to be fed through the full sample path at near ambient conditions in order to assess the complete sampling train, which is known as “through the probe” verification. The tee is sheltered under a funnel to protect the probe from precipitation.

All Washington Network monitoring sites must use fluoropolymer tubing throughout the sampling train and calibration system. Recommended probe material is ¼” inch outer diameter ($^5/_{32}$” inner diameter) PFA. Gas cylinder-to-calibrator lines are typically ⅛” outer diameter. All fittings that connect calibration gases and zero air to regulators, manifolds and analyzers must be made of FEP Teflon®, stainless steel, or brass. Kynar® is not an acceptable material for fittings.

Residence time from the sample inlet to the reaction cell must be less than 20 seconds, and can be calculated using Equation 2-1:

Equation 2-1: Residence time calculation

$$\boldsymbol{RT} = \frac{\boldsymbol{L\pi}\left(\frac{\boldsymbol{d}}{2}\right)^2}{\boldsymbol{flow}}$$

Where:

RT = Residence Time (min).

L = length of sample inlet (cm)

d = inner diameter of sample inlet (cm)

flow = instrument flow rate (sccm)

Note: this equation will yield a result in minutes. Multiply by 60 to convert to seconds.

The zero-air supply should remain turned on and the cylinder gas flow should be enabled to allow for routine automatic QC checks. The pressure of zero air and cylinder gas to the calibrator should be regularly monitored and maintained between 25 and 35 psig. Teledyne API zero air supplies have a dewpoint sensor and corresponding dewpoint indicator light on the front panel. If the light is not green, refer to the manufacturer’s operation manual for corrective action.

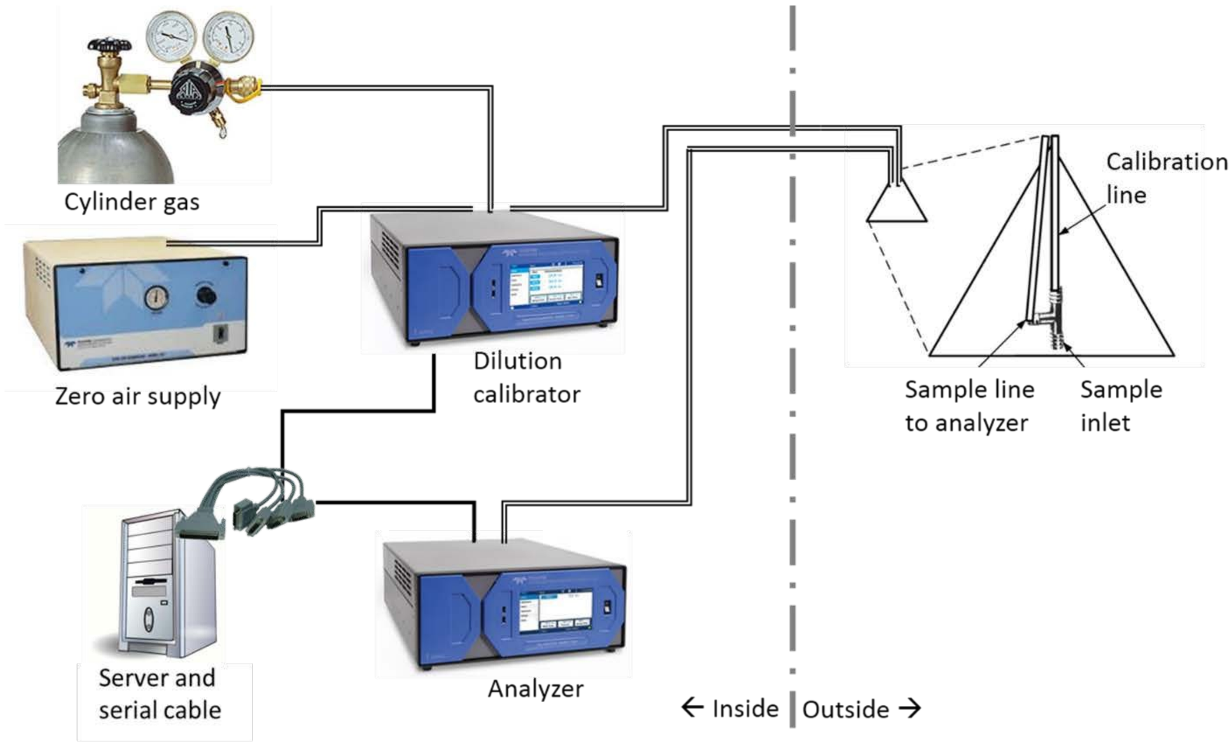

Figure 2-1: Configuration of station probes and instruments (photos from Teledyne API)

2.2.2.2. Configuration for multiple gaseous analyzers

Several monitoring sites contain multiple analyzers for gaseous pollutants. Such sites can be configured with a single calibrator and a single calibration tank containing a blend of the appropriate EPA Protocol Gases.

If a single calibrator is used, the calibration gas should feed through a solenoid array to isolate the feed of calibration gas to a specific analyzer, allowing the remaining analyzers to continue sampling ambient air. Figure 2-2 shows an example solenoid array for challenging multiple gaseous analyzers using a single calibrator. For analyzers with multiple channels (e.g. NO_X and NO_Y), all analyzer channels must be flagged on the data logger when any channel is being challenged. Contact the Calibration and Repair Laboratory for assistance setting up an appropriate solenoid array.

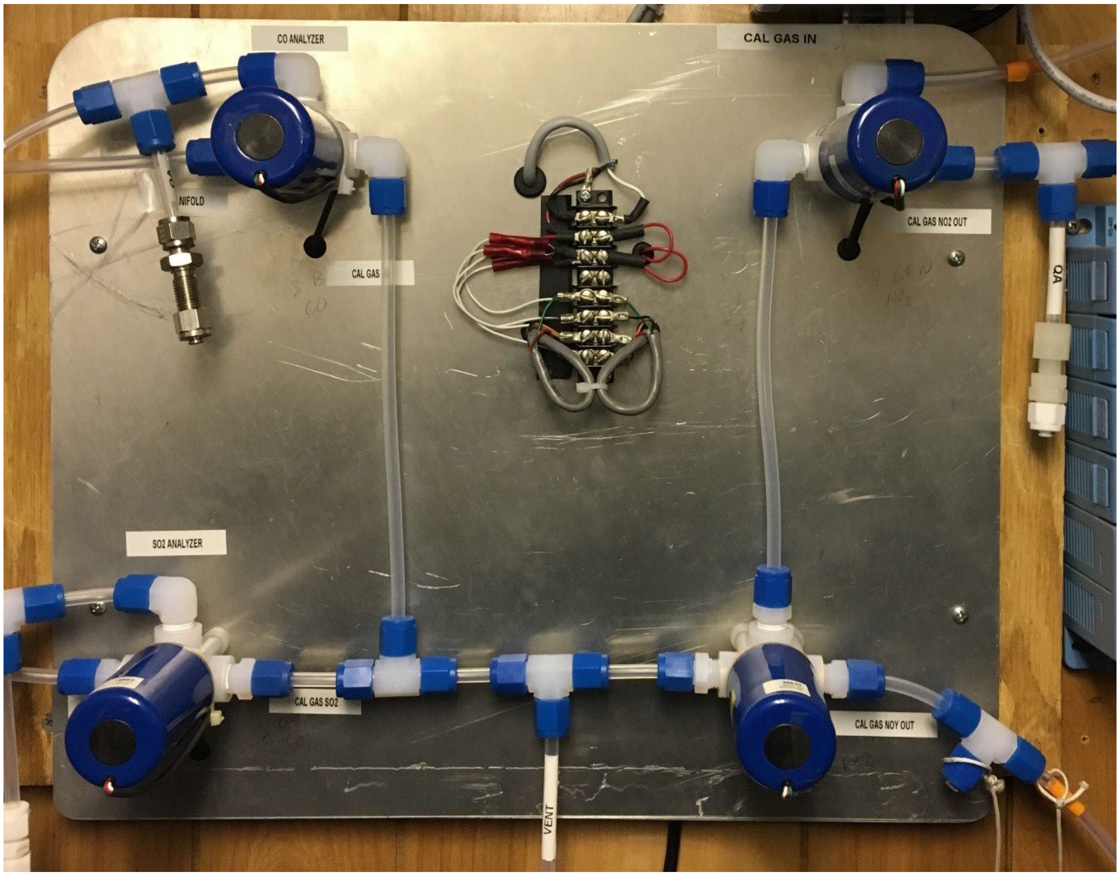

Figure 2-2: Example solenoid array for multiple gas analyzers (Beacon Hill, Seattle)

2.3. Quality control and maintenance

The quality control (QC) procedure for gaseous pollutant analyzers consists of both automatic quality control checks and manually initiated QC checks conducted during site visits at required routine intervals. All QC checks must be triggered through Envidas Ultimate in order to ensure consistency in quality control check procedures throughout the Washington Network and to ensure that the results are captured by the data acquisition system.

Note: A number of terms for various quality control checks and challenge points exist throughout EPA literature, existing SOPs, the Envidas Ultimate framework, etc. This SOP adopts the uniform terminology of “Primary QC Check” and “Secondary QC Check” in place of these terms. These terms are paired with their corresponding EPA terms in Table 2-1 below.

Table 2-2: Ecology and EPA quality control check terms

Ecology Term	EPA Term	Must Include In
Primary QC Point	One-Point QC Value; Precision Check	Primary QC Check; Secondary QC Check
Secondary QC Point	Span Check Value;	Secondary QC Check
Upscale Point	Multi-Point Calibration Upscale Point	Verification check after calibration

2.3.1. Automatic quality control checks

2.3.1.1. Frequency

At a minimum, QC checks must be conducted at the frequencies shown in Table 2-2. Given the relatively low expense and small amount of data lost from automatic QC checks, Ecology recommends they be conducted more often than the minimum required frequency. More frequent QC checks alert operators and quality assurance staff to analyzer performance issues, thereby increasing data completeness and providing valuable precision information. On a case-by-case basis, Ecology may require more frequent QC checks at certain sites; such arrangements supersede the minimum required frequencies listed in Table 2-2.

Table 2-3: Minimum required and recommended quality control check frequencies

Quality Control Check	EPA Minimum Required	Ecology Minimum
Type	Frequency	Recommended Frequency
Primary QC Check	Once every 14 days	Once every 4 days*
Secondary QC Check	Once every 14 days	Once every 14 days

* When running NO_2 as part of PAMS, primary QC checks every 2 days are recommended.

2.3.1.2. Timing

Note: For NAAQS compliance at SO_2 sites, operators will not conduct any QC checks or analyzer / sample train maintenance when the most recent 1-hour SO_2 concentration is ≥ 20 ppb.

Automatic QC checks should be timed during the hours of lowest expected concentrations, which can be determined by looking at the daytime trends for previous years data. Start times should be selected to minimize the number of data hours lost, given that hours with more than 15 minutes of data missing are not valid. QC checks lasting up to 88 minutes should be timed to start at :46 after the hour so that only the middle hour is lost. For example, if a QC check starts at 1:46 and lasts until 3:14, only the 2:00 hour will be lost. Both the 1:00 and 3:00 hours have enough 1-minute sample data to be considered valid.

2.3.1.3. QC check concentrations

QC check concentrations should be chosen based on the monitoring objectives and the concentrations routinely measured at the monitoring site. The recommended approach is described below and illustrated in Figure 2-3. Contact the Calibration and Repair Laboratory for verification and guidance when selecting QC check concentrations and calibration scales.

1. Plot the most recent 3 years of 1-hour concentration data, excluding any obvious outliers. Figure 2-3 shows an example of CO data from a near-road monitoring site.
2. Select a concentration at or near the 99th percentile. This value should be rounded for ease of use. In the example shown in Figure 2-3 the value is 2000 ppb.
3. Multiply the 99th percentile by 1.5 to establish the calibration scale (3000 ppb in this example). If the 99th percentile value is below 100 ppb for SO_2, NO, NO_X, NO_Y, or NO_2 contact the Calibration and Repair Laboratory to determine an appropriate calibration scale. The instrument should be calibrated at the calibration scale. Calibration instructions specific to each analyzer are in Chapters 4-7.
4. Multiply the calibration scale by 0.75 to find the secondary QC point, which is measured during a secondary QC check (2250 ppb in this example).
5. Select a point at or near the peak of the data distribution for the primary QC point (550 ppb in this example). It is suggested that this point not be the same as a multi-point verification point. If this point is below the capabilities of the calibration system, the operator should select the lowest point that can be practically generated and measured. All primary QC points must fall within EPA's prescribed ranges of 5 and 80 ppb for SO_2 and NO_2 and 0.5 and 5 ppm for CO.
6. Operators can add optional additional QC points during primary or secondary QC checks if desired. Any additional point(s) should be evenly distributed between the primary and secondary QC points.

Note: During primary QC checks, the analyzer must be challenged at zero and the primary QC point(s). During secondary QC checks, the analyzer must be challenged at zero, the primary QC point(s), and the secondary QC point(s).

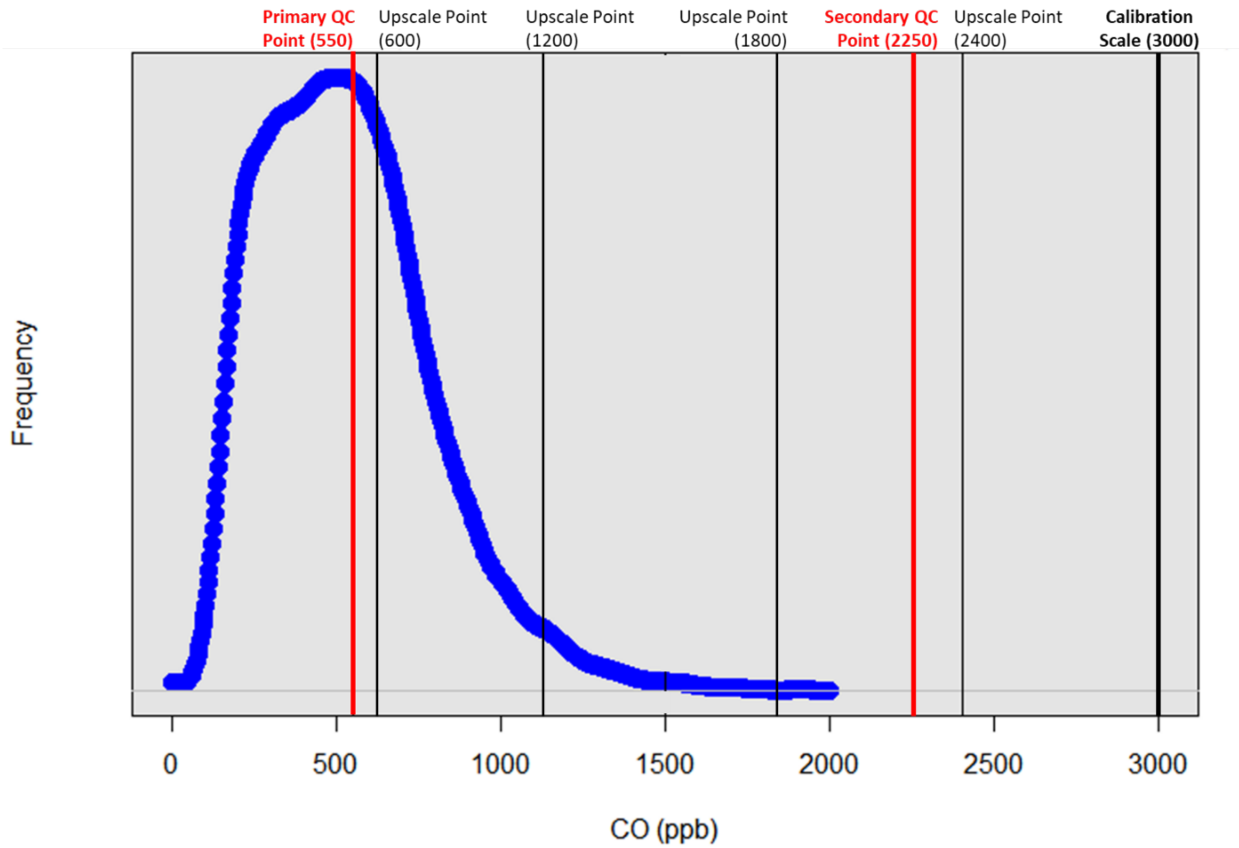

Figure 2-3: Selection of QC concentration points and upscale concentration points

2.3.2. Linearity Checks

An analyzer's calibration must be verified with a linearity check:

- upon installation.
- following instrument calibration.
- at least every 180 days.

The 5-point linearity check consists of a zero and four upscale points. The upscale point concentrations should be evenly distributed across the calibration scale and differ from the primary and secondary QC points. For the example in Figure 2-3 these points are 600, 1200, 1800, and 2400 ppb. An associated linearity check form must be completed and submitted to the Quality Assurance Coordinator. See Appendix B for an example of the Linearity Check Form. Contact the Calibration and Repair Laboratory or Quality Assurance Unit to obtain the latest version of an electronically fillable Linearity Check Form.

2.3.3. Flow requirements

Using Equation 3-1 (Section 3.2.1), total calibration gas flow ($Q_{cyl} + Q_{dil}$) must be greater than 120% of the analyzer's demand. This will ensure that ambient air does not dilute the calibration gas. If the total calibration gas flow exceeds 5 liters per minute (lpm), a ⅜" outer diameter calibration gas line should be used to avoid over-pressuring the multi-gas calibrator. Q_{cyl} and Q_{dil} should be between 10% and 90% of the full scale of the corresponding mass flow controller (MFC). Most multi-gas calibrators in the Washington Network are equipped with 0-100 standard cubic centimeters per minute (sccm) MFCs. In this case, Q_{cyl} must be between 10 and 90 sccm. The addition of a 0-10 sccm MFC allows for Q_{cyl} between 1 and 9 sccm as well. The standard dilution air MFC is 0-20 lpm, allowing for Q_{dil} between 2 and 18 lpm.

2.3.4. Acceptance criteria

Acceptance criteria vary by parameter and are summarized in Table 2-3. For further information on parameter-specific action levels, see Chapters 4–7.

Table 2-4: QC check acceptance criteria

Parameter	Zero Limits	Primary/Secondary QC Check Point Limits
SO_2	< ± 1.1 ppb	< ± 10.1% or < ± 1.51 ppb, whichever is greater
CO	< ± 50.1 ppb	< ± 10.1%
NO, NO_X, NO_Y and NO_2	< ± 1.51 ppb	< ± 15.1% or < ± 1.51 ppb, whichever is greater
NO_2 (PAMS)	< ± 0.21 ppb	< ± 10.1%

2.3.5. Corrective actions

When a QC check falls outside the acceptance criteria, operators must first confirm whether the QC check failure is due to the analyzer or other components. For example: pump failure in the transfer standard, out-of-spec shelter temperature, or blockage of the sampling probe can all lead to failing QC check results. Operators should check the analyzer's diagnostic parameters and visit the site to verify the shelter conditions meet all siting requirements and the calibration system is functioning properly. An additional as-found QC check may be needed to verify the analyzer performance. If the analyzer is confirmed to be the source of QC check failures, it must be calibrated. For instructions on calibrating gaseous pollutant analyzers, refer to the instrument specific operation manuals and Chapters 4–7.

2.3.6. Manually triggering QC checks

Occasionally, operators may need to manually trigger primary or secondary QC checks. This is necessary if automatic QC checks fail to run properly or if operators need to initiate additional QC checks before and after calibration. Even when manually triggering QC checks, operators must initiate the QC check from Envidas Ultimate and not from the calibrator itself. This ensures that all results are captured by the data acquisition system and are reportable to EPA's Air Quality System (AQS). Additionally, manual QCs should always be recorded in the Electronic Logbook.

To trigger a QC check manually, navigate to the Operational tab in Envidas Ultimate Viewer and select Calibration > Sequence, then select the name of the primary or secondary QC sequence to trigger as shown in Figure 2-4.

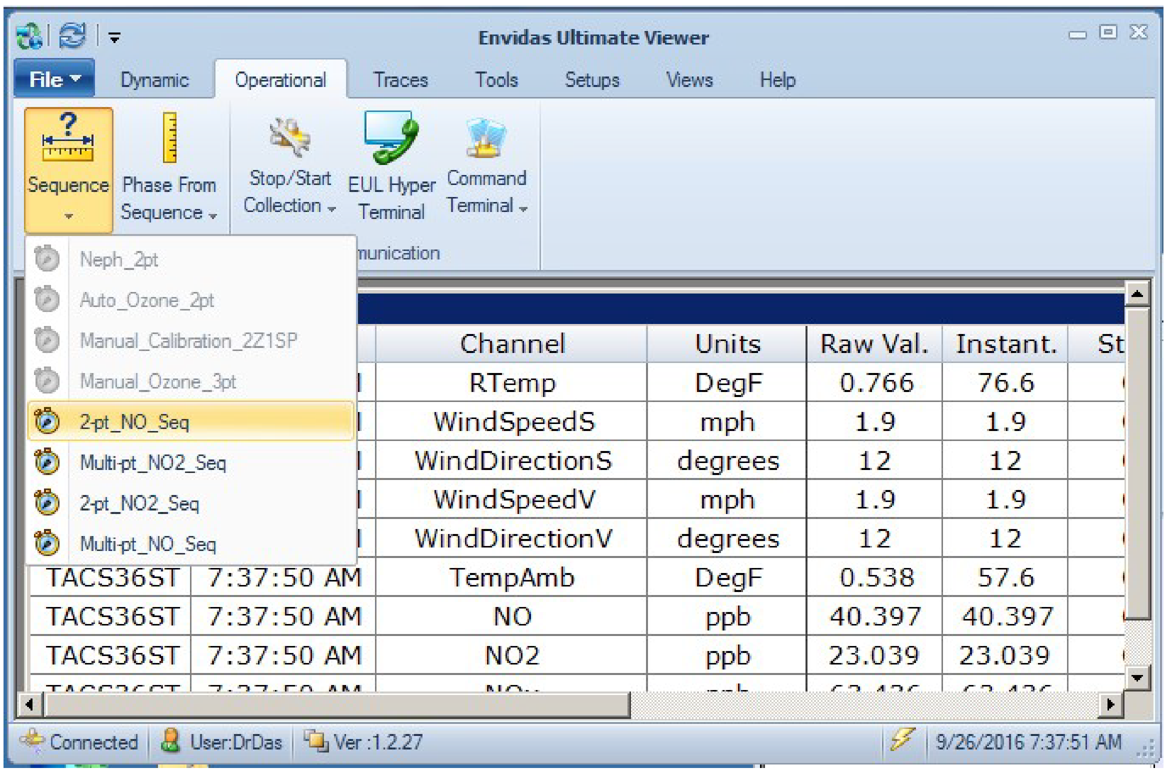

Figure 2-4: Example of triggering QC check manually from Envidas Ultimate

2.3.7. Site visits

Site operators are required to visit each monitoring site a minimum of once every 30 days, though more frequent site visits are recommended. Operators are required to fill out an electronic QC check form during the monthly site visit and email it to the Quality Assurance Coordinator no later than the 10th day of the following month. Operators should also keep their own copies of QC check forms. It is recommended that site visits occur in conjunction with every other secondary QC check so that operators can promptly resolve any issues raised by secondary QC check results.

In addition to the verifications listed on the form, operators ***must*** do the following during each site visit:

1. Create an electronic logbook entry in Envidas Ultimate Reporter (Operational > Logbook > Add) documenting the operator's name, the time the site visit began, and the parameters to be checked.
2. Check the results of both primary and secondary QCs in Envidas Ultimate Reporter (Operational > Calibration).
3. Take corrective actions for any analyzers with QC check results in the action or invalid levels.
4. Check the particulate filter and change if necessary. See Chapters 4-7 for parameter specific instructions on changing particulate filters.
5. Verify that the shelter conditions meet the requirements in Section 2.2.1.
6. Verify that the shelter temperature device is checked against a certified NIST-traceable temperature standard every 180 days. Contact the Calibration and Repair Laboratory or Quality Assurance Unit to obtain the latest version of the RoomTempDeviceCheck QC form.
7. Verify that the logger is collecting and transmitting data correctly.
8. Check each analyzer's diagnostics in Envidas Ultimate Reporter for indications of any problems (Operational > Digital > Diagnostic).
9. Create an electronic logbook entry documenting any changes made to the site, any periods of invalid data, and any unusual air quality conditions that may affect sample concentrations (e.g., wildfires, nearby construction impacts from diesel equipment, etc.).
10. Record QC results and additional site visit information on the "Gaseous Pollutant QC Form". Example QC forms are in Appendix A. Contact the Calibration and Repair Laboratory or Quality Assurance Unit to obtain the latest version of a QC form.

Note: There is no such thing as too many logbook entries. Please record any aberrations in conditions, malfunctioning equipment, or any other information that may be useful when conducting data validation, audits, or problem-solving equipment failure at a later date. Data validation may take place months later and staff may not remember details like construction equipment or a nearby cooking fire that could explain spikes in data, as an example.

3. Calibration System

3.1. Introduction

All gaseous pollutant monitoring sites in the Washington Network are equipped with a Teledyne API dynamic dilution calibrator with external zero air generator (calibration system) and compressed source of EPA Protocol Gas (SO_2, NO, CO). This chapter covers the general guidelines for installation of gaseous pollutant monitoring sites, calibration with dynamic dilution calibration systems, and brief guidelines for Quality Assurance. This chapter applies to all gaseous pollutant monitoring sites, except ozone, and should be referenced in conjunction with Chapters 4–7, which go over each gas specifically.

3.2. Principles of operation

3.2.1. Dilution calibrator

The dilution calibrator is microprocessor-controlled and equipped with mass flow controllers (MFCs) to challenge gaseous pollutant analyzers across a wide range of concentrations. The dilution calibrator uses separate MFCs to control flow rates of dilution (zero) air and cylinder gas, which are blended in a mixing chamber in desired ratios. The output concentration from the calibrator can be calculated from Equation 3-1:

Equation 3-2: Calibration gas concentration calculation.

$$C_{cal} = \frac{Q_{cyl} * C_{cyl}}{Q_{cyl} + Q_{dil}}$$

Where:

C_{cal} = Calibration gas concentration
C_{cyl} = Cylinder gas concentration
Q_{cyl} = Cylinder gas flow
Q_{dil} = Dilution air flow

3.2.1.1. Gas Phase Titration (GPT): Generation of NO2

Note: During GPT phases, Q_{cyl} from Equation 3-1 must be greater than 45 sccm to meet the residence time requirement of 2 minutes for the GPT reaction chamber.

Ecology uses Gas Phase Titration (GPT) to generate NO_2 for calibration checks. NO_2 is produced by GPT per the following reaction:

$$NO + O_3 \rightarrow NO_2 + O_2 + hv(light)$$

In excess NO, one mole of NO_2 is produced for every mole of O_3 added, assuming all O_3 is consumed. More detailed information on GPT can be found in 40 CFR Part 50 Appendix F and the dilution calibrator manufacturer's operation manual. The GPT method of generating NO_2 is recommended over the method of dilution of NO_2 from a cylinder, as NO_2 from a high-pressure cylinder stick to the interior walls of the gas delivery lines. This results in slow instrument responses and negatively biased concentrations.

If the dilution calibrator is equipped with an internal O_3 photometer, a GPT Preset (GPTPS) can be run to fine-tune O_3 generation during the subsequent GPT phase. The GPTPS phase must have the same NO concentration, O_3 concentration target, and total flowrate as the associated GPT phase. During the GPTPS phase, zero air replaces NO gas in the reaction cell so there is no reaction to create NO_2. The generated O_3 concentration is measured by the internal O_3 photometer and the O_3 GEN DRIVE value is adjusted to achieve the specified O_3 concentration. The instrument stores the updated O_3 GEN DRIVE value for later use when performing an actual GPT.

3.2.2. Zero air supply

All gaseous pollutant monitoring sites in the Washington Network are equipped with a Teledyne API zero air generator. Zero air generators provide dry air with minimal levels of contaminants (SO_2, NO, NO_2, O_3, H_2S, and CO) as specified by the manufacturer. Air is drawn into the generator with a pump and routed into a water trap, regenerative dryer, disposable filter unit (DFU) and chemical scrubbers to remove water vapor and contaminants.

For specific principles of operation for gaseous analyzers, see Chapters 4–7.

3.3. Equipment and supplies

The diagnostic tools, parts and supplies necessary to operate and maintain a gaseous pollutant monitoring site are summarized in Table 3-1.

Table 3-5: Summary of gaseous pollutant standard hardware, tools, parts and supplies

Category	Equipment	Purchase Schedule
Tools and Equipment	Two-stage stainless steel (SO_2, NO_X, NO_Y) or brass (CO) regulator	Once
	Flexible fluoropolymer tubing (¼” and ⅛”)	Yearly or as needed
	Fluoropolymer and stainless steel fittings (¼” and ⅛”)	Once; replace as needed
	Sampling cone	Once; replace as needed
	NIST-traceable flow meter certified to the minimum flow to be generated	Once
	Various hand tools (screwdriver, cylinder wrench, voltmeter, etc.)	Once
Consumables	In-line PTFE particulate filters (47 mm diameter, pore size 1 µm, for SO2, CO, O3, and 5 µm, for NO_Y and NO_X)	Monthly or as needed
	Compressed cylinder of EPA Protocol gas (SO_2, NO, CO in single or multi-component blend) with current certification	Once; refilled every 3 years
	Leak detection solution (e.g. Snoop®)	As needed
	Extra charcoal and Purafil®	Yearly or as needed

3.3.1. Calibration system maintenance

Table 3-2 summarizes the required maintenance schedule for the calibration system. This table does not include maintenance for the O_3 module components necessary for NO_X and NO_Y monitoring. For calibrators with an O_3 generator installed, the operator should refer to Chapters 6 and 7 and the manufacturer's operation manual for specific maintenance schedules and procedures.

Aside from cleaning or replacing sample and calibration lines (Section 3.3.1.9), all calibration system maintenance is conducted by the Calibration and Repair Laboratory.

Maintenance procedures for the gaseous pollutant analyzers are described in Chapters 4–7.

Table 3-6: Summary of required calibrator system maintenance

Component	Procedure	Frequency	Section
Dilution calibrator	Diagnostic data verification	Weekly or after any maintenance	3.3.1.1
	Flow check and calibration	Annually or after any maintenance	3.3.1.2
	Leak check	Annually or after any maintenance	3.3.1.3
	Pneumatic line inspection	Annually	3.3.1.4
	Verify cylinder gas concentration	Monthly	3.3.1.5
Zero air source	Zero air generator maintenance	Annually	3.3.1.6
Cylinder gas	Verify cylinder gas certification	Annually	3.3.1.7
Shelter temperature	Verify shelter temperature device	180 days	3.3.1.8
Station	Clean or replace sample and calibration lines	Annually	3.3.1.9

3.3.1.1. Verify calibrator diagnostic data

Diagnostic data, referred to by Teledyne API as "test functions," can be used to predict and diagnose instrument failures. At a minimum, operators should review the diagnostic data weekly to identify any problems with the analyzer's operation.

Table 3-3 below shows the diagnostic parameters available and their interpretation.

Table 3-7: Summary of dilution calibrator diagnostic data

Diagnostic Parameter	Interpretation
CAL PRES	Measures the pressure delivered to gas MFCs. Possible causes of faults such as the MFC PRESSURE WARNING.
DIL PRES	Measures the pressure delivered to diluent MFC. Possible causes of faults such as the MFC PRESSURE WARNING.
BOX TEMP	Typically ~ 7°C warmer than ambient temperature. If out of range, ensure that the exhaust fan is running, and there is sufficient ventilation area to all sides of the instrument.
CLOCKTIME	If calibrator clock is not correct, battery in clock chip on CPU board may be dead.
O3GENDRV	Measures the drive voltage (mV) of the O_3 generator UV lamp.
REG PRES	Measures the gas pressure at the pressure regulator on the O_3 generator supply line.
TEST	Reports the analog signal (mV) of the TEST analog output channel.
PH MEAS	Measures the average output (mV) of the UV Detector during the Sample portion of the photometer's measurement phase.
PH REF	Measures the average output (mV) of the UV Detector during the reference portion of the photometer's measurement phase.
PH LTEMP	Reports the temperature of the photometer's UV lamp (°C)
PH PRES	Measures the pressure of the gas inside the photometer's sample chamber (in-Hg-A).
PH STEMP	Reports the temperature of the gas inside the photometer's sample chamber (°C).
PH SLOPE	Photometer slope.
PH OFFST	Photometer offset.
A-CAL	Calibrator output flow rate of source gas (lpm).
T-CAL	Calibrator set flow rate of source gas (lpm).
A-DIL	Calibrator output flow rate of diluent gas (lpm).
T-DIL	Calibrator set flow rate of diluent gas (lpm).
O3FLOW	Measures the O_3 gas flow rate (lpm).
O3LAMPTMP	Measures the O_3 generator UV lamp temperature (°C)
A-GAS	Actual concentration of source gas generated by the calibrator.
T-GAS	Target concentration of source gas generated by the calibrator.

3.3.1.2. Calibrator flow check and calibration

The output flow of the calibrator should be verified annually and after calibration of the internal digital-to-analog converter (DAC). The flow check procedure verifies the output flow of each MFC at 20 incremental points corresponding to drive voltages from 0 to 5000 mVDC. Directions for the flow check and calibration can be found in the manufacturer's operation manual.

Note: Flow from the MFCs is checked using a flow audit device, such as a low-flow Alicat. The flow device must be set to 0°C, NOT 25°C (the default).

3.3.1.3. Calibrator leak check

An automatic leak check must be performed annually and after any maintenance or repair.

Directions can be found in the manufacturer's operation manual.

3.3.1.4. Calibrator pneumatic line inspection

Visually inspect the lines from the calibrator for any signs of dirt, condensation, obstructions, cracking, kinks, or any other damage. Clean or replace the lines annually or as needed.

3.3.1.5. Calibrator cylinder gas concentration check

Verify that the cylinder gas concentration in the calibrator matches the certified gas concentration on the cylinder. This should not change but should be checked.

3.3.1.6. Zero air generator maintenance

The charcoal and Purafil® in the zero air source canisters and the particulate filter on the zero air generator must be replaced annually. A leak check must be conducted following any maintenance. Directions can be found in the manufacturer's operation manual. If evidence of zero air contamination is present, the HC scrubber, CO scrubber, and regenerative dryer should also be replaced. Refer to the manufacturer's operation manual or contact the Calibration and Repair Laboratory for assistance.

3.3.1.7. Verify cylinder gas certification

All calibration gases used within the Washington Network must have current certification. Expiration dates of EPA Protocol gas cylinders must be checked and recorded on QC forms during site visits to ensure that cylinders maintain current certification.

3.3.1.8. Verify shelter temperature device

At a minimum, operators should verify the shelter temperature device performance using a certified NIST-traceable temperature standard every 180 days. The acceptable limit must be less than 2.1°C. Operators must perform a single-point ambient temperature check and document the results in the RoomTempDeviceCheck QC form. Contact the Calibration and Repair Laboratory or Quality Assurance Unit to obtain the latest version of the QC form. This requirement applies to all FRM/FEM monitoring stations.

3.3.1.9. Clean or replace sample and calibration lines

Sample and calibration lines must be cleaned or replaced when necessary, but at least annually. Dust, bugs, moisture, organic compounds, elemental carbon, and other contaminants can build up in the lines over time and affect gas flows and concentrations. It is recommended that operators replace sample lines with new tubing annually. Operators can clean sample lines with a soap mixture followed by deionized water and pressurized dry zero air. If cleaning the lines, operators must first disconnect them from the instruments and ensure that no moisture remains in the sample line before reconnecting them.

3.4. Data collection and storage

All gaseous pollutant monitoring sites in the Washington Network are equipped with loggers running the Envidas Ultimate data acquisition system. These servers must be configured to collect and telemeter 1-minute and 1-hour average concentrations. SO_2 monitoring sites must also collect and telemeter 5-minute average concentrations in order to meet the requirement to report maximum hourly 5-minute average concentrations to EPA.

The channel configurations and diagnostic settings for the calibrator channel are shown below.

For analyzer-specific channel and diagnostic configurations, see Chapters 4–7.

3.4.1. Envidas channel configuration

All loggers at gaseous pollutant sites in the Washington Network must be configured with a channel to capture the actual concentration of calibration gas delivered by the calibrator. This channel is typically called ACTCONC for “actual concentration.” Figure 3-1 shows the correct configuration for the ACTCONC channel in Envidas Ultimate.

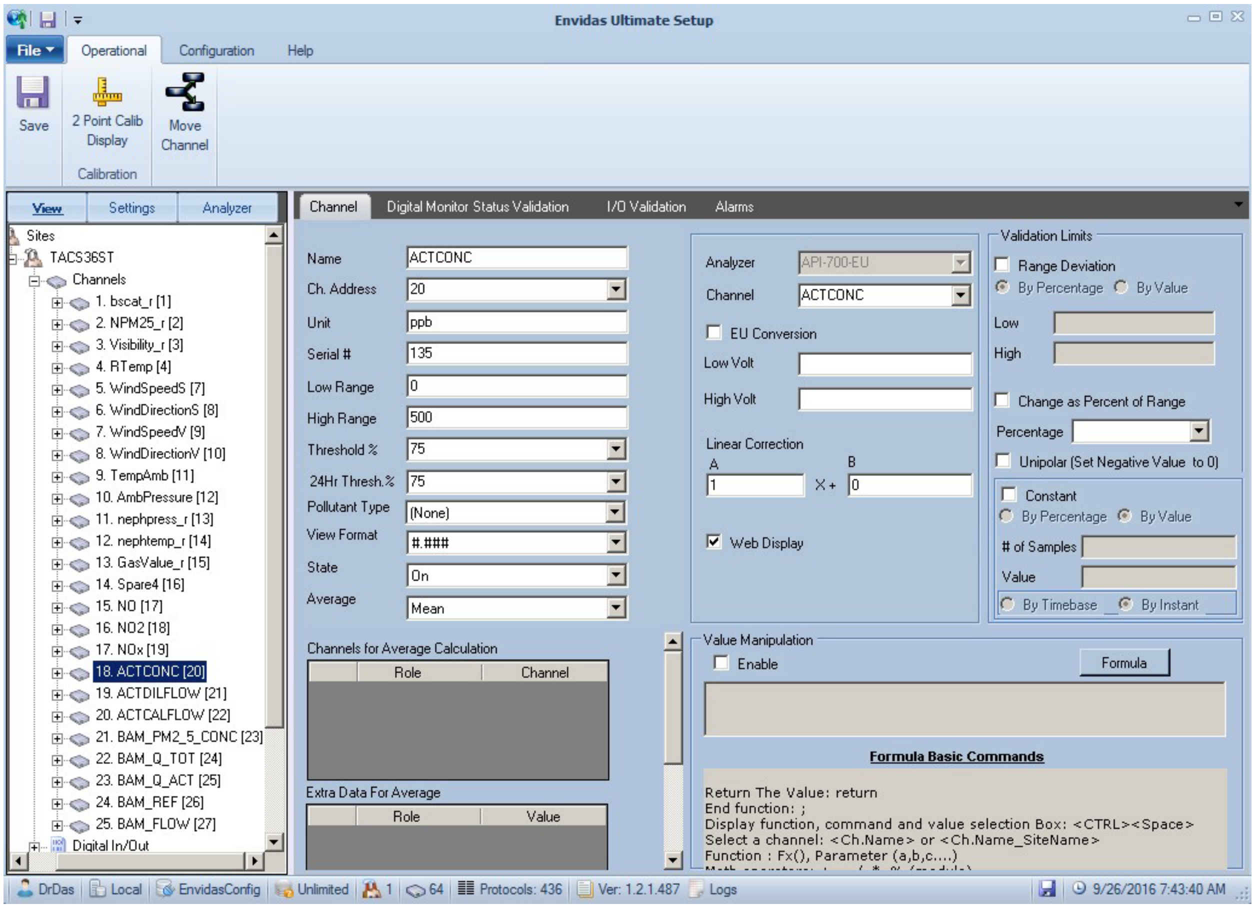

Figure 3-5: Example ACTCONC channel configuration

3.4.2. Diagnostic data collection

The calibrator channel must be configured to collect the following diagnostic parameters at least every 30 minutes: ACTCALFLOW, TARGCALFLOW, ACTDILFLOW, TARGDILFLOW, CALPRESS, DILPRESS, REGPRESS, ACTCONC, TARGCNC, and BOXTEMP.

For calibrators equipped with an O_3 generator module for NO_X and NO_Y calibration, the following additional parameters should be collected: O3GENREF, O3GENFLOW, O3GENDRIVE, O3GENTEMP, ACTO3, TARGO3, TESTCHAN, PHOTOMEAS, PHOTOREF, PHOTOFLOW, PHOTOLTEMP, PHOTOSPRESS, PHOTOSTEMP, PHOTOSLOPE, PHOTOOFFSET, and O3GENMODE.

Note: During QC checks parameters are collected every minute.

The correct configuration for collection of a complete set of diagnostic parameters is shown in Figure 3-2.

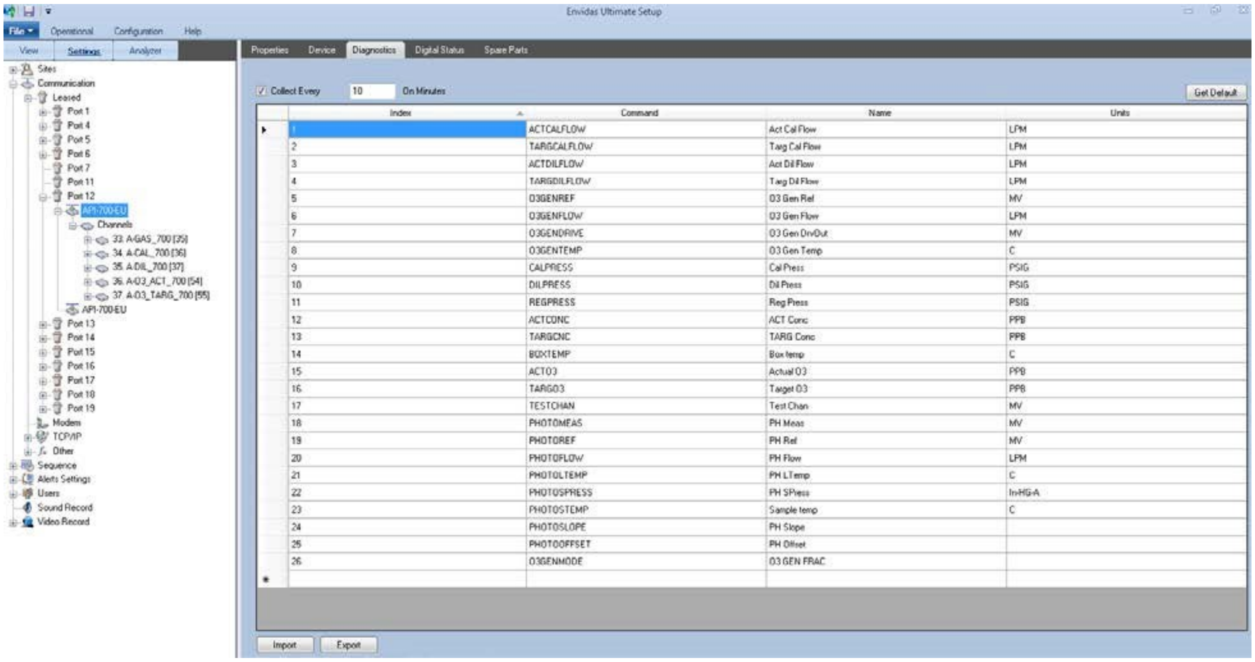

Figure 3-6: Configuration of dilution calibrator diagnostic parameter collection

3.5. Data validation and quality assurance

The operator is responsible for preliminary level review and data validation of collected sample data. Operators must review all quality control check results in a timely fashion to catch problems early and prevent data loss. It is recommended that operators review calibration results via the data acquisition system software each Monday morning. Operators should also review data for reasonability and comparability with other similar monitors. Operators must notify the Quality Assurance unit via email when invalid data are identified. When required by Ecology, operators must submit the completed "Gaseous Pollutant QC Form" to the Quality Assurance unit by the 10th of the following month.

The Quality Assurance unit is responsible for final level data validation. Data validity is evaluated using several criteria including, but not limited to, the results and frequency of quality control checks, performance audit results, and diagnostic data. The critical, operational, and systematic criteria used by the Quality Assurance unit to help determine data validity are summarized in the most current version of EPA's criteria pollutant validation templates.

For more detailed information on data review and validation, please refer to Ecology's Air Monitoring Documentation, Data Review, and Validation Procedure.

4. Sulfur Dioxide (SO_2) Monitoring

4.1. Introduction

This chapter describes Ecology's procedures for monitoring trace- and ambient-level SO_2 concentrations using the Teledyne API T100U and T100 analyzers. It includes procedures for installation, operation, quality control, maintenance, and data acquisition. It is intended to be used with the manufacturer's model-specific operation manual and Chapters 2 and 3, which describes general procedures for gaseous pollutant monitoring and the calibration system.

4.2. Principles of operation

The SO_2 measurement is based on the principle of characteristic fluorescence released by excited SO_2 when exposed to ultraviolet (UV) light. The SO_2 analyzer collects ambient samples and detects the decaying radiation emitted by SO_2 present in the sample with a photo multiplier tube (PMT). It then converts the signal to a measurable voltage that corresponds to ambient concentrations. A wavelength range of approximately 190–230 nm is used to charge SO_2 to its excited state and a longer wavelength near 330 nm with lower energy is used in the PMT to measure fluorescence.

Both the Teledyne API T100 and T100U are equipped with a scrubber to remove hydrocarbons that fluoresce similarly to SO_2 and could create positive interference. The primary difference between T100 and the modified T100U is how the PMT and UV reference signals are acquired and processed. The T100 achieves stability through use of an optical shutter that compensates for sensor drift and a reference detector that corrects for UV lamp intensity variations. The T100U, on the other hand, employs a sync demodulator to capture the dark and light PMT and UV reference signals several times per second and synchronize the operation of the UV source with these measurements. This method of signal processing minimizes the error that could occur when changing offsets, especially for an instrument designated to operate near its detection limit. Thus, the T100U is more ideal for monitoring SO_2 at near zero concentrations and is required for trace-level SO_2 monitoring in the Washington Network.

4.3. Equipment and supplies

In addition to the standard equipment in Table 3-1, operators should purchase a pump rebuild kit directly from Teledyne API or contact the Calibration and Repair Laboratory to obtain a rebuilt pump or pump rebuild kit.

4.4. Installation

In addition to the siting criteria described in Section 2.2.1, the SO_2 sample probe must be located 2–15 m above ground level.

4.5. Quality control and maintenance

4.5.1. Quality control checks

Note: For NAAQS compliance SO_2 sites, operators will not conduct any QC checks or analyzer / sample train maintenance when the most recent 1-hour SO_2 concentration is ≥ 20 ppb.

No additional quality control is required beyond the steps described in Section 2.3. The recommended action levels are illustrated in Figure 4-1. For QC check points from 5-15 ppb, the acceptance criteria is ± 1.51 ppb.

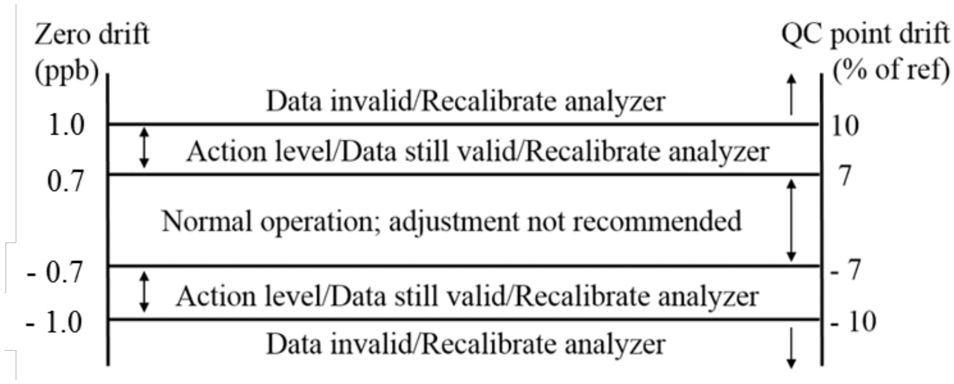

Figure 4-7: SO_2 action levels

4.5.2. Maintenance

The maintenance schedule for the Teledyne API T100 and T100U SO_2 analyzers is summarized in Table 4-1 below.

Table 4-8: Summary of required SO_2 analyzer maintenance

Procedure	Frequency	Section
Analyzer calibration	If analyzer is out of specifications (see above), or every 6 months	4.5.2.1
Change particulate filter	Inspect every 30 days, replace every 90 days or more frequently when the filter becomes noticeably dirty	4.5.2.2
Verify diagnostic data	Weekly	4.5.2.3
Flow check	Every 6 months	4.5.2.4
Pressure leak check	Annually or after pneumatic repairs	4.5.2.5
Test pump diaphragm	Annually	4.5.2.6

4.5.2.1. Analyzer calibration

After a failed QC check, operators must take corrective actions (Section 2.3.5) to determine if the failure was caused by the analyzer or than any other component, such as a pump failure, calibrator system issue, blockage of the sampling probe, or telemetry issue. If the failure is confirmed to be due to the analyzer, the analyzer must be calibrated. The calibration scale for the analyzer can be calculated as the 99^{th} percentile of hourly concentrations at the site over the previous 3 years multiplied by 1.5. If the 99^{th} percentile value is below 100 ppb contact the Calibration and Repair Laboratory to determine an appropriate calibration scale. More specific details and an example are in Section 2.3.1.3. Check with the Calibration and Repair Laboratory to verify the calibration scale prior to calibrating the analyzer.

Before the calibration operators must perform an “as found” QC check. If needed, the particulate filter should be replaced after the “as found” QC check and before calibration.

After the calibration the operators must perform a post-calibration verification to verify the linear response of the analyzer (Section 2.3.2). In accordance with 40 CFR Part 50 Appendix A-1 Section 4.2.9, compute the linear regression between analyzer response (Y-axis) versus Actual concentration (X-axis) and plot the regression line to verify that no point deviates from this line by more than ± 2%. See Appendix B for an example of the Linearity Check Form. Contact the Calibration and Repair Laboratory or Quality Assurance Unit to obtain the latest version of an electronically fillable Linearity Check Form.

To calibrate an TAPI SO_2 analyzer:

1. Ensure that the pressures of zero air and cylinder gas to the calibrator are between 25 and 30 psi.
2. Select CAL > CONC and change the concentration displayed to the value of the calibration scale (see section 2.3.1.3). Select ENTER, then EXIT.
3. From the calibrator, generate zero air to the instrument for at least 30 minutes or until analyzer stability is at or below 0.01 ppb (trace-level) or 1 ppb (ambient-level).
4. Select CAL > ZERO > ENTER on the analyzer. The analyzer will automatically advance to the span calibration screen.
5. Generate calibration gas at the level of the calibration scale for at least 30 minutes or until instrument stability is at or below 0.01 ppb (trace-level) or 1 ppb (ambient-level).
6. Select SPAN and ENTER.
7. Select EXIT to return to the main menu.

Note: The ZERO or SPAN buttons may not display during the zero or span calibration if the measured concentration is too different from the expected value. Refer to the manufacturer’s operation manual for more information.

4.5.2.2. Change particulate filter

The particulate filter should be inspected every 30 days for signs of plugging or excess dirt. The particulate filter should be changed at least every 90 days or when the color has noticeably changed. Operators should wear gloves and take care not to touch the inside surfaces, including glass window, PTFE or Viton O-rings, or assembly body, as contamination may lower the accuracy of readings. Parts may be cleaned with distilled water if lightly contaminated and replaced if heavily contaminated or damaged.

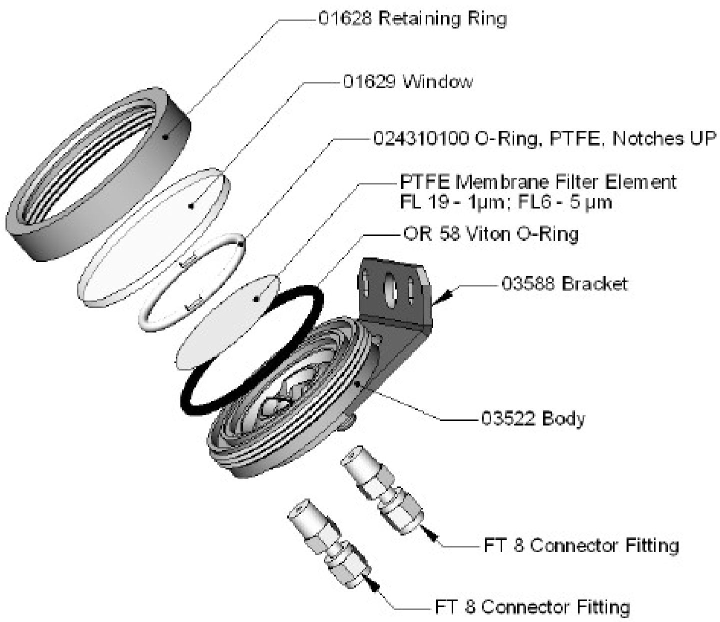

Figure 4-8: Particulate filter assembly (Teledyne API 2016)

1. Check the analyzer flow rate and note the value for comparison with the flow rate after replacing the filter.
2. Turn off the analyzer.
3. Open the front panel and unscrew the knurled retaining ring of the filter assembly.
4. Carefully remove the retaining ring, glass window, and PTFE O-ring. Use tweezers to remove the filter element.
5. Replace the filter element, centering it in the bottom of the holder.
6. Reinstall the PTFE O-ring (notches face up), the glass cover, and the retaining ring in the order shown in Figure 4-2. Hand tighten. Visually inspect the seal between the glass cover and the O-ring to ensure that it is tight. If the retaining ring is not tightened enough, it can result in a leak in the sample flow.
7. Reinstall the filter assembly and restart the analyzer.
8. Verify that the analyzer flow is similar to the value observed before changing the filter. If not, repeat the process above until the flowrate returns to a similar value.
9. Record the maintenance in the electronic logbook.

4.5.2.3. Verify diagnostic data

At a minimum, operators should review the diagnostic data weekly to identify any problems with the analyzer's operation. Table 4-2 below shows the diagnostic parameters available and their interpretation.

Table 4-2: Teledyne API T100 and T100U diagnostic data (Teledyne API 2016)

Diagnostic Parameter	Condition	Expected	Actual	Interpretation
SAMPPRESS	Sample gas	Constant with atm. changes	Fluctuating	Developing leak in pneumatics.
	Sample gas	Constant with atm. changes	Slowly increasing	Flow path is clogged: • Check critical flow orifice • Replace particulate filter
	Sample gas	Constant with atm. changes	Slowly decreasing	Developing leak in pneumatics to vacuum.
DARKPMT	Output when UV lamp shutter closed	± 20 of check out value	Increasing	PMT cooler failure. Shutter failure.
SO_2	At span with IZS option	Constant response	Decreasing over time	Change in instrument response.
	At span with IZS option	Constant response	Decreasing over time	Degradation of IZS permeation tube.
	Standard configuration at span	Stable for constant conc.	Decreasing over time	Instrument drift. Excessively low UV lamp output.
SAMPFLOW	Sample	Stable	Fluctuating	Leak in gas flow path.
	Sample	Stable	Slowly decreasing	Flow path is clogged: • Pump diaphragm has worn out and needs replacing (more common) • Critical flow orifice/ sintered filter is clogged and needs replacing (rare) • Replace particulate filter

Diagnostic Parameter	Condition	Expected	Actual	Interpretation
LAMPRATIO	Sample	Stable near 100%	Fluctuating or slow increasing	UV detector wearing out. Pin holes in UV source filter.
	Sample	Stable near 100%	Slow decreasing	UV detector wearing out. UV lamp aging. Oxides build-up on UV source filter.
SLOPE	Linearity of instrument	1.0 ± 0.3	Outside normal range	Poor calibration/Incorrect span gas concentration/Light leak/ UV lamp output decay.
	UV Source Filter Contaminated	1.0 ± 0.3	Outside normal range High offset	UV source filter needs to be replaced.

4.5.2.4. Flow check

In addition to reviewing the analyzer's reported flow via diagnostics, operators should verify the analyzer's flow every 6 months using a certified, NIST-traceable flow meter.

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a flow meter to the sample inlet port on the rear panel. Ensure that the inlet to the flow meter is at atmospheric pressure.
3. The sample flow measured with the external flow meter should be 650 sccm ± 10%.

Low flows indicate that the pneumatic pathways are blocked. Refer to the manufacturer's operation manual or contact the Calibration and Repair Laboratory for troubleshooting assistance.

4.5.2.5. Pressure leak check

Note: Do not do a vacuum leak check on this instrument.

Note: Do not exceed 15 psi when performing a pressure leak check

To perform a pressure leak check, operators must pressurize the instrument to 10 psi and hold the pressure for about 10 minutes. This can be achieved with a hand-held pressure pump with pressure gauge or with a tank of pressured gas (ultrapure air or nitrogen) with a two-stage regulator adjusted to <15 psi, a shutoff valve and a pressure gauge.

1. Turn off the analyzer and remove the instrument cover.
2. Install the pressure source on the SAMPLE inlet on the rear panel of the instrument.
3. Pressurize the instrument to approximately 10 psi, allowing enough time for full pressurization through the critical orifice. Do not exceed **15** psi.

4. Turn off pressure to the instrument and allow to sit for 10 minutes. If the pressure gauge measures a loss exceeding 0.8 psi during that time, the pneumatics have a leak.
5. If the leak check fails, use a liquid leak detector (e.g. Snoop®) to search for leaks. Pressurize the instrument to 10 psi and check each tube connection (fittings, hose clamps) with solution and look for bubbles. Wipe off all leak detection fluid before reconnecting sample lines to ensure that fluid is not sucked into the instrument.
6. Reconnect the sample and exhaust lines and replace the instrument cover.

4.5.2.6. Replace pump diaphragm

Low flow or no flow can be a sign of worn-out seals in the pump. Pumps should be tested annually and replaced using the Teledyne API pump rebuild kit if found to be faulty. Detailed instructions are included with the rebuild kit.

4.6. Data collection and storage

4.6.1. Envidas channel configuration

All Washington Network SO_2 monitoring sites must be configured to collect 1-minute, 5-minute, and 1-hour average concentrations. The 5-minute average concentrations are used to compute the hourly maximum 5-minute concentration, which is an EPA reporting requirement for SO_2 monitoring. This configuration is set at the logger level. An example of the correct timebase setting is shown in Figure 4-3.

Figure 4-9: Timebase setting for collecting 5-minute average SO_2 concentration

The correct configuration for the SO_2 concentration channel is shown in Figure 4-4 below.

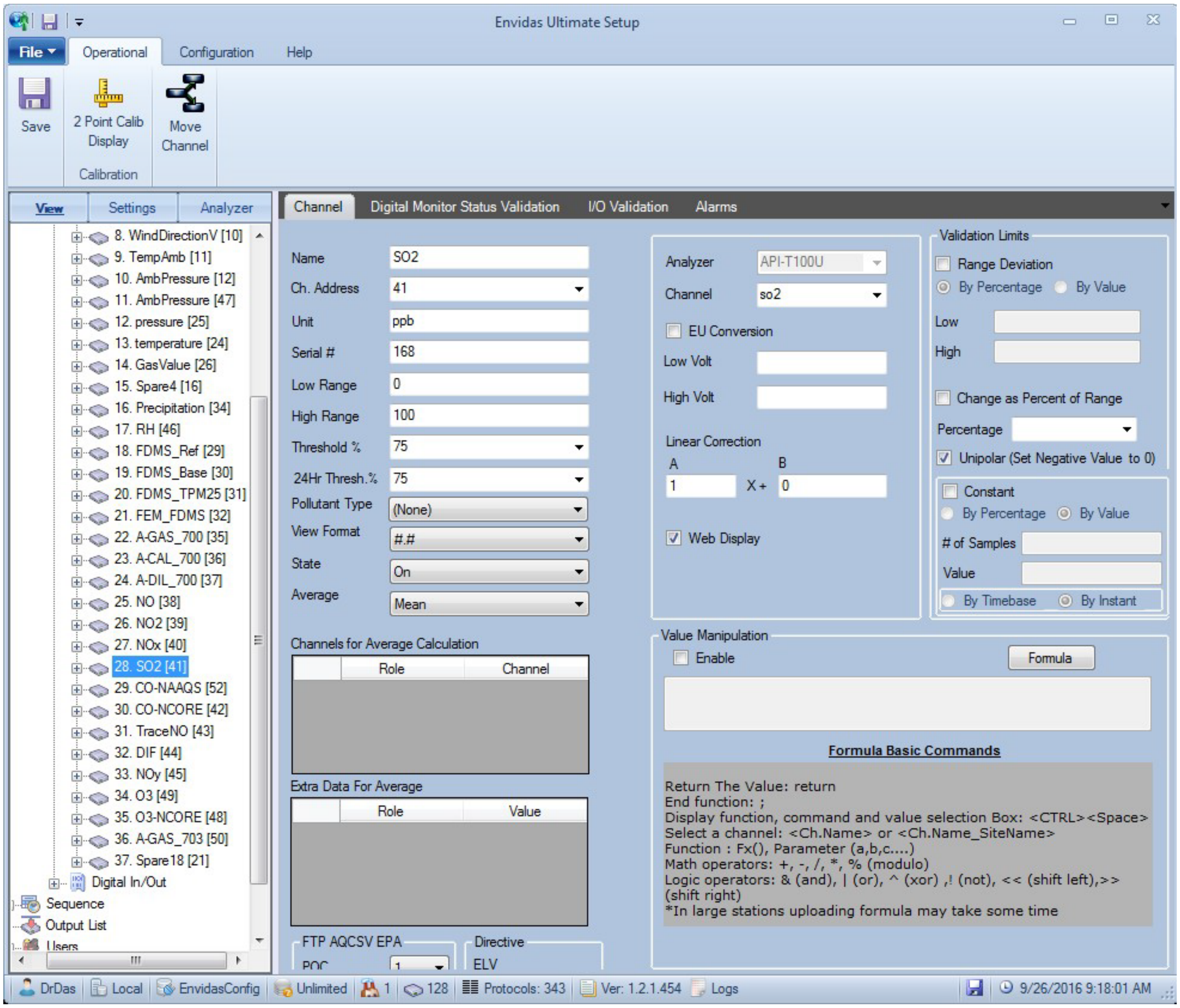

Figure 4-10: SO_2 channel configuration

The configuration for a primary QC check set to run every 2 days is shown in Figure 4-5 through Figure 4-9. This sequence can be modified with an additional point for a secondary QC check. For span points, the phase should last a minimum of 20 minutes, and the reference value should be a 2-minute average of the ACTCONC channel that does not include the last minute of the phase (Figure 4-9).

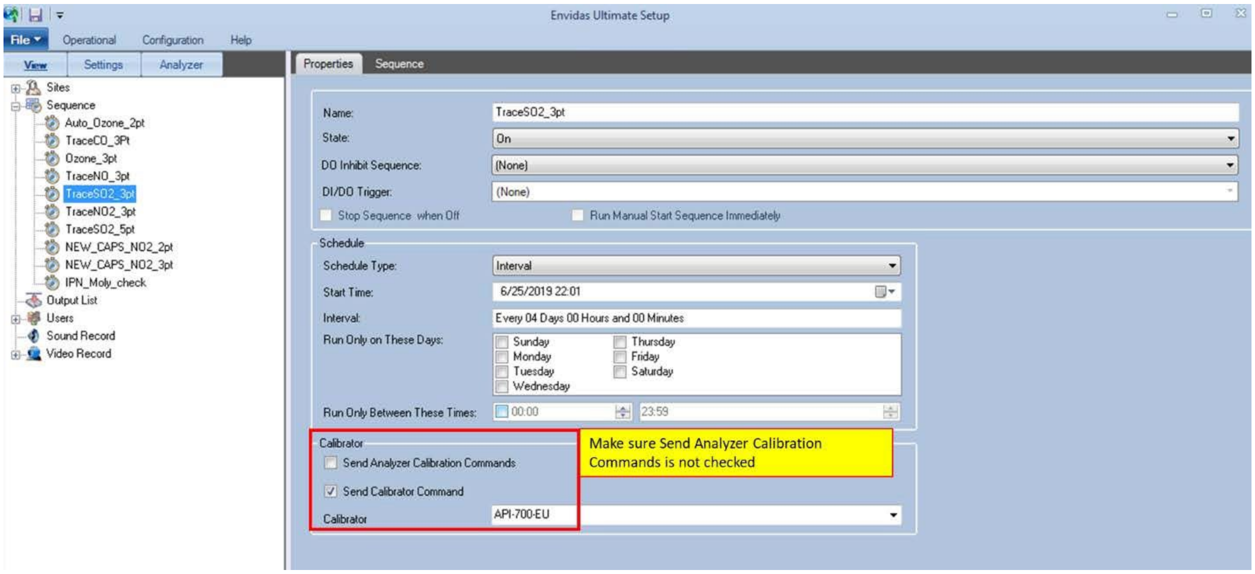

Figure 4-11: SO_2 primary QC sequence properties

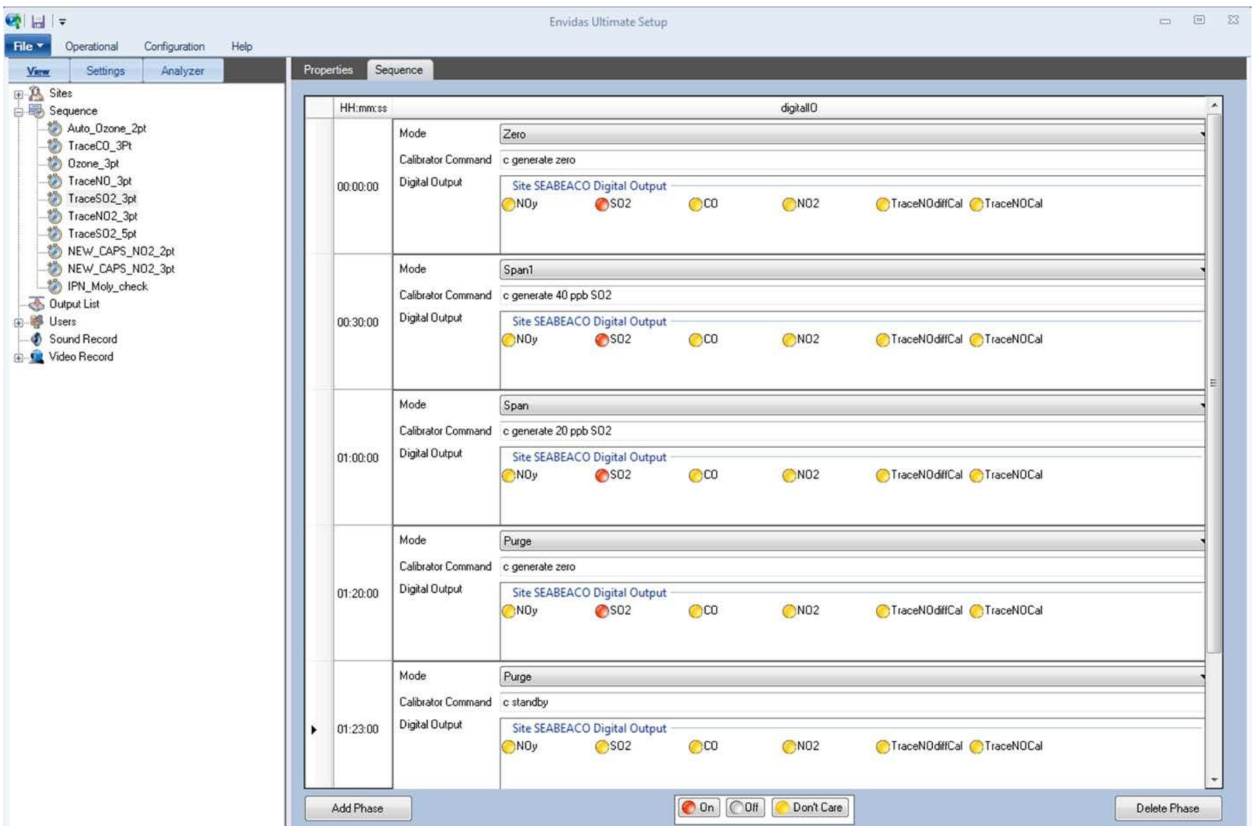

Figure 4-12: SO_2 primary QC sequence configuration part 1

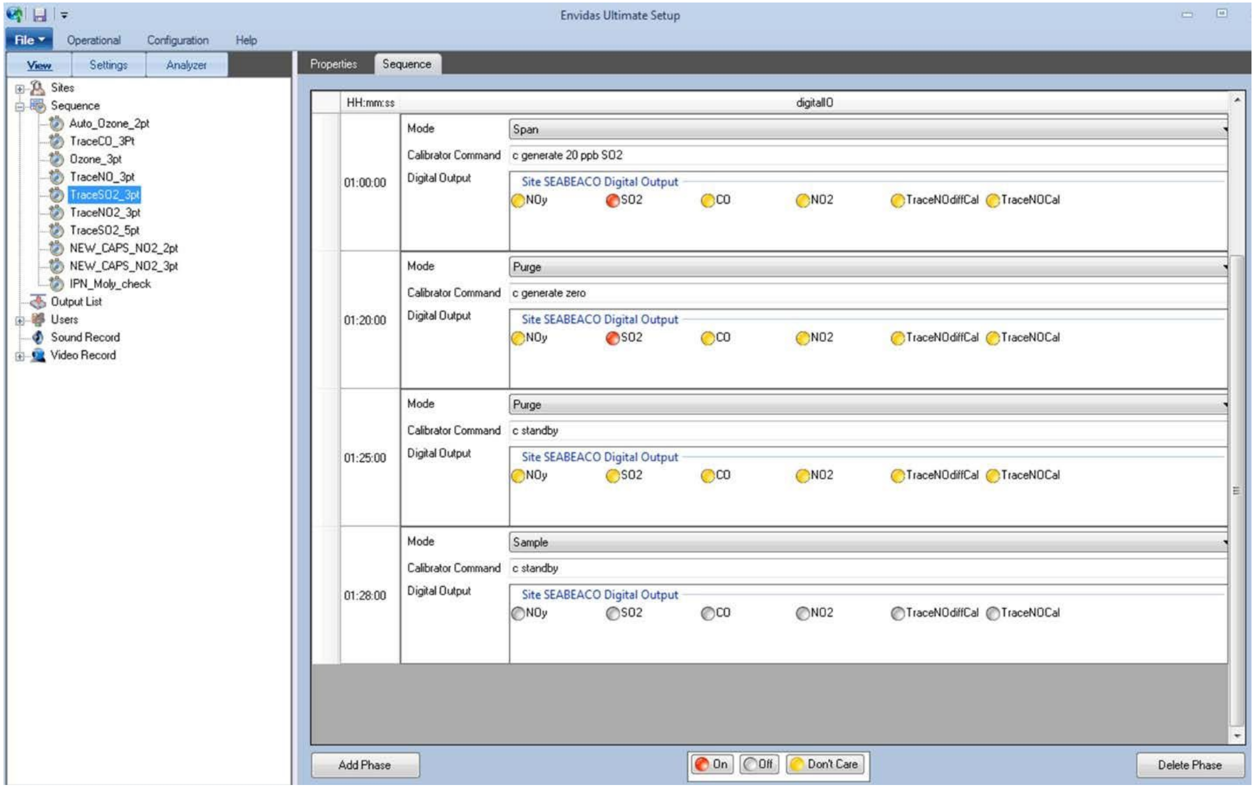

Figure 4-13: SO_2 primary QC sequence configuration part 2

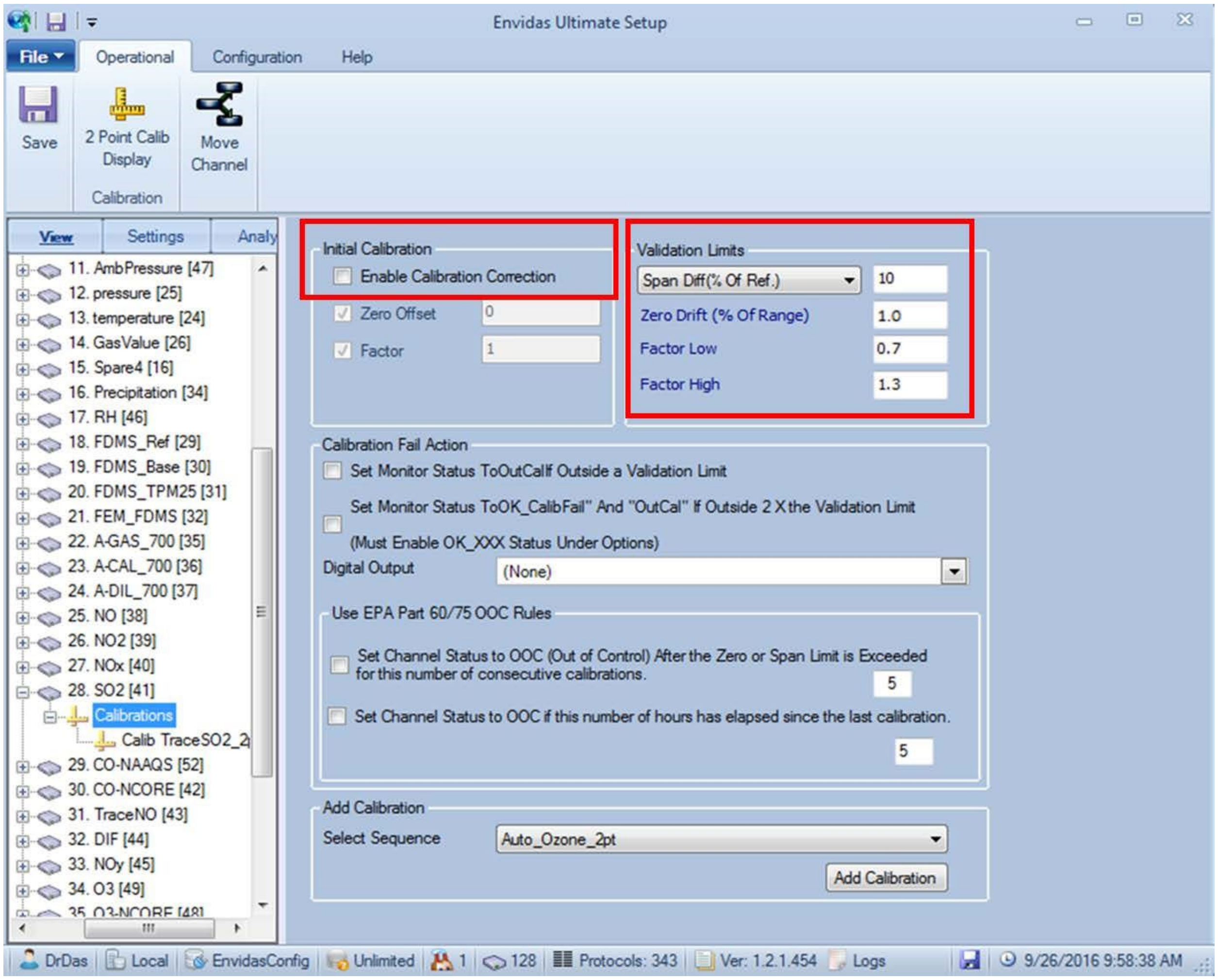

Figure 4-14: SO_2 primary QC configuration of validation limits

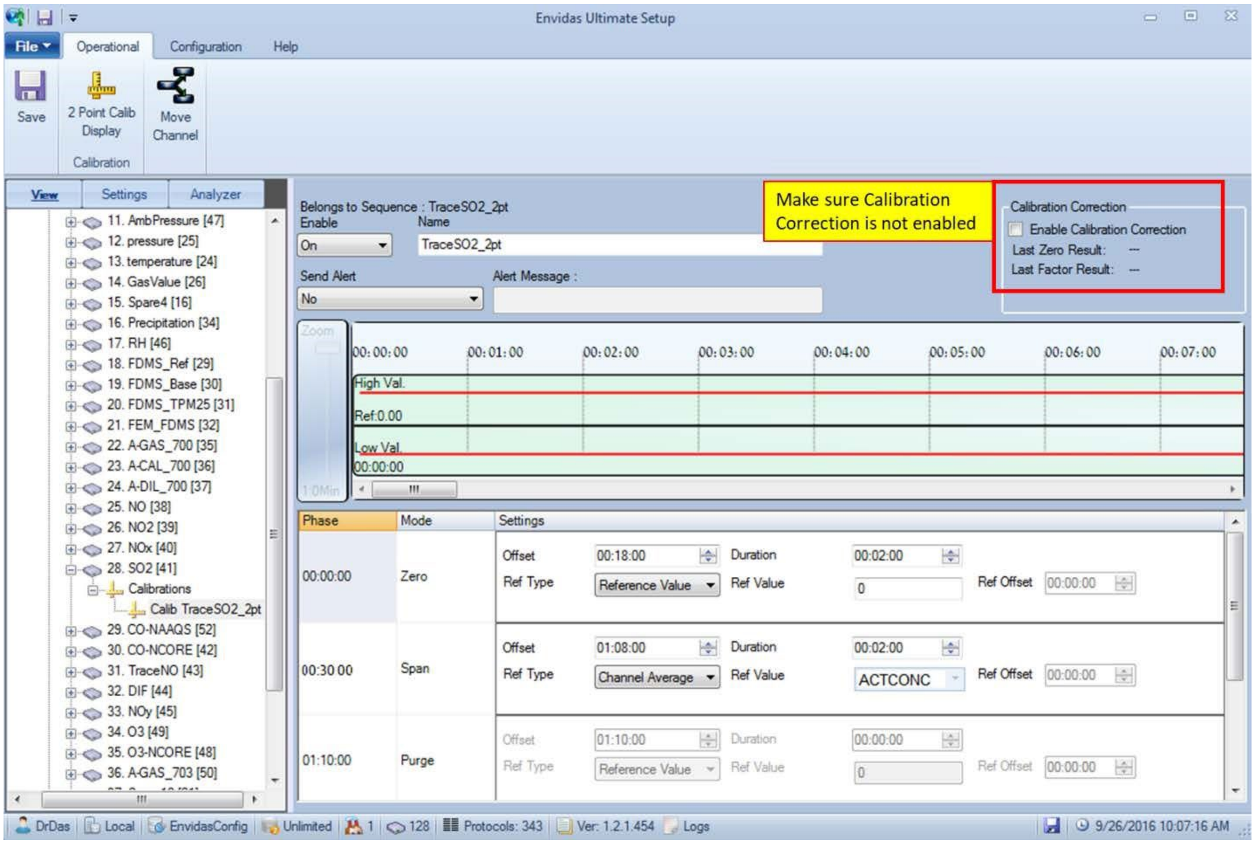

Figure 4-15: SO_2 primary QC configuration of phases and reference values

4.6.2. Diagnostic data collection

At a minimum, the server should be configured to collect the diagnostic parameters listed in Table 4-2 at least every 30 minutes, except during QC checks, during which they are collected every minute. Operators may elect to collect additional diagnostic parameters. The configuration for collection of a complete set of diagnostic parameters is shown in Figure 4-10.

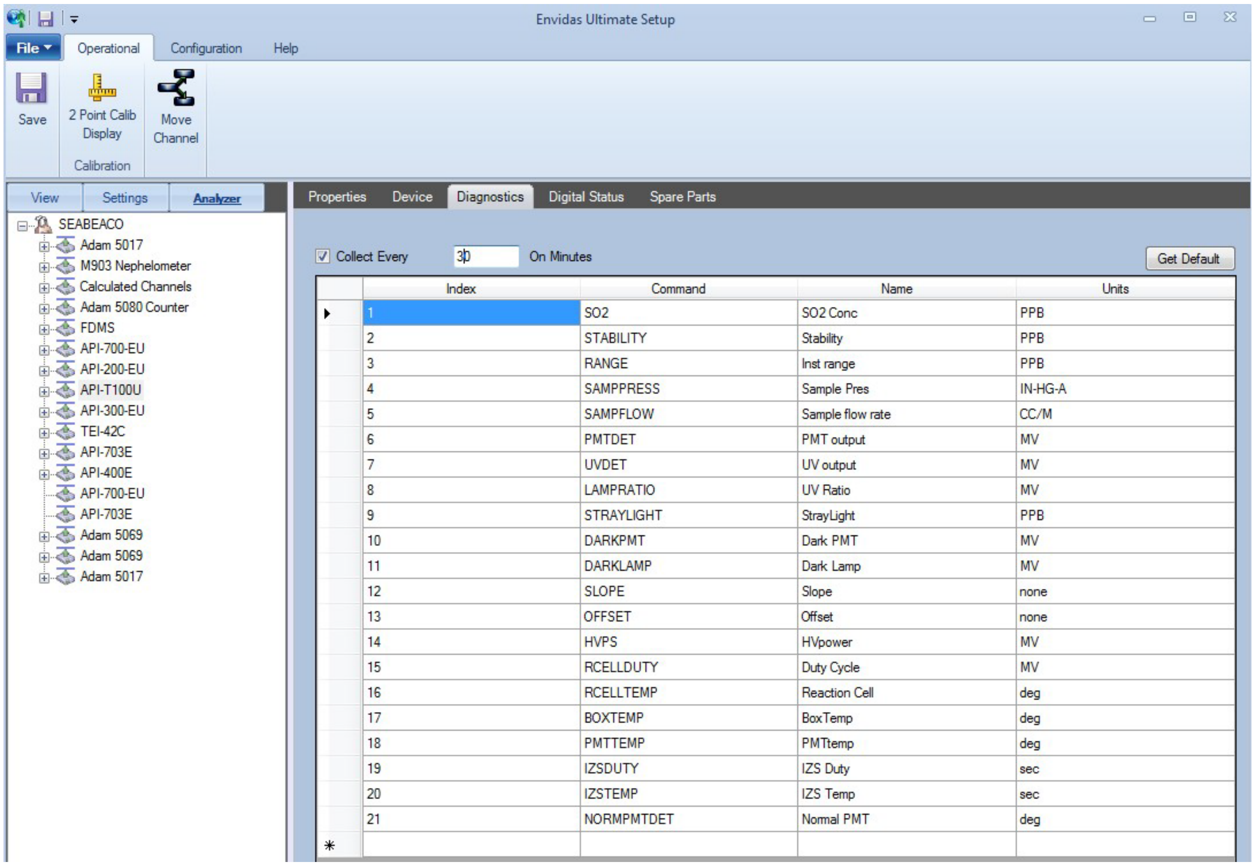

Figure 4-16: Configuration of SO_2 analyzer diagnostic parameter collection

5. Carbon Monoxide (CO) Monitoring

5.1. Introduction

This chapter describes Ecology's procedures for monitoring trace- and ambient-level CO concentrations using the Teledyne API T300U and T300 analyzers. It includes procedures for installation, operation, quality control, maintenance, and data acquisition. It is intended to be used with the manufacturer's model-specific operation manual and Chapters 2 and 3, which describes general procedures for gaseous pollutant monitoring and the calibration system.

5.2. Principles of operation

The CO concentrations in the ambient air are measured based on the absorption of infrared radiation (IR) by CO. A source IR beam is passed into a sample chamber where mirrors reflect the light beam multiple times to increase the path length and achieve sufficient IR absorption to accurately measure low CO concentrations. Upon exiting the chamber, the beam is passed through a band-pass filter to only allow IR at a wavelength of 4.7 µm to reach a photometer. To overcome the measurement interference from gases such as water vapor and carbon dioxide that also absorb at this wavelength, the instrument uses Gas Filter Correlation (GFC) upstream of the sample chamber.

The GFC Wheel consists of two semi-circle cells, a measurement cell and a reference cell. Pure nitrogen (N_2) fills the measurement cell and the reference cell contains N_2 and a high concentration of CO. As the IR source passes through the spinning wheel and the sample air in the chamber, the alternating IR absorption capacities in the two cells create pulses of measurement peak (CO MEAS) and reference peak (CO REF) since N_2 does not absorb any IR. The ratio of CO MEAS to CO REF, or M/R ratio, can thus be calculated. If interfering gas is present in the sample chamber, it only reduces the IR signals the same way in both measurement and reference cells while the M/R ratio stays unchanged. As a result, GFC rejects the effects of interfering gases and the analyzer only responds to the CO in the sample air. Once the M/R ratio is obtained, the analyzer uses an internal look-up table to interpolate the reading and applies calibration (slope and offset) to calculate the final CO concentrations.

The primary difference between the trace-level (300EU and T300U) and ambient-level analyzers (300E and T300) is the auto-reference (A-REF) ratio and the Nafion® dryer installed in the trace level analyzers. The A-REF ratio is used to correct drift caused by the aging photometer components (e.g. IR lamp, IR detector, etc.), variation in ambient temperature and interfering gases. It is derived in the same way as the M/R ratio, except that the air sample is routed to a CO scrubber prior to entering the sample chamber so the difference between CO MEAS and CO REF represents the exact state of the sample gas and the photometer component free of CO. AREF cycle is triggered every 4 hours by the analyzer and takes approximately 15 minutes. After the cycle, the analyzer averages the last five A-REF ratios and applies the value in the final CO calculation as an offset. The Nafion® dryer is located upstream of the CO scrubber and consists of a bundle of Nafion® tubes housed within a single shell. The Nafion® tubes absorb water and the dryer purges moisture with a flow countercurrent to the sample flow. These two additional components ensure that any low level of signal caused by interfering gases or aging instrument is effectively minimized.

5.3. Equipment and supplies

In addition to the standard equipment in Table 3-1, operators should purchase pump rebuild kit PU0000110 from Teledyne API online or contact the Calibration and Repair Laboratory to obtain a pump rebuild kit.

5.4. Installation

In addition to the siting criteria described in Section 2.2.1, the CO sample probe must be situated according to the monitoring site's spatial scale, as summarized in Table 5-1. Operators should refer to 40 CFR Part 58 Appendices D and E for extensive siting criteria on CO monitoring.

Table 5-10: Summary of CO siting criteria

Parameter	Spatial Scale	Siting Requirement
Inlet height	Neighborhood, urban, or regional scale (e.g. NCore sites)	2 - 15 m above ground level
	Near-road microscale in downtown areas or urban street canyons	2.5 - 3.5 m above ground level
Distance from monitoring paths	Neighborhood, urban, or regional scale (e.g. NCore sites)	No specific requirement for CO
	Near-road microscale in downtown areas or urban street canyons	• 2 - 10 m from the edge of the nearest traffic lane. • ≥ 10 m away from an intersection; preferably at a midblock location.

5.5. Quality control and maintenance

5.5.1. Quality control checks

Besides the procedures described in Section 2.3, operators must ensure the QC checks, particularly automatic, are timed appropriately to avoid overlapping with A-REF cycle. Any QC check containing an interference with A-REF cycle is considered invalid.

The recommended action levels are illustrated in Figure 5-1.

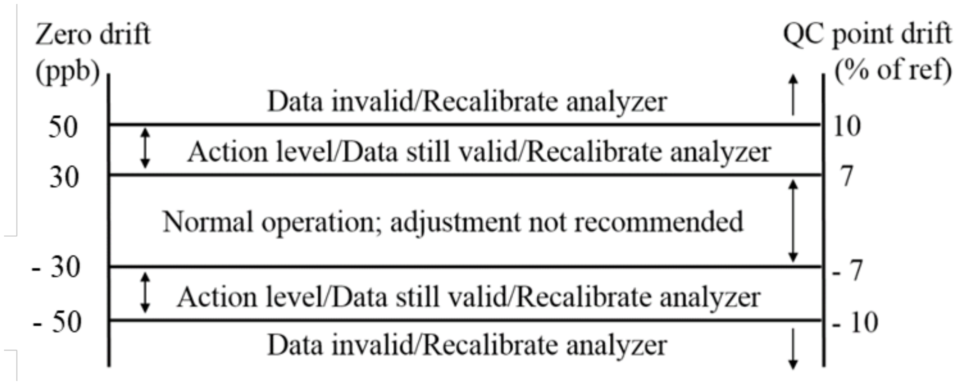

Figure 5-17: CO action levels

5.5.2. Maintenance

The maintenance schedule for the Teledyne API 300 and 300U CO analyzers is summarized in Table 5-2.

Table 5-11: Summary of required CO analyzer maintenance

Procedure	Frequency	Section
Analyzer calibration	If analyzer is out of specifications, or every 6 months	5.5.2.1
Change particulate filter	Inspect every 30 days, replace every 90 days or more frequently when the filter becomes noticeably dirty	5.5.2.2
Verify diagnostic data	Weekly	5.5.2.3
Flow check	Every 6 months	5.5.2.4
Vacuum leak check	Before and after filter change and pneumatic repairs	5.5.2.5
Pressure leak check	Annually or after pneumatic repairs	5.5.2.5
Replace pump diaphragm	Annually or when reaction cell pressure exceeds 4 in-Hg-A at sea level	5.5.2.6

5.5.2.1. Analyzer calibration

After a failed QC check, operators must take corrective actions (Section 2.3.5) to determine if the failure was caused by the analyzer or than any other component, such as a pump failure, calibration system issue, blockage of the sampling probe, or telemetry issue. If the failure is confirmed to be due to the analyzer, the analyzer must be calibrated. The calibration scale for the analyzer can be calculated as the 99th percentile of hourly concentrations at the site over the previous 3 years multiplied by 1.5. More specific details and an example are in Section 2.3.1.3. Check with the Calibration and Repair Laboratory to verify the calibration scale prior to calibrating the analyzer.

Before the calibration operators must perform an "as found" QC check. If needed, the particulate filter should be replaced after the "as found" QC check and before calibration.

After the calibration the operators must perform a post-calibration verification to verify the linear response of the analyzer (Section 2.3.2). In accordance with 40 CFR Part 50 Appendix C Section 4.4.7, compute the linear regression between analyzer response (Y-axis) versus actual concentration (X-axis) and plot the regression line to verify that no point deviates from this line by more than ± 2%. See Appendix B of this document for an example of the Linearity Check Form. Contact the Calibration and Repair Laboratory or Quality Assurance Unit to obtain the latest version of an electronically fillable Linearity Check Form.

To calibrate a TAPI CO analyzer:

1. Ensure that the pressures of zero air and cylinder gas to the calibrator are between 25 and 30 psi.
2. Select CAL > CONC and change the concentration displayed to the value of the calibration scale (see section 2.3.1.3). Select ENTER, then EXIT.
3. From the calibrator, generate zero air to the instrument for at least 30 minutes or until analyzer stability is at or below 10 ppb for trace-level CO.
4. Select CAL > ZERO > ENTER on the analyzer.
5. Generate calibration gas at the level of the calibration scale for at least 30 minutes or until instrument stability is at or below 10 ppb for trace-level CO.
6. Select CAL > SPAN > ENTER on the analyzer to complete calibration.
7. Select EXIT to return to the main menu.

Note: The ZERO or SPAN buttons may not display during the zero or span calibration if the measured concentration is too different from the expected value. Refer to the manufacturer's operation manual for more information.

5.5.2.2. Change particulate filter

The particulate filter must be inspected every 30 days for signs of plugging or excess dirt. The particulate filter must be changed every 90 days, or more frequently when the filter becomes noticeably dirty or discolored. Operators should wear gloves and take care not to touch the inside surfaces, including glass window, PTFE or Viton O-rings, or assembly body, as contamination may lower the data accuracy.

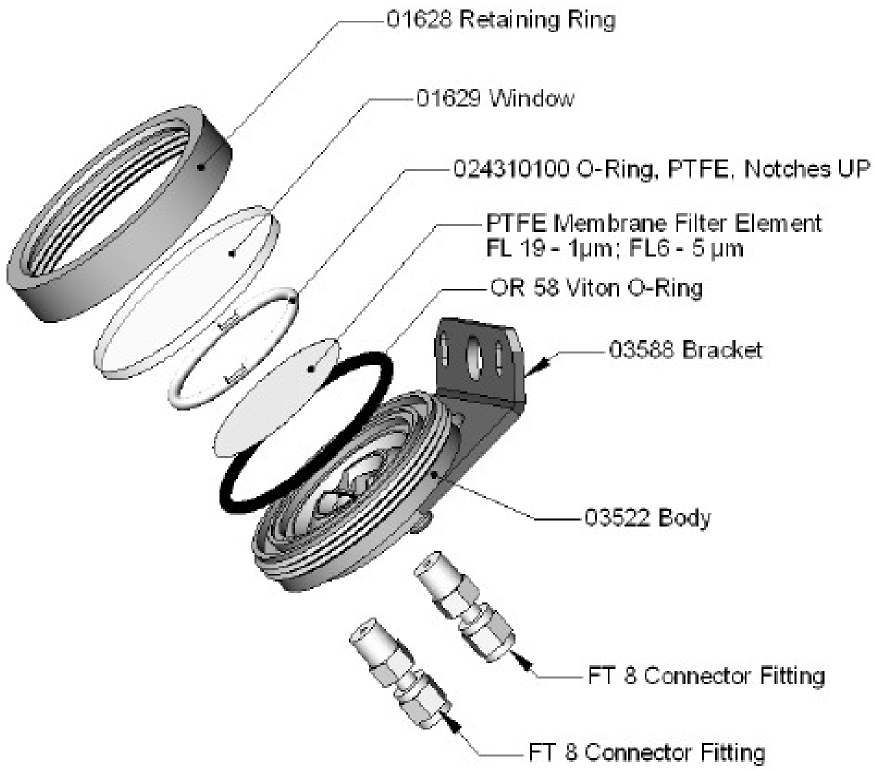

Figure 5-18: Particulate filter assembly (Teledyne API 2016)

1. Check the analyzer flow rate and note the value for comparison with the flow rate after replacing the filter.
2. Perform an as-found vacuum leak check and record the sample flow and pressure.
3. Turn off the analyzer.
4. Open the front panel and unscrew the knurled retaining ring of the filter assembly.
5. Carefully remove the retaining ring, glass window, and PTFE O-ring. Use tweezers to remove the filter element.
6. Replace the filter element, centering it in the bottom of the holder. Reinstall the PTFE Oring (notches face up), the glass cover, and the retaining ring in the order shown in Figure 5-2.
7. Hand tighten. Visually inspect the seal between the glass cover and the O-ring to ensure that it is tight. If the retaining ring is not tightened enough, it can result in a leak in the sample flow.
8. Reinstall the filter assembly and restart the analyzer.
9. Verify that the analyzer flow is similar to the value observed before changing the filter. If not, repeat the process above until the flowrate returns to a similar value.
10. Perform an as-left vacuum leak check and record the sample flow and pressure. Verify that the sample flow and pressure is similar to the value observed before changing the filter. If not, repeat the process above until the sample flow and pressure returns to a similar value.
11. Record the maintenance in the electronic logbook.

5.5.2.3. Verify diagnostic data

At a minimum, operators should review the diagnostic data weekly to identify any problems with the analyzer's operation. Table 5-3 below shows the diagnostic parameters available and their interpretations.

Table 5-12: Teledyne API T300 and T300U diagnostic data (Teledyne API 2012)

Diagnostic Parameter	Condition	Behavior	Interpretation
STABILITY	Zero Cal	Increasing	• Pneumatic leaks in instrument & sample system. • Detector deteriorating.
CO MEAS	Zero Cal	Decreasing	• Source aging. • Detector deteriorating. • Contaminated optics.
MR RATIO	Zero Cal	Increasing	• Source aging. • Detector deteriorating. • Contaminated zero gas (H_2O).
	Zero Cal	Decreasing	• Source aging. • Detector deteriorating. • GFC Wheel leaking. • Pneumatic leaks. • Contaminated zero gas (CO).
	Span Cal	Increasing	• Source aging. • Pneumatic leaks in instrument & sample system. • Calibration system deteriorating. • GFC Wheel leaking.
	Span Cal	Decreasing	• Source aging. • Calibration system deteriorating.
PRES	Sample	Increasing > 1"	• Leaks between sample inlet and sample cell. • Change in sampling manifold.
	Sample	Decreasing > 1"	• Dirty particulate filter. • Pneumatic obstruction between sample inlet and sample cell. • Obstruction in sampling manifold. • Pump diaphragm has worn out.
PHT DRIVE	Any, with Bench Temp at 48 °C	Increasing	• Poor mechanical connection between IR-photodetector and sample cell. • IR-photodetector deteriorating.

Diagnostic Parameter	Condition	Behavior	Interpretation
OFFSET	Zero Cal	Increasing	See MR Ratio - Zero Cal Decreasing.
	Zero Cal	Decreasing	See MR Ratio - Zero Cal Increasing.
SLOPE	Span Cal	Increasing	See MR Ratio - Span Cal Decreasing.
	Span Cal	Decreasing	See MR Ratio - Span Cal Increasing.

5.5.2.4. Flow check

In addition to reviewing the analyzer's reported flow via diagnostics, operators must verify the analyzer's flow every 6 months using a certified, NIST-traceable flow meter. The external flow device should be capable of measuring flows between 0 and 3000 sccm. Do not use the flow measurement displayed on the front panel for this flow check.

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a flow meter to the sample inlet port on the rear panel. Ensure that the inlet to the flow meter is at atmospheric pressure.
3. The sample flow measured with the external flow meter should be 2000 sccm ± 10%.
4. If needed, adjust the internal flow sensor following the procedures in the instrument manual.

Low flows indicate that the pneumatic pathways are blocked. Refer to the manufacturer's operation manual or contact the Calibration and Repair Laboratory for troubleshooting assistance.

5.5.2.5. Leak check

Leaks are the most common cause of analyzer malfunction. This section presents a simple vacuum leak check, and a more thorough pressure leak check procedure.

5.5.2.6. Vacuum leak check

This method is easy and fast. It detects but does not locate most leaks. It also verifies that the sample pump is in good condition.

1. Turn the analyzer ON and allow enough time for flows to stabilize.
2. Cap the sample inlet port.
3. After several minutes, when the pressure has stabilized, note the SAMPLE PRESSURE and SAMPLE FLOW readings.
   - If the sample pressure is <10 in-Hg, the pump is in good condition and there are no large leaks.
   - If the sample flow is <10 cm^3/min and stable, there are no large leaks in the instrument's pneumatics.
   - If the pressure is near or ≥10 in-Hg-A, the pump diaphragm should be replaced.
   - If the sample pressure is >10 in-Hg-A and the flow is >10 cm/min, there is a leak that requires corrective action, and a detailed pressure leak check should be performed to identify the location of the leak.

5.5.2.7. Pressure leak check

Note: Do not exceed 15 psi when performing a pressure leak check

To perform a pressure leak check, operators must pressurize the instrument to 10 psi and hold the pressure for about 10 minutes. This can be achieved with a hand-held pressure pump with pressure gauge or with a tank of pressured gas (ultrapure air or nitrogen) with a two-stage regulator adjusted to ≤ 15 psi, a shutoff valve and a pressure gauge.

1. Turn off the analyzer and remove the instrument cover.
2. Install the pressure source on the SAMPLE inlet on the rear panel of the instrument.
3. Pressurize the instrument to approximately 10 psi, allowing enough time for full pressurization through the critical orifice. Do not exceed **15** psi.
4. Turn off pressure to the instrument and allow to sit for 10 minutes. If the pressure gauge measures a loss exceeding 0.8 psi during that time, the pneumatics have a leak.
5. If the leak check fails, use a liquid leak detector (e.g. Snoop®) to search for leaks. Pressurize the instrument to 10 psi and check each tube connection (fittings, hose clamps) with solution and look for bubbles. Wipe off all leak detection fluid before reconnecting sample lines to ensure that fluid is not sucked into the instrument.
6. Reconnect the sample and exhaust lines, and replace the instrument cover.

5.5.2.8. Replace pump diaphragm

Normal sample pressure is 29.92 in-Hg at sea level. Actions should be taken if pressure reading is < 10 in-Hg or > 35 in-Hg (see **Pres** in Table 5-3). A simple pump check can be performed prior to pump replacement following instructions in the operation manual. Low flow or no flow can be a sign of worn-out seals in the pump. Pumps must be rebuilt using the Teledyne API pump rebuild kit annually. Detailed instructions are included with the rebuild kit. Always perform flow and leak check after the pump is rebuilt.

5.6. Data collection and storage

5.6.1. Envidas channel configuration

The correct configuration for CO concentration channels is shown in Figure 5-3 and Figure 5-4. Two channels must be set up to record CO concentrations in ppb for NAAQS compliance purposes (Figure 5-3) and in ppm for WAQA calculation purposes on the Ecology web page

(Figure 5-4).

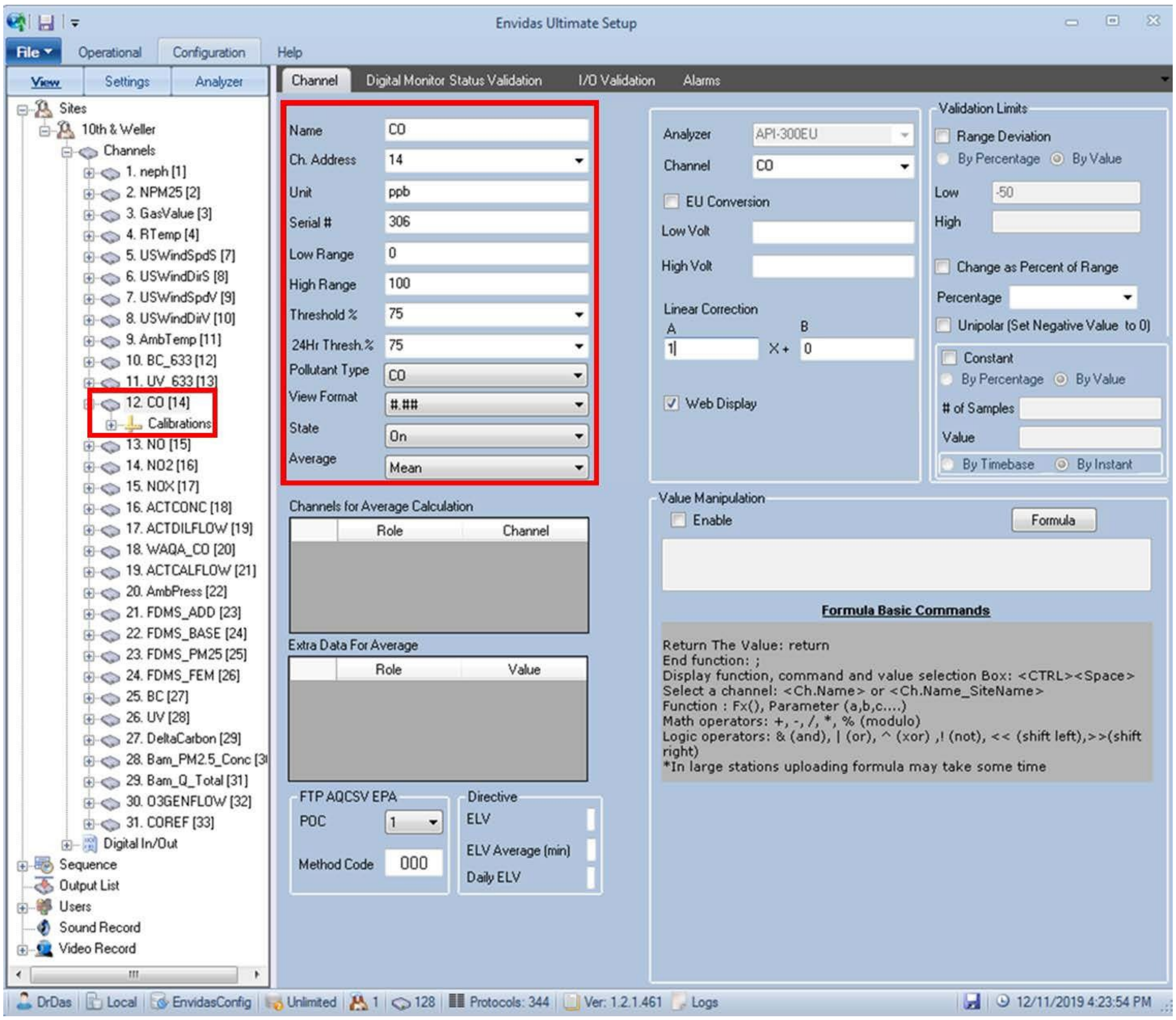

Figure 5-19: CO channel configuration for NAAQS compliance

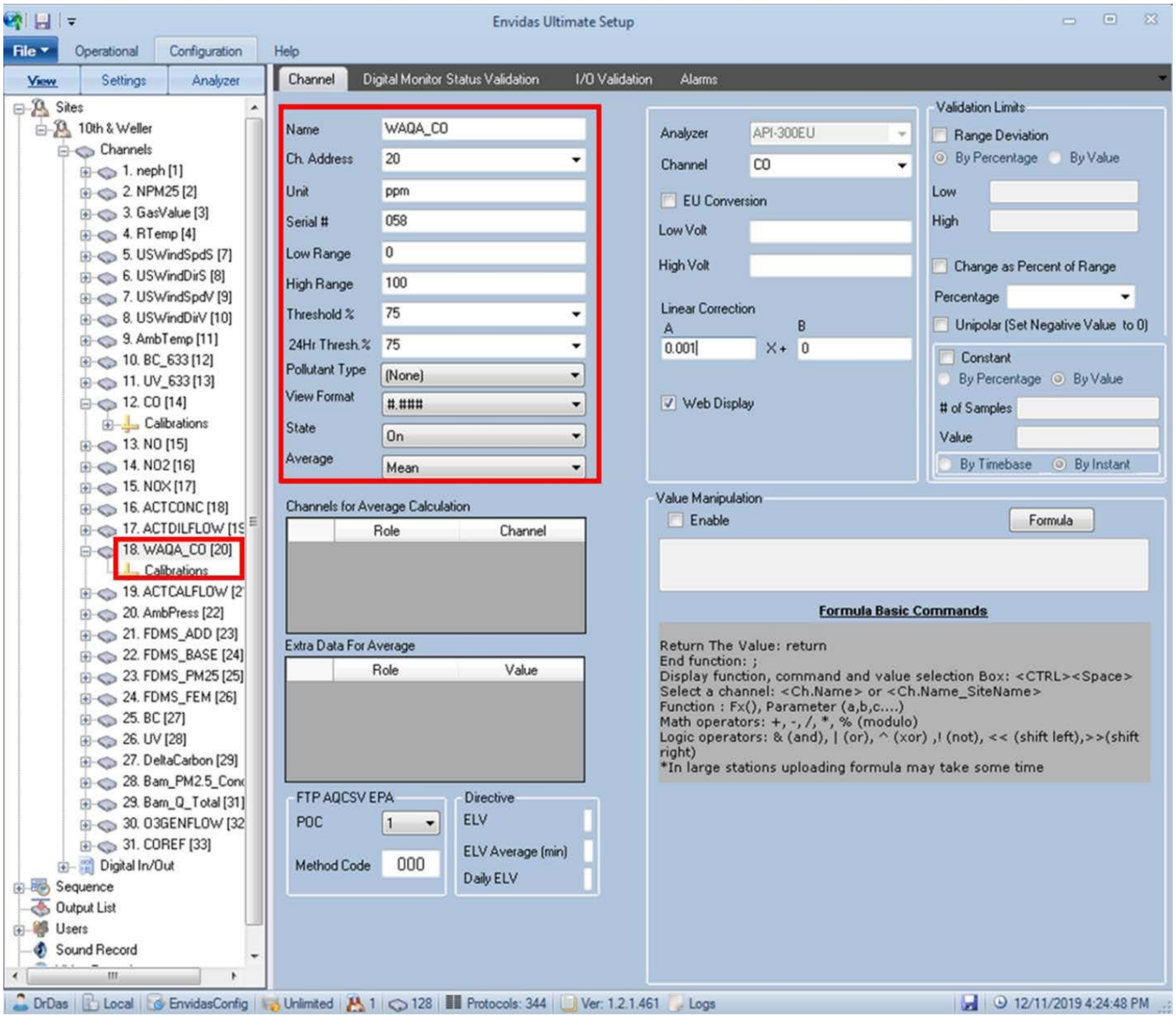

Figure 5-20: CO channel configuration for WAQA calculation

The configuration for a QC check set to run every Sunday and Wednesday is shown in Figure 5-5 through Figure 5-8. This sequence can be modified with an additional point for a secondary QC check For span points, the phase should last a minimum of 20 minutes and the reference value should be a 2-minute average of the ACTCONC channel that does not include the last minute of the phase (Figure 5-8).

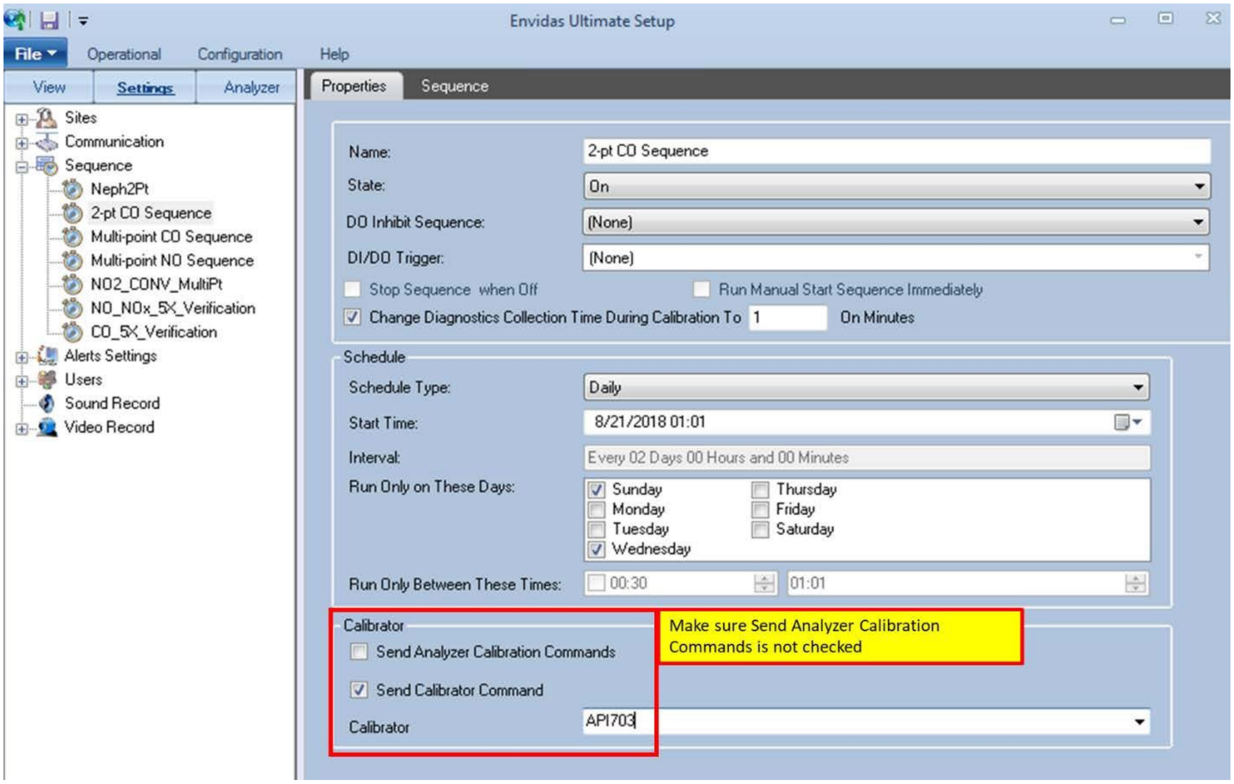

Figure 5-21: CO QC sequence properties

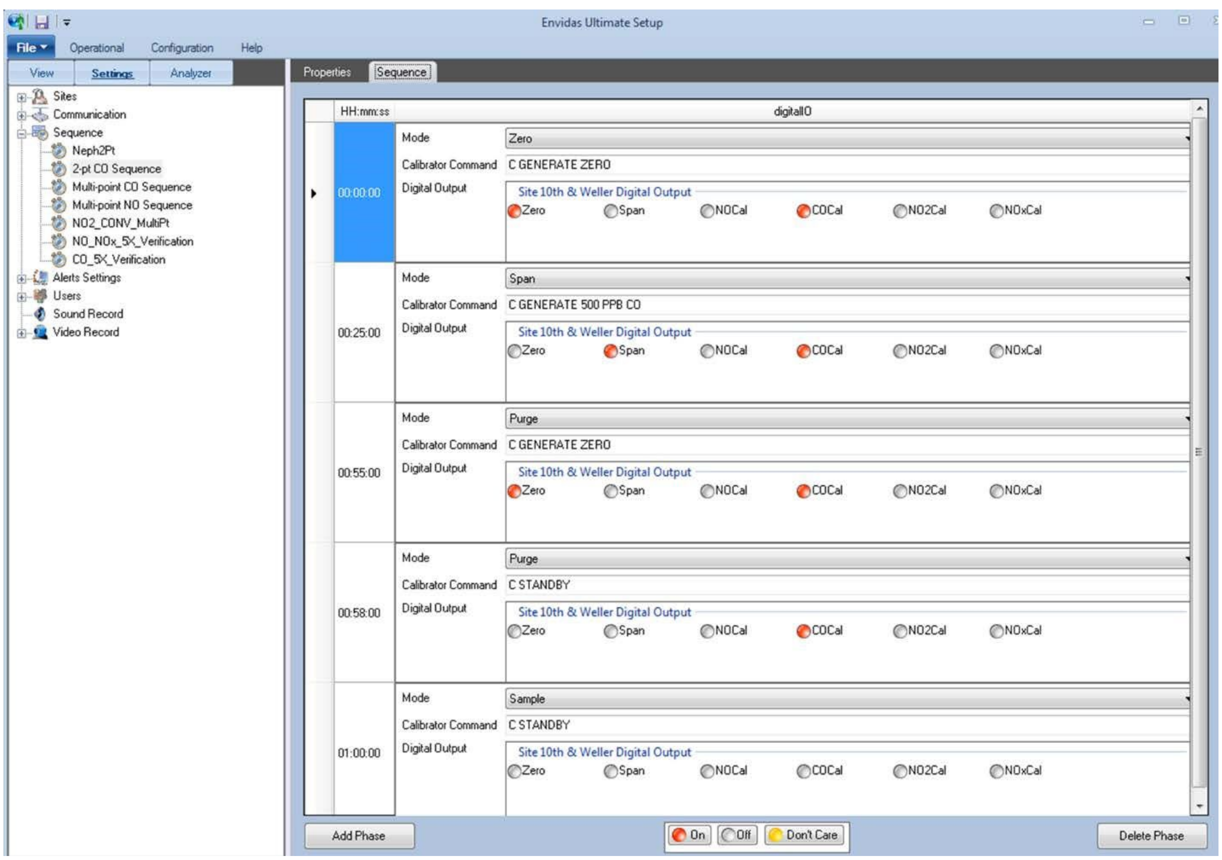

Figure 5-22: CO QC sequence configuration

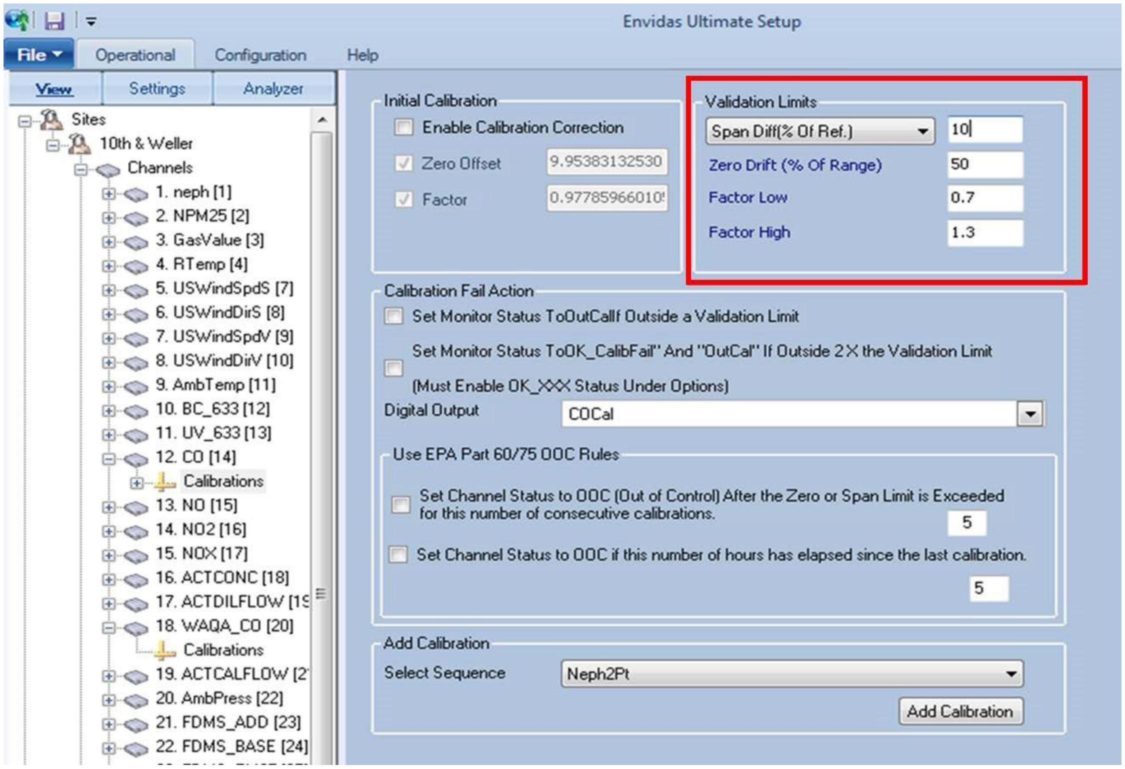

Figure 5-23: CO QC configuration of validation limits

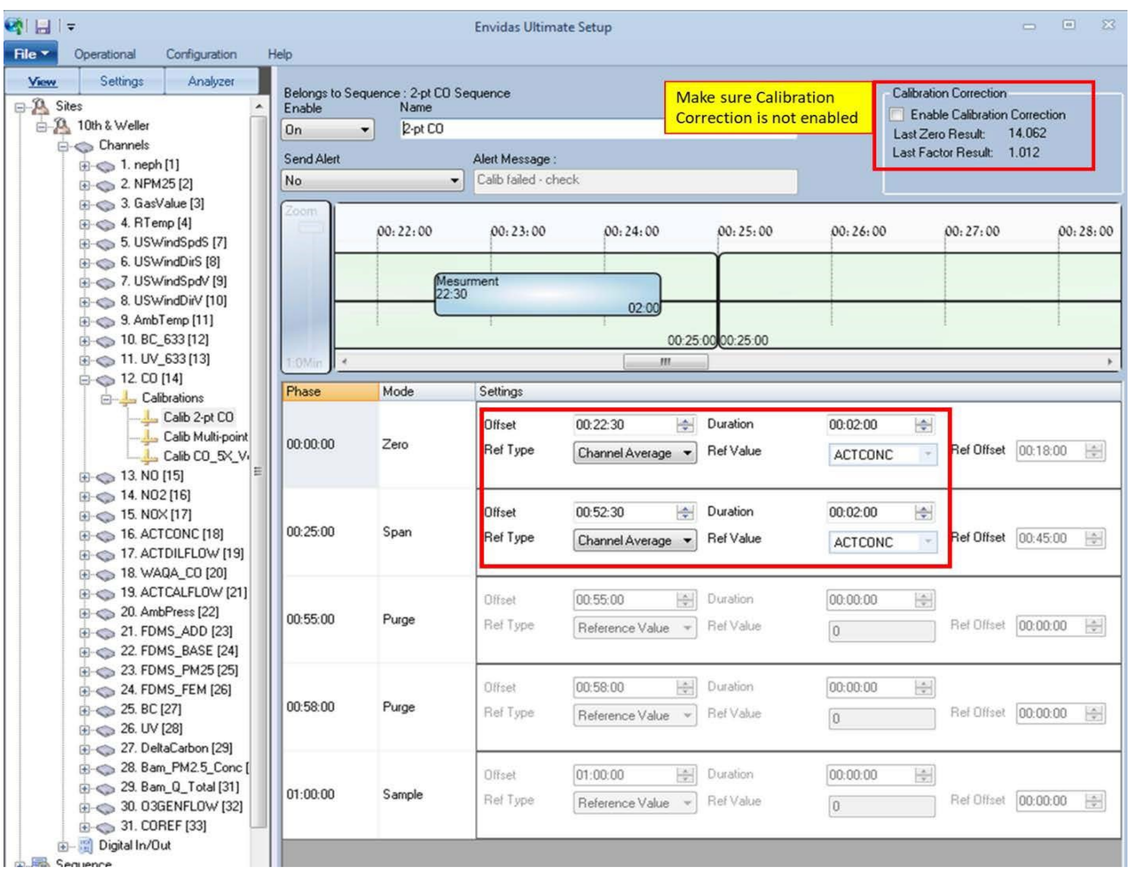

Figure 5-24: CO QC configuration of phases and reference values

5.6.2. Diagnostic data collection

At a minimum, the server should be configured to collect the diagnostic parameters listed in Table 5-3 at least every 30 minutes, except during QC checks, where they should be collected every minute. Operators may elect to collect additional diagnostic parameters. The configuration for collection of a complete set of diagnostic parameters is shown in Figure 5-9.

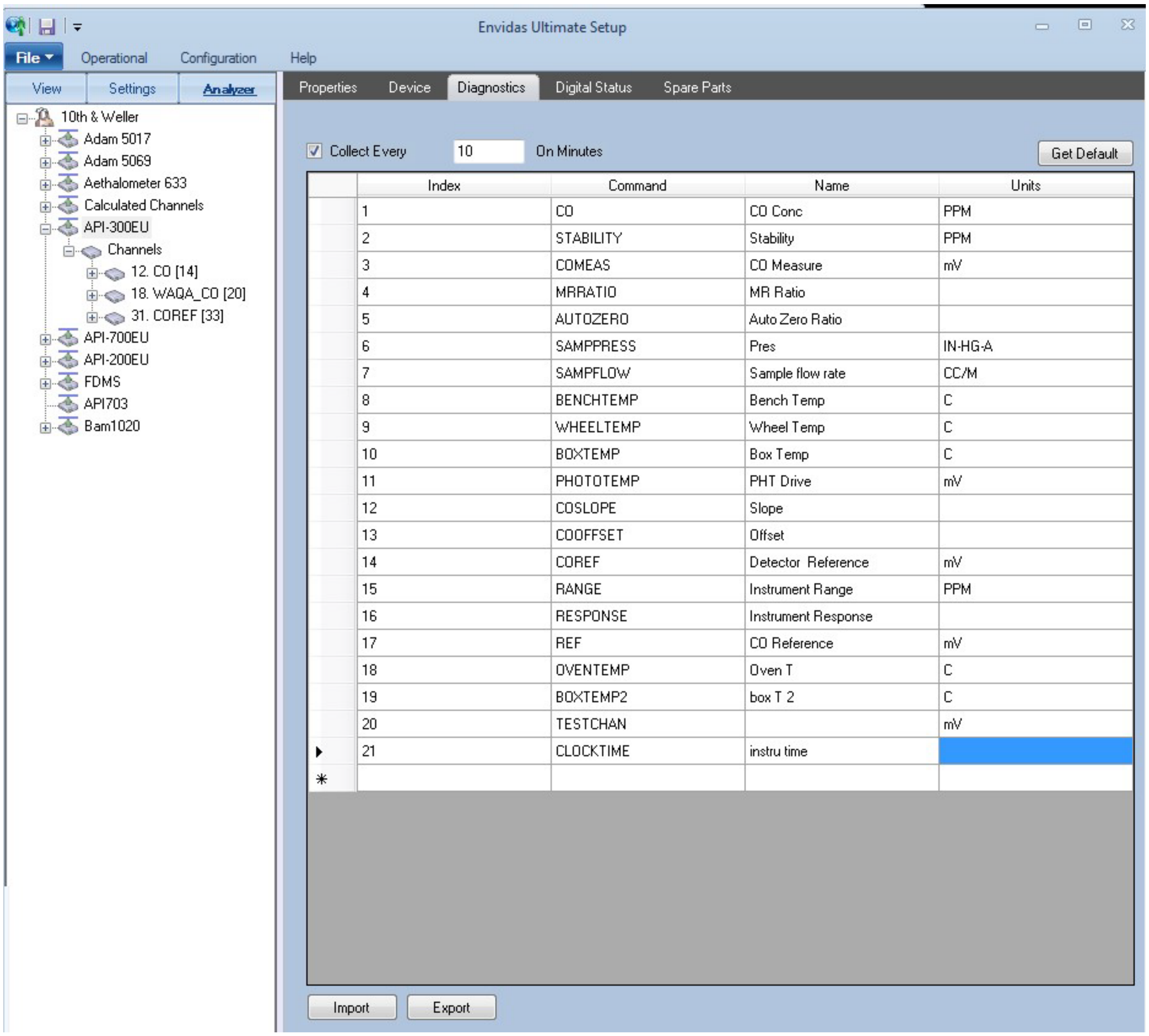

Figure 5-25: Configuration of CO analyzer diagnostic parameter collection

6. Nitrogen Oxides (NO_X) and Reactive Nitrogen (NO_Y) Monitoring

6.1. Introduction

This chapter describes Ecology's procedures for monitoring trace- and ambient-level nitrogen oxides (NO_X) and reactive nitrogen compounds (NO_Y) using the Teledyne API 200EU, T200U, and T200U-NO_Y and other analyzers. The concentration of nitrogen oxides (NO_X) in ambient air is defined as the sum of the concentration of nitric oxide (NO) and nitrogen dioxide (NO_2). Total reactive oxides of nitrogen (NO_Y) are the sum of NO_X and NO_z, which includes other reactive nitrogen compounds such as nitric and nitrous acid and particulate and organic nitrates.

This chapter includes procedures for installation, operation, quality control, maintenance, and data acquisition. While specific procedural steps have been included for the TAPI 200EU and T200U, this chapter is intended to be used with the manufacturer's model-specific operation manuals and Chapters 2 and 3, which describe general procedures for gaseous pollutant monitoring and the calibration system.

6.2. Principles of operation

The NO_X and NO_Y analyzers described here detect the chemiluminescence that occurs when NO reacts with O_3. As ambient air is drawn through the analyzer's reaction cell, the analyzer introduces O_3 to the reaction cell. The NO in the ambient air reacts with the O_3 to form NO_2 and O_2, with a portion of the newly formed NO_2 retaining excess energy in an excited energy state (denoted as NO_2^*). The NO_2^* quickly releases its excess energy in the form of a quantum of light emitting between 600 nm and 3000 nm, with a peak near 1200 nm. A photo multiplier tube (PMT), with an optical filter designed to minimize interference from other light sources, detects the light emitted. The analyzer uses a linear relationship between the quantities of NO and light emitted from the reaction to calculate the concentration of NO entering the reaction cell.

Because the analyzers only measure NO, a portion of the sampled air is periodically passed through a molybdenum converter at approximately 315°C. At this temperature, any NO_2 present in the air sample reacts with the molybdenum and forms NO and molybdenum oxides. The sample is then passed to the reaction cell, where the concentration of NO detected by the PMT represents the sum of NO + NO_2 concentrations for the NO_X analyzers. The analyzer calculates the NO_2 concentration in the sample by subtracting the NO concentration measured when the sample bypasses the molybdenum converter from the NO_X concentration ($NO_2 = NO_X – NO$). The NO_Y analyzer differs from the NO_X analyzer in that it places the molybdenum converter very close to the probe inlet. The very reactive NO_z compounds, which otherwise might have been lost during transit through the tubing, are converted immediately and included.

The PMT temperature is maintained near 5°C to minimize signal noise. The remaining noise is determined while the analyzer diverts sample flow away from the reaction cell for 8 seconds per minute. During this period only O_3 is present in the reaction cell and, while it is completely dark with no chemiluminescence, the PMT output is recorded. These PMT dark period auto zero (AZERO) values are averaged and subtracted from raw PMT output during NO and NO_X measurement phases. Both analyzers also use a gold-plated reaction cell with opaque tubing leading into it and external pumps capable of maintaining reaction cell (RCEL) pressures at or below 4 in-Hg-A to reduce interferences and increase sensitivity at low levels as compared to the base 200E and T200 models.

6.3. Equipment and supplies

In addition to the standard equipment in Table 3-1 operators should purchase a pump rebuild kit or contact the Calibration and Repair Laboratory to obtain a rebuilt pump or pump rebuild kit.

6.4. Installation

In addition to the siting criteria described in Section 2.2.1, the NO_X/NO_Y sample probe must be located according to the monitoring site's spatial scale, as summarized in Table 6-1. Operators should refer to 40 CFR Part 58 Appendices D and E for extensive siting criteria on NO_X/NO_Y monitoring. To the extent practical, the NO_Y external molybdenum converter should be mounted approximately 10 m above ground and as close as possible to the point of sampling.

Table 6-13: Summary of $NO/NO_2/NO_X/NO_Y$ siting criteria

Parameter	Spatial Scale	Siting Requirement
Inlet height	Neighborhood, urban, or regional scale (e.g. NCore sites)	2 - 15 m above ground level
	Near-road microscale in downtown areas or urban street canyons	2 - 7 m above ground level
Distance from roadway to sampling Inlet	Neighborhood, urban, or regional scale (e.g. NCore sites)	Based on average daily traffic count – refer to 40 CFR 58, Appendix E, Table E-1.
	Near-road microscale	As near as possible to and ≤ 50 m from the edge of the nearest traffic lane.

6.5. Quality control and maintenance

6.5.1. Quality control checks

In addition to the procedures described in Section 2.3, operators must be particularly attentive to scheduling QC checks and maintenance to minimize data loss. The recommended action levels are illustrated in Figure 6-1. For QC check points from 5-10 ppb, the acceptance criteria is ± 1.51 ppb.

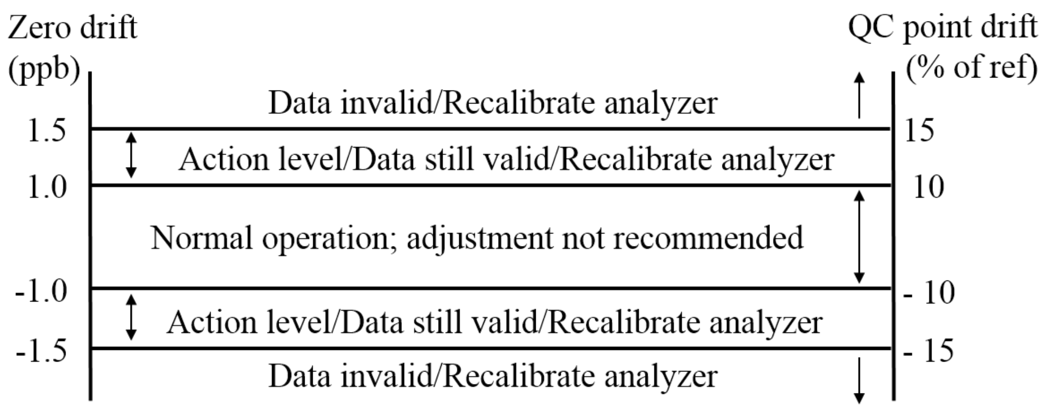

Figure 6-26: NO/NO_2/NO_X/NO_Y action levels

6.5.2. Maintenance

The maintenance schedule for the Teledyne API 200EU and T200U analyzers is summarized in Table 6-2 below. The maintenance schedule for the T200U NO_Y is described in the TAPI T200U NO_Y addendum to the TAPI T200U manual. Other analyzers should be maintained according to their SOPs and associated requirements in their federal reference or equivalent method (FRM/FEM) designations. Additional questions regarding maintenance schedules should be directed to the Calibration and Repair Laboratory or Quality Assurance personnel.

Table 6-14: Summary of required NO_X/NO_Y analyzer maintenance

Procedure	Frequency	Section
Analyzer calibration	If analyzer is out of specifications, or every 6 months	6.5.2.1
Change particulate filter	Inspected every 30 days, replaced every 90 days or more frequently when the filter becomes noticeably dirty	6.5.2.2
Converter efficiency check	Upon installation or maintenance, after QC check action limit exceedance, and every 14 days	6.6.1.2, 6.6.1.3
Replace molybdenum converter	Every 3 years or when converter efficiency ≤ 96% or ≥ 104%	6.6.1.2, 6.6.1.3
Verify diagnostic data	Weekly	6.5.2.3
Flow check	Every 6 months	6.5.2.4
Vacuum leak check	Before and after filter change and pneumatic repairs	6.5.2.5
Pressure leak check	Annually or after pneumatic repairs	6.5.2.5
Replace pump diaphragm	Annually or when reaction cell pressure exceeds 4 in-Hg-A at sea level	6.5.2.6

Procedure	Frequency	Section
Replace external pump NO_X exhaust scrubber	Annually or as needed	6.5.2.7
Clean reaction cell window	Annually or as needed	6.5.2.7
Replace reaction cell o-rings & sintered filters	Annually or as needed	6.5.2.7
Replace DFU filters	Annually or as needed	6.5.2.7
Change ozone filter chemical	Annually or as needed	6.5.2.7
PMT sensor hardware calibration	When NO or NO_X slope exceeds 1.0 ± 0.3 after cleaning reaction cell window or after PMT or PMT preamp replacement.	6.5.2.7

6.5.2.1. Analyzer calibration

After a failed QC check, operators must take corrective actions (Section 2.3.5) to determine if the failure was caused by the analyzer or than any other component, such as a pump failure, calibrator system issue, blockage of the sampling probe, or telemetry issue. If the failure is confirmed to be due to the analyzer, the analyzer must be calibrated. The calibration scale for the analyzer can be calculated as the 99^{th} percentile of hourly concentrations at the site over the previous 3 years multiplied by 1.5. If the 99^{th} percentile value is below 100 ppb contact the Calibration and Repair Laboratory to determine an appropriate calibration scale. More specific details and an example are in section 2.3.1.3. Check with the Calibration and Repair Laboratory to verify the calibration scale prior to calibrating the analyzer.

Before the calibration operators must perform an “as found” QC check. If needed, the particulate filter should be replaced after the “as found” QC check and before calibration.

After the calibration the operators must perform a post-calibration verification to verify the linear response of the analyzer (section 2.3.2). See Appendix B for an example of the Linearity Check Form. Contact the Calibration and Repair Laboratory or Quality Assurance Unit to obtain the latest version of an electronically fillable Linearity Check Form.

To calibrate a TAPI NO_X/NO_Y analyzer:

1. Ensure that the pressures of zero air and cylinder gas to the calibrator are 30 psi when total flow from the calibrator is ≤ 10 LPM, and 35 psi for total flows between 10 and 20 LPM.
2. Select TST to display the current NO and NO_X slope and offset and note the pre-calibration values to include in the electronic logbook entry for the visit.
3. Select CAL > CONC > CONV > SET and verify converter efficiency is set to 1.0000.

4. Select CAL > CONC > NO_X and change the concentration displayed to the value of the calibration scale calculated for NO_X as described in Section 2.3.1.3, step 4 or otherwise determined for the site in coordination with the Quality Assurance unit. Select ENTER, then EXIT.
5. Select CAL > CONC > NO and change the concentration displayed to the value entered in the previous step for NO_X. Select ENTER, then EXIT.
6. From the calibrator, generate zero air to the instrument for at least 10 minutes and until analyzer stability is at or below 0.3 ppb.
7. Select CAL > ZERO > ENTER on the analyzer.
8. Generate calibration gas (NO) at the level of the calibration scale for at least 15 minutes and until instrument stability is at or below 0.5 ppb.
9. Select CAL > CONC > NO and change the concentration displayed to the actual concentration (from the current ACTCONC channel 1 minute average in Envidas) of the NO span gas delivered. Select ENTER, then EXIT.
10. Select CAL > CONC > NO_X and change the concentration displayed to the actual concentration (from the current ACTCONC channel 1 minute average in Envidas) of the NO span gas delivered. This should be the same number entered for NO in the previous step. Select ENTER, then EXIT.
11. Select CAL > SPAN > ENTER on the analyzer to complete calibration.
12. Select EXIT to return to the main menu. Select TST to display the current NO and NO_X slope and offset. Note the post-calibration values along with the analyzer and calibrator serial or Ecology equipment tag numbers to include in the electronic logbook entry. If the NO or NO_X slope falls outside 1.0 ± 0.3, contact the Calibration and Repair Laboratory for assistance with evaluating the PMT sensor response.

Note: The ZERO or SPAN buttons may not display during the zero or span calibration if the measured concentration is too different from the expected value. Refer to the manufacturer's operation manual for more information.

6.5.2.2. Change particulate filter

The particulate filter should be inspected every 30 days for signs of plugging or excess dirt. The particulate filter should be changed at least every 90 days or when the color has noticeably changed. Operators should wear gloves and take care not to touch the inside surfaces, including glass window, PTFE or Viton O-rings, or assembly body, as contamination may lower the accuracy of readings.

Note that NOx and NO_Y analyzers use different filters from ozone, SO_2, and CO.

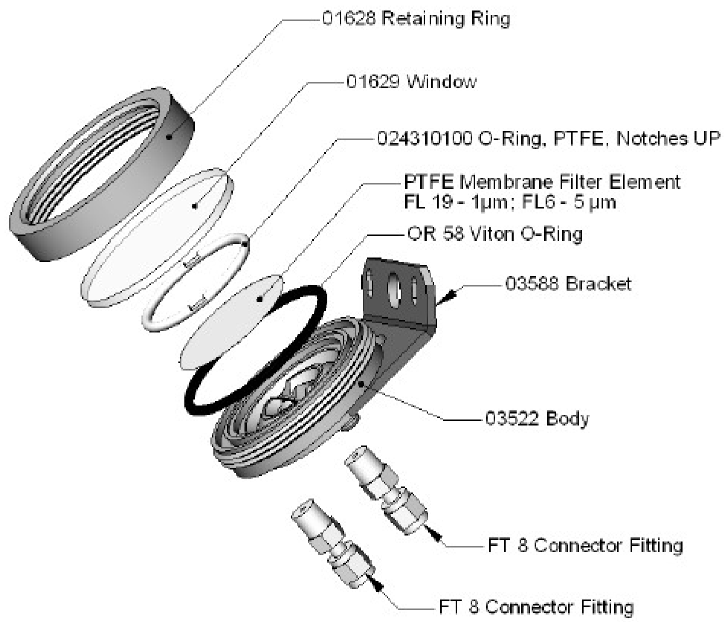

Figure 6-27: Particulate filter assembly (Teledyne API 2016)

1. Check the analyzer flow rate and note the value for comparison with the flow rate after replacing the filter.
2. Perform an as-found vacuum leak check and record the sample flow and pressure.
3. Turn off the analyzer.
4. Open the front panel and unscrew the knurled retaining ring of the filter assembly.
5. Carefully remove the retaining ring, glass window, and PTFE O-ring. Use clean tweezers to remove the filter element.
6. Replace the filter element, centering it in the bottom of the holder. Reinstall the PTFE Oring (notches face up), the glass cover, and the retaining ring in the order shown in Figure 6-2.
7. Hand tighten. Visually inspect the seal between the glass cover and the O-ring to ensure that it is tight. If the retaining ring is not tightened enough, it can result in a leak in the sample flow.
8. Reinstall the filter assembly and restart the analyzer.
9. Verify that the analyzer flow is similar to the value observed before changing the filter. If not, repeat the process above until the flow rate returns to a similar value.
10. Perform an as-left vacuum leak check and record the sample flow and pressure. Verify that the sample flow and pressure is similar to the value observed before changing the filter. If not, repeat the process above until the sample flow and pressure returns to a similar value.
11. Record the maintenance in the electronic logbook.

6.5.2.3. Verify diagnostic data

At a minimum, operators should review the diagnostic data weekly to identify any problems with the analyzer's operation. Table 6-3 below shows the diagnostic parameters available and their interpretation.

Table 6-15: Teledyne API 200EU and T200U diagnostic data (Teledyne API 2010)

Diagnostic Parameter	Expected	Actual	Interpretation & Action
RCEL (pressure)	Constant to within ± 0.5 in-Hg-A	Fluctuating	Pneumatic leaks in instrument & sample system. Check for leaks.
	Constant to within ± 0.5 in-Hg-A	Slowly increasing	Pump performance is degrading. Rebuild pump when pressure is above 4 in-Hg-A.
SAMP (pressure)	Constant within atmospheric changes	Fluctuating	Pneumatic leaks in instrument & sample system. Check for leaks.
	Constant within atmospheric changes	Slowly increasing	Flow path developing restrictions. Replace orifice filters.
	Constant within atmospheric changes	Slowly decreasing	Developing leak in pneumatic system to vacuum (valve failure). Check for leaks.
OZONE FL	Constant to within ± 15 cm^3/min (cc/m)	Slowly decreasing	Flow path developing restrictions. Replace orifice filters.
AZERO	Constant within ± 20 MV of check-out valve	Significantly increasing	Developing AZERO valve failure. Replace valve.
	Constant within ± 20 MV of check-out valve	Significantly increasing	PMT cooler failure. Check cooler, circuit, and power supplies.
	Constant within ± 20 MV of check-out valve	Significantly increasing	O_3 air filter cartridge is exhausted. Change chemical.
NO_2 (Concentration)	Constant for constant concentrations	Slowly decreasing signal for same concentration	Converter efficiency may be degrading. Check converter efficiency and replace converter components if needed.
	Constant response from day to day	Decreasing over time	Change in instrument response. Low level (hardware) calibrate the PMT sensor.
	Constant response from day to day	Heavily fluctuating from day to day	Ambient changes in moisture may be affecting the performance. Check the zero air source.

Diagnostic Parameter	Expected	Actual	Interpretation & Action
NO (Concentration)	Constant for constant concentrations	Decreasing over time	Drift of instrument response. Clean RCEL window. Check for flow leaks or irregularities.

6.5.2.4. Flow check

In addition to reviewing the analyzer's reported flow via diagnostics, operators should verify the analyzer's flow every 6 months using a NIST-traceable flow meter certified to 1000 sccm. NO_Y analyzers have two sample ports, one for NO and one for NO_Y. Repeat this for both, they have slightly different flow rates.

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a flow meter to the sample inlet port on the rear panel. Ensure that the inlet to the flow meter is at atmospheric pressure.
3. The sample flow measured with the external flow meter should be 1000 sccm ± 10%.
4. If needed, adjust the internal flow sensor according to the procedures in the instrument manual.

Low flows indicate that the pneumatic pathways may be blocked. Refer to the manufacturer's manual or contact the Calibration and Repair Laboratory for troubleshooting assistance.

6.5.2.5. Leak check

Leaks are the most common cause of analyzer malfunction. This section presents a simple vacuum leak check, and a more thorough pressure leak check procedure.

6.5.2.6. Vacuum leak check

This method is easy and fast. It detects but does not locate most leaks. It also verifies that the sample pump is in good condition.

1. Turn the analyzer ON and allow enough time for flows to stabilize.
2. Cap the sample inlet port.
3. After several minutes, when the pressure has stabilized, note the SAMP (sample pressure) and RCEL (reaction cell pressure).
   - If both pressure readings are within 10% and <10 in-Hg-A, the analyzer is free of large leaks and the pump is acceptable.
   - If either pressure is near or ≥10 in-Hg-A, the pump diaphragm should be replaced.
   - If the readings exceed 10% difference, there is a leak that requires corrective action, and a detailed pressure leak check should be performed to identify the location of the leak.

6.5.2.7. Pressure leak check

Note: Do not exceed 15 psi when performing a pressure leak check

To perform a pressure leak check, operators must pressurize the instrument to 10 psi and hold the pressure for about 10 minutes. This can be achieved with a hand-held pressure pump with pressure gauge or with a tank of pressured gas (ultrapure air or nitrogen) with a two-stage regulator adjusted to < 15 psi, a shutoff valve and a pressure gauge.

1. Turn off the analyzer and remove the instrument cover.
2. Install the pressure source on the SAMPLE inlet on the rear panel of the instrument.
3. Disconnect the pump tubing on the outside rear panel and cap the pump port. Cap all zero/span ports.
4. Pressurize the instrument to approximately 10 psi, allowing enough time for full pressurization through the critical orifice. Do not exceed 15 psi.
5. Turn off pressure to the instrument and allow to sit for 10 minutes. If the pressure gauge measures a loss exceeding 0.8 psi during that time, the pneumatics have a leak.
6. If the leak check fails, use a liquid leak detector (e.g. Snoop®) to search for leaks. Pressurize the instrument to 10 psi and check each tube connection (fittings, hose clamps) with solution and look for bubbles. Wipe off all leak detection fluid before reconnecting sample lines to ensure that fluid is not sucked into the instrument.
7. Reconnect the sample and exhaust lines and replace the instrument cover.

6.5.2.8. Replace pump diaphragm

Low flow or no flow can be a sign of worn-out seals in the pump. Pumps must be rebuilt using the Teledyne API pump rebuild kit annually or more frequently as the RCEL pressure values approach 4 in-Hg-A. Detailed instructions are included with the rebuild kit. Always perform flow and leak checks after the pump is rebuilt.

6.5.2.9. Annual maintenance and repair

Many of the required annual maintenance procedures are best performed in a laboratory environment; please contact the Calibration and Repair Laboratory to obtain parts and supplies and to coordinate annual maintenance items. Follow procedures in the applicable analyzer manuals for the following activities:

- replacing the external pump NO_X exhaust scrubber
- cleaning the reaction cell window
- replacing reaction cell o-rings and sintered filters
- replacing DFU filters
- changing the ozone filter chemical
- PMT sensor hardware calibration

There may be multiple manuals and applicable addenda for a particular analyzer. For example, the TAPI T200U NO_Y requires familiarity with the T200 manual and T200U and T200U NO_Y addenda and the 200EU requires the 200E manual and the 200EU addendum. Most procedures are described in the base version of the manual but requirements and parts specific to the high sensitivity models are described in the addenda, like the requirement for pumps to maintain less than 4 in-Hg-A in the reaction cell. Reading only the procedures in the 200E manual, an operator might mistakenly believe the pump doesn't need to be rebuilt until the vacuum reaches 10 in-Hg-A.

Some tasks may need to be performed more often than annually due to site-specific conditions or in response to other maintenance. Also, some items in Table 6-2 may require additional evaluation before performing recommended corrective actions. For example, if it has been several months since annual maintenance, cleaning the reaction cell may correct a slope exceeding specifications and a PMT hardware calibration may not be necessary or advised.

Consult with the Calibration and Repair Laboratory for troubleshooting assistance.

6.6. Data collection and storage

6.6.1. Envidas channel configuration

The correct configurations for $NO/NO_2/NO_X$ concentration channels are shown in Figure 6-3 through Figure 6-5. Three data channels must be configured to record NO, NO_2 and NO_X concentrations in ppb for NAAQS compliance evaluation, to support modeling and other applications and for display on Ecology's public website. For the NO_Y analyzer these channels are NO, NO_Y and DIF, where DIF is the difference measurement between NO_Y and NO.

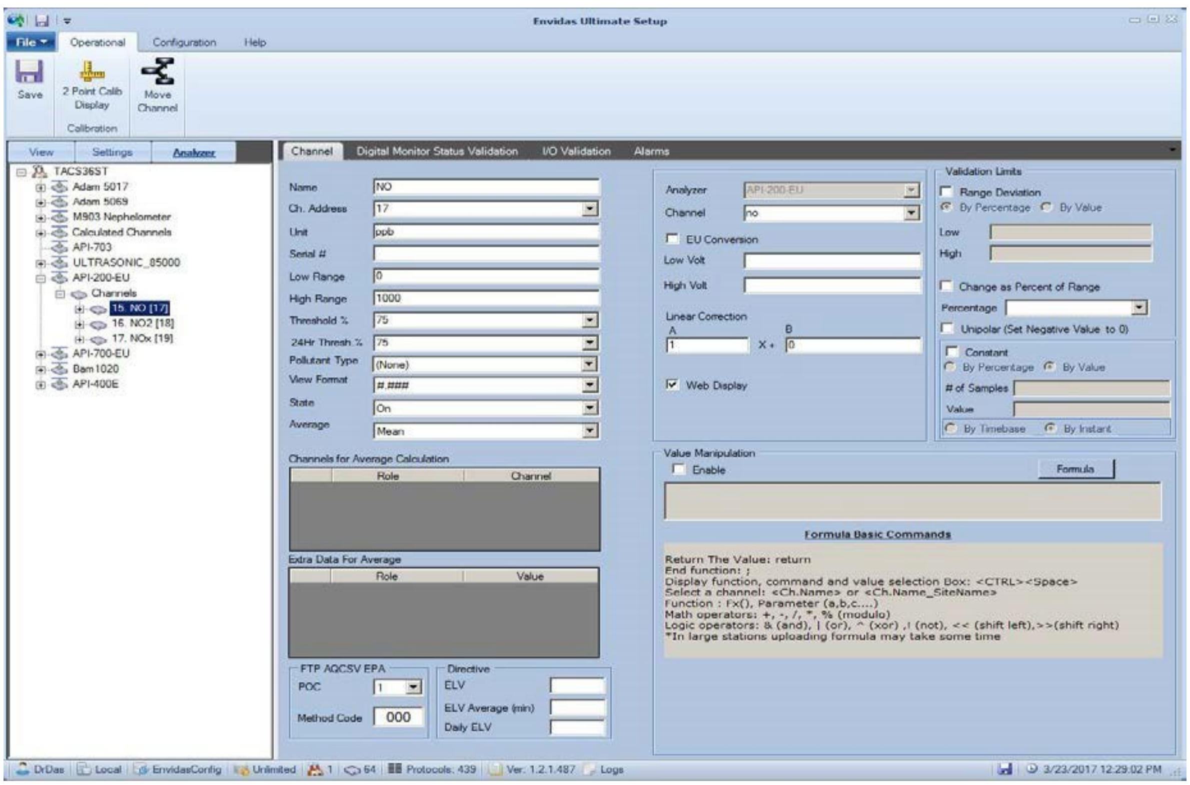

Figure 6-28: NO channel configuration

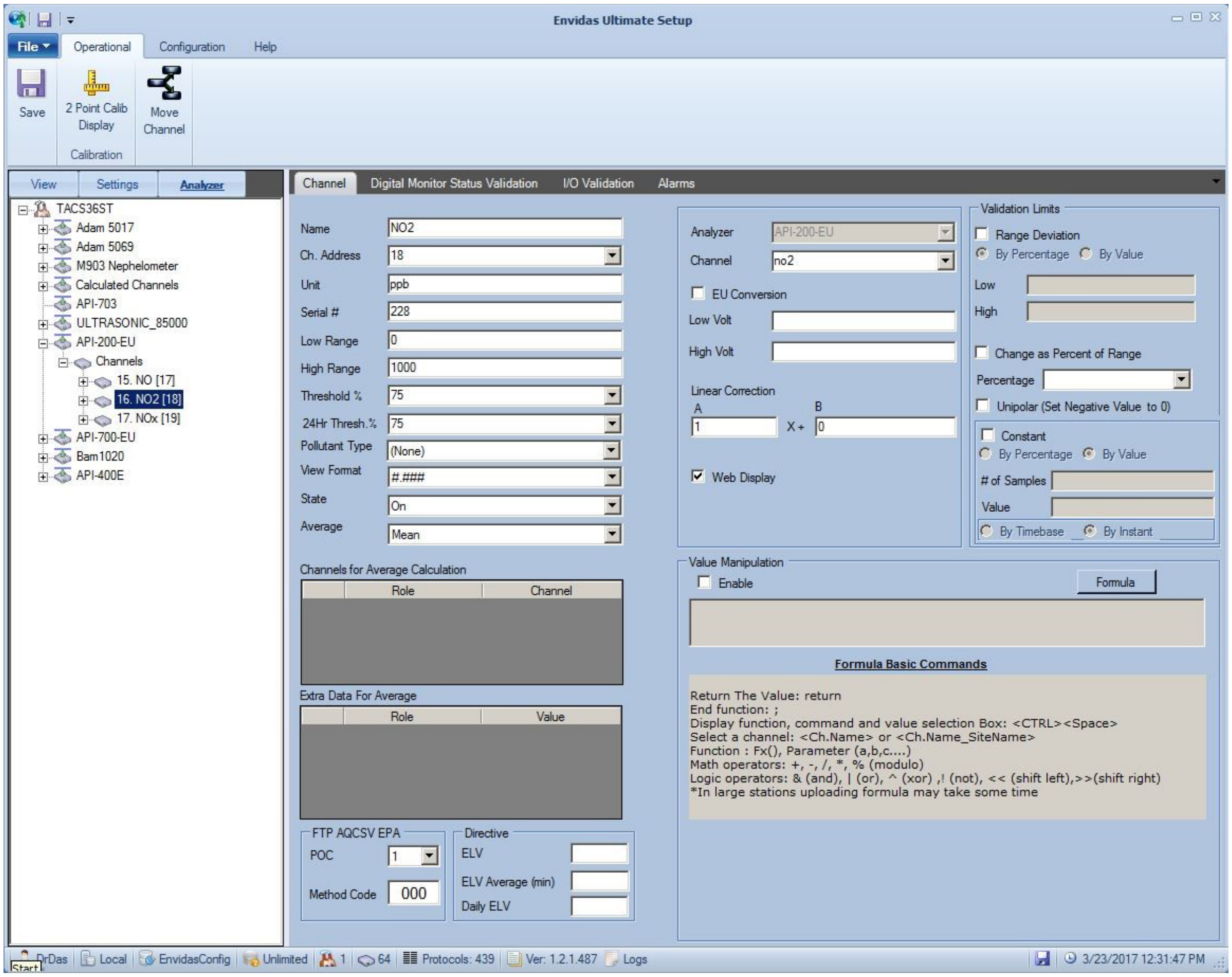

Figure 6-29: NO_2 channel configuration

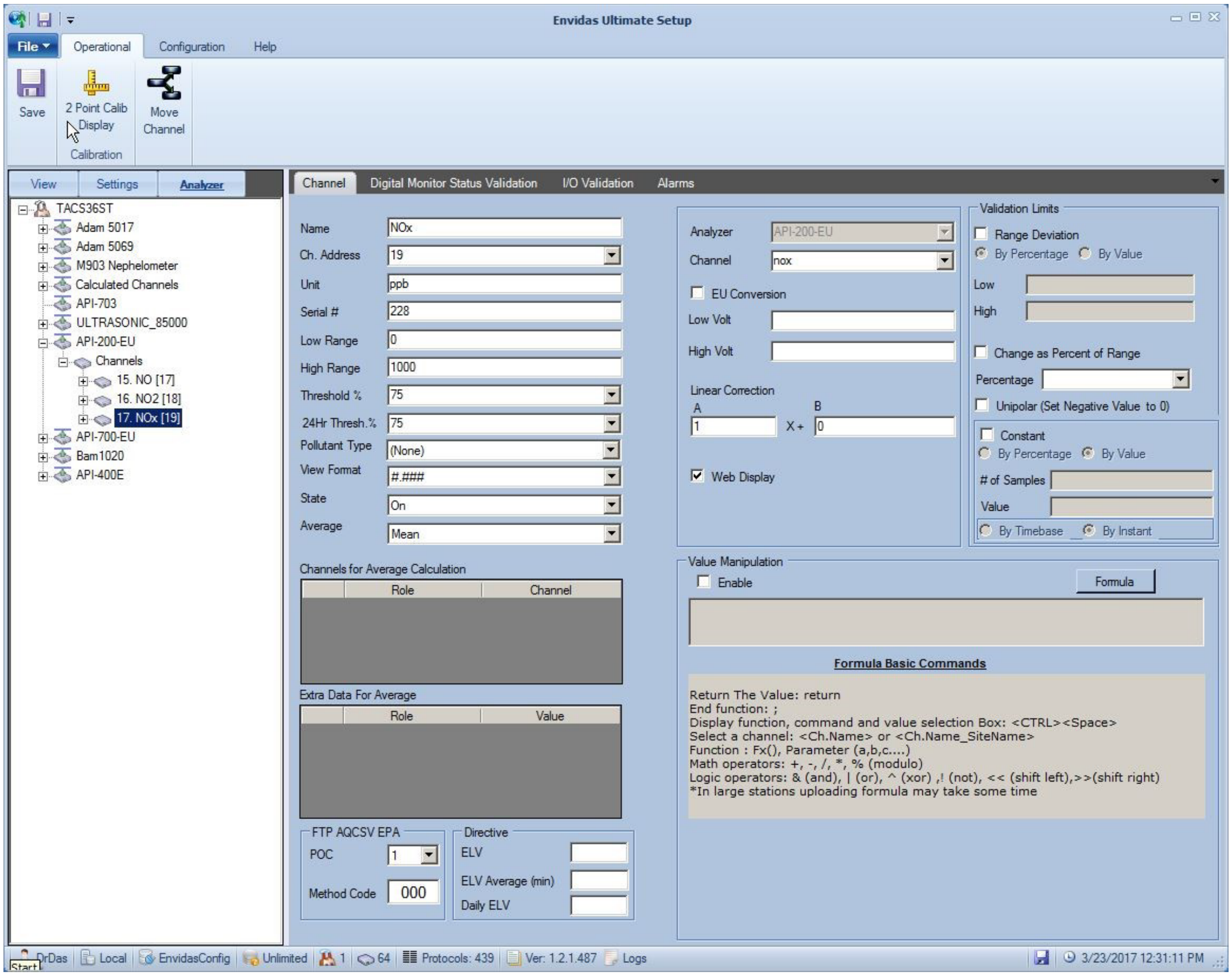

Figure 6-30: NO_X channel configuration

There are two separate QC check sequences run for $NO/NO_X/NO_Y$ chemiluminescence instruments. The first is a QC check for the $NO/NO_X(NO_Y)$ channels, and the second is a QC check for the NO_2 (DIF) channel and converter efficiency. The $NO/NO_X(NO_Y)$ QC check is a dilution calibration where NO gas is used to QC the NO and $NO_X(NO_Y)$ channels. The NO_2 QC check uses GPT to generate different concentrations of NO_2 through the reaction of NO and O_3.

6.6.1.1. $NO/NO_X(NO_Y)$ QC check sequence

The configuration for a multi-point QC check for NO and NO_X set to run every Tuesday and Saturday is shown in Figure 6-6 through Figure 6-9. The QC sequence is run simultaneously for both NO and NO_X. For span points, the phase should last a minimum of 20 minutes, and the reference value should be a 2-minute average of the ACTCONC channel that does not include the last minute of the phase (Figure 6-9).

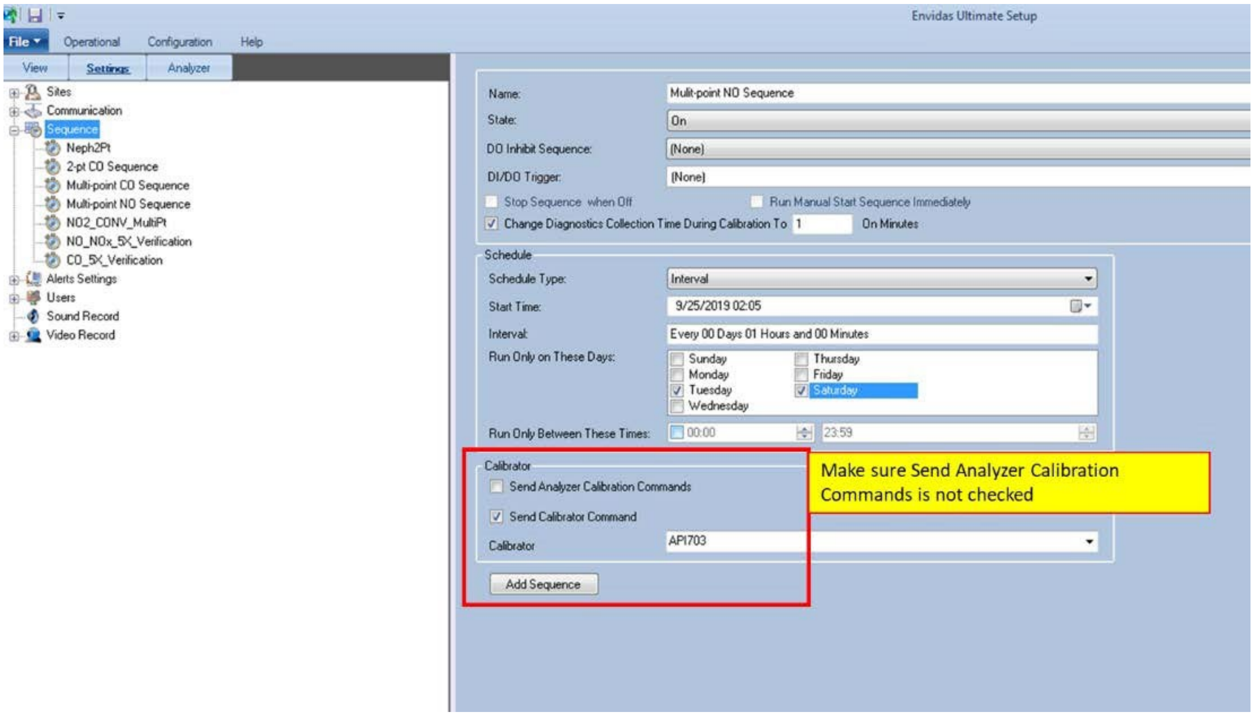

Figure 6-31: NO/NO$_X$ QC sequence properties

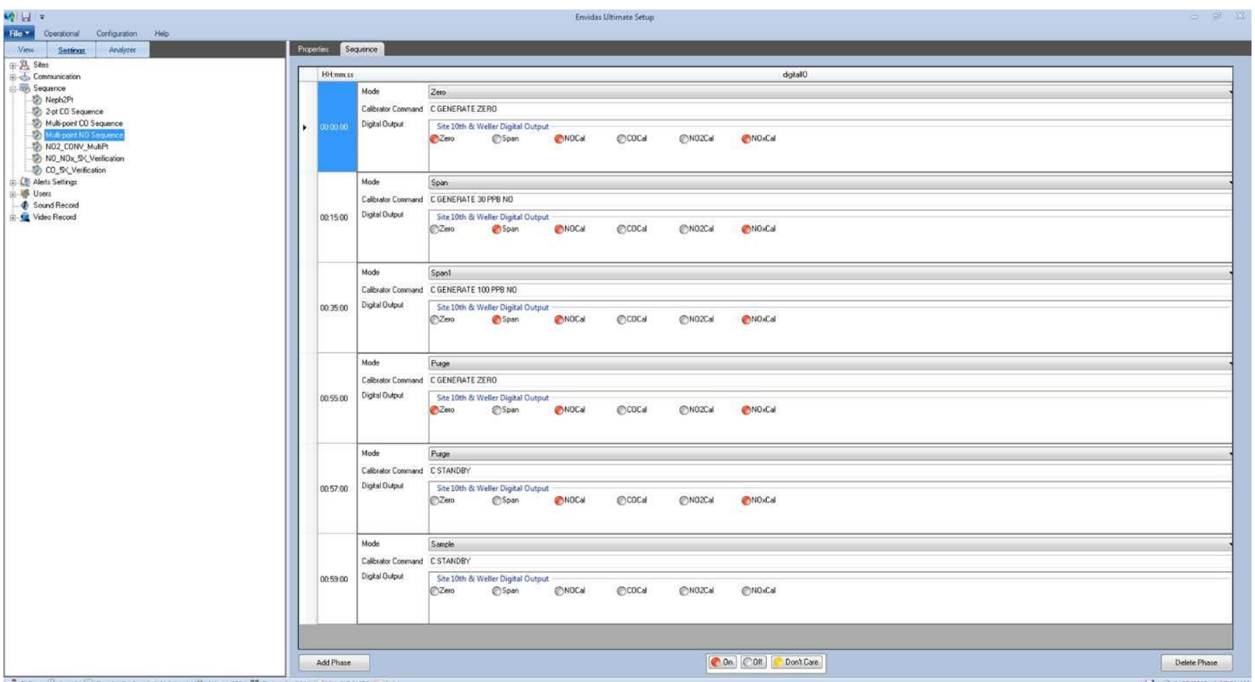

Figure 6-32: NO/NO$_X$ QC sequence configuration

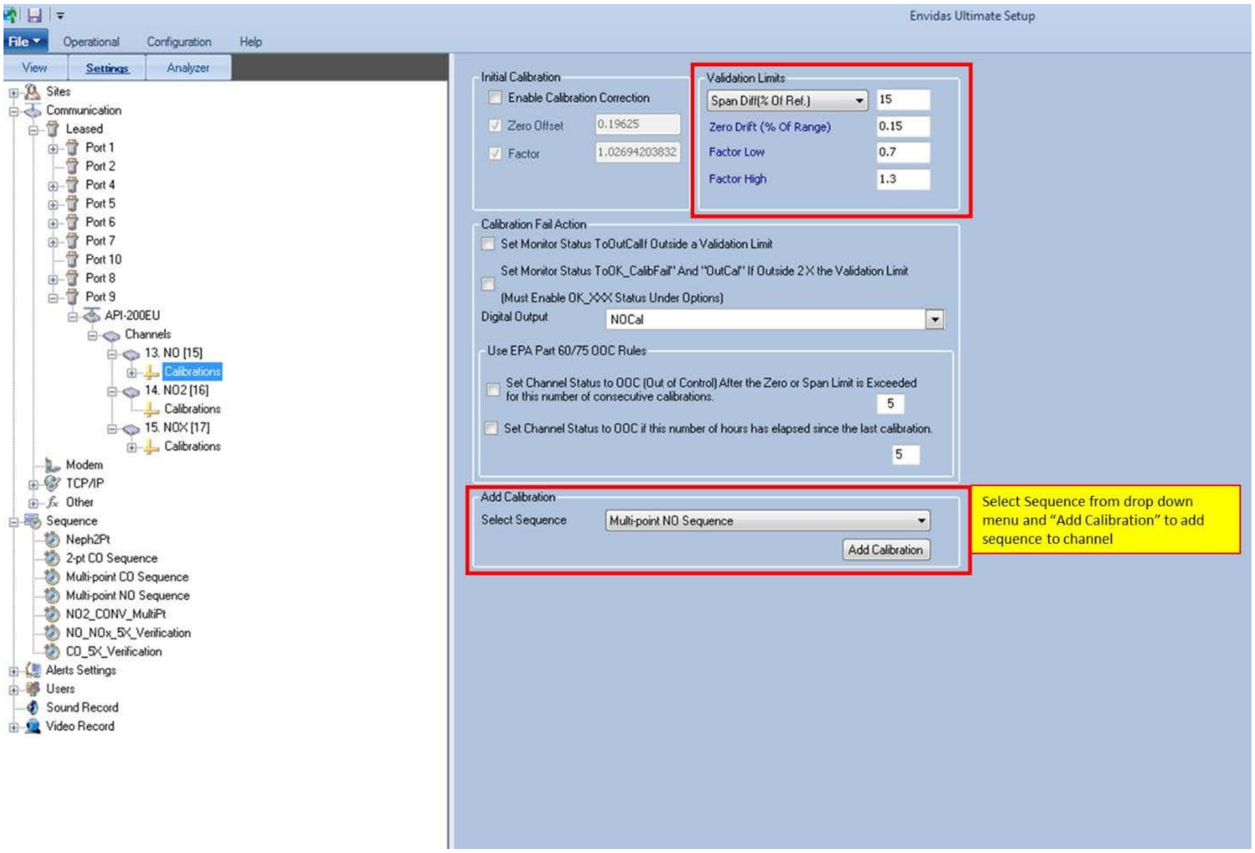

Figure 6-33: NO/NO$_X$ QC validation limits configuration

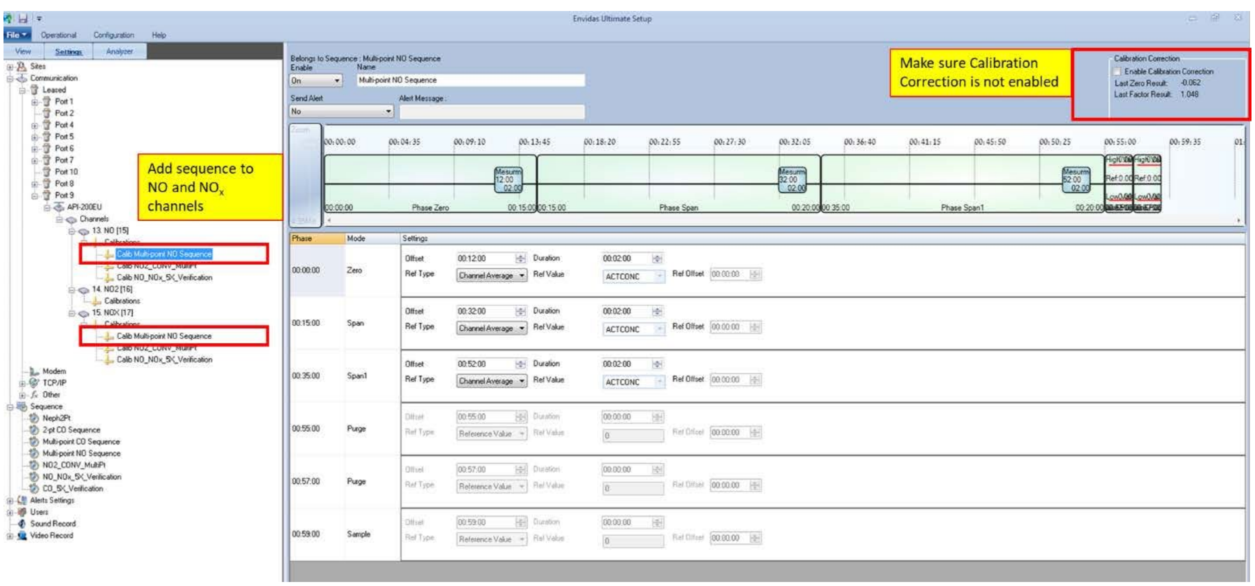

Figure 6-34: NO/NO$_X$ QC configuration of phases and reference values

6.6.1.2. NO_2 QC check sequence (converter efficiency check)

The configuration for a multi-point NO_2 converter efficiency QC check set to run once a week is shown in Figure 6-10 through Figure 6-16. This QC check verifies the efficiency of the molybdenum converter, which converts NO_2 to NO. The structure of the sequence is to run a Zero first, then GPT Zero (GPTZ) at

100 ppb, followed by two Gas Phase Titration (GPT) phases generating 40 and 80 ppb of NO_2, respectively. During GPTZ, NO gas is generated in the same manner as a GPT calibration, but the O_3 generator lamp is un-energized, thus producing no O_3. The GPTZ phase is used for obtaining the baseline NO and NO_X readings. The GPTZ readings are referred to as $[NO]_{original}$ and $[NO_X]_{original}$. The GPT phases subsequent to the GPTZ phase generate 40 and 80 ppb of O_3, which generate 40 and 80 ppb NO_2. The GPTZ and GPT phases must have the same flowrate and NO concentration. During the GPT phase the NO and NO_X readings are referred to as $[NO]_{remaining}$ and $[NO_X]_{remaining}$. The GPTZ phases should last a minimum of 15 minutes and the GPT phases should last a minimum of 25 minutes. A time-series of NO, NO_X and NO_2 with descriptions of each phase is shown in Figure 6-17. GPTZ and GPT phases must be programmed into the site calibrator following procedures in this SOP and analyzer manual. The GPT and GPTZ calibrator sequences are initiated by Envidas using the EXECSEQ command in the Envidas QC sequence (Figure 6-11). More detailed information on GPT can be found in Section 3.2.1.1 and in the dilution calibrator manual.

This calibration sequence has to be run simultaneously for the NO and NO_X channels, and the ACTDILFLOW, ACTCALFLOW, and O3GENFLOW channels of the dilution calibrator. For each channel the reference value should be a 1-minute average of the that channel as seen in Figure 6-10 through Figure 6-16. The output of all of these channels is used to calculate the NO_2 channel and converter efficiency using equations 6-1 through 6-3. Appendix A3 shows an example of the NO_2 converter efficiency QC excel worksheet. This must be filled out when an NO_2 QC check sequence is run. For more detailed information on how to fill out the form properly, contact the Calibration and Repair Laboratory.

Equation 6-3:

$$NO_{2\,out} = [NO]_{original} - [NO]_{remaining} + [NO_2]_{impurity}$$

Where: $[NO_2]_{impurity} = [NO_2]_{actual} - [NO]_{actual}$ during the GPTZ phase. $[NO]_{actual}$ and $[NO_2]_{actual}$ are calculated from the dilution calibration flowrates ACTDILFLOW, ACTCALFLOW, and O3GENFLOW, and the NO and NO_X cylinder concentrations.

Equation 6-4:

$$NO_{2\,conv} = [NO_2]_{out} - [NO_X]_{original} + [NO_X]_{remaining}$$

Equation 6-5:

$$Converter\ Efficiency\ (\%) = \frac{NO_{2\,conv}}{NO_{2\,out}} * 100$$

Note: A GPTPS phase does not need to be run before every sequence. The NO_2 Actual concentrations are calculated as $[NO]_{original}$-$[NO]_{remaining}$, and therefore are not reliant on the ActO3 matching the Target O_3. To ensure consistency, if the NO_2 Actual is greater than 10 ppb from the target NO_2 in the GPT sequence, manually run a GPTPS using the same concentrations and flowrates.

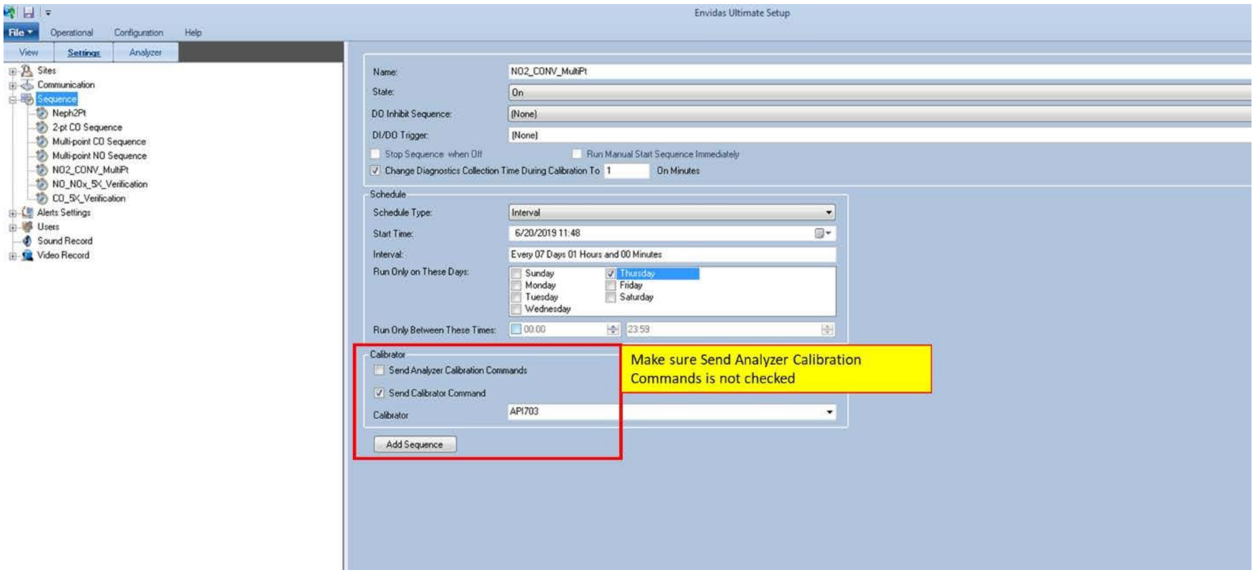

Figure 6-35: NO_2 converter efficiency QC sequence properties

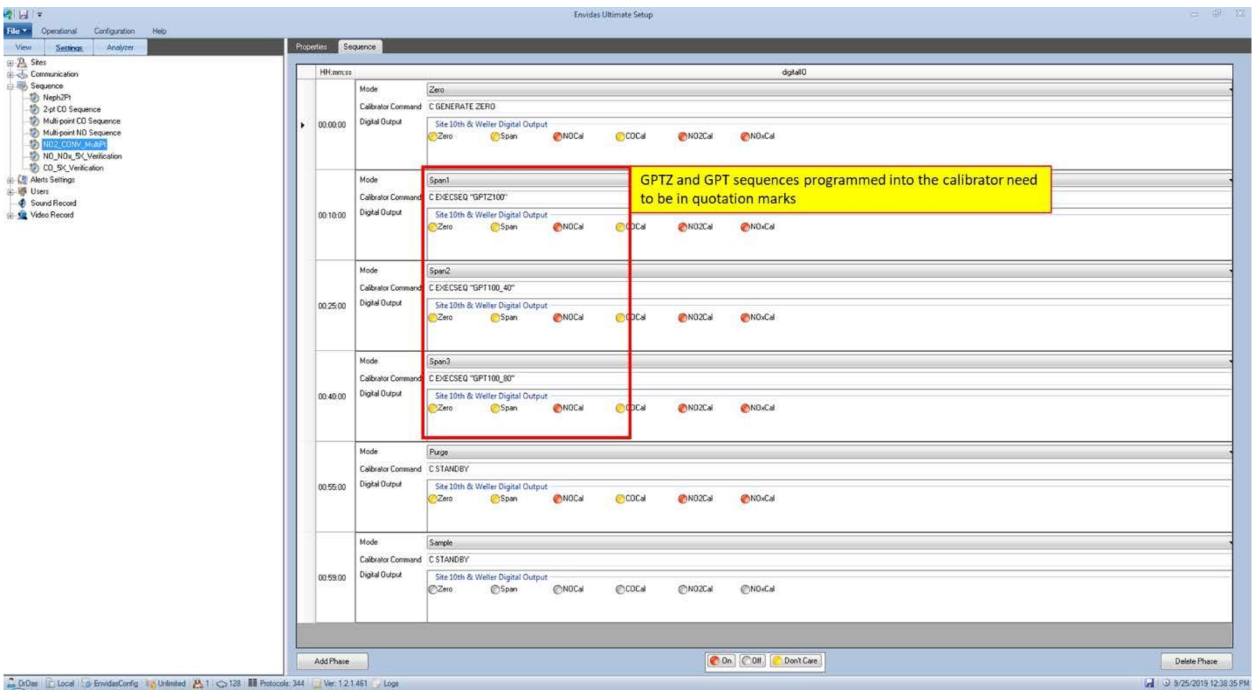

Figure 6-36: NO_2 converter efficiency QC sequence configuration

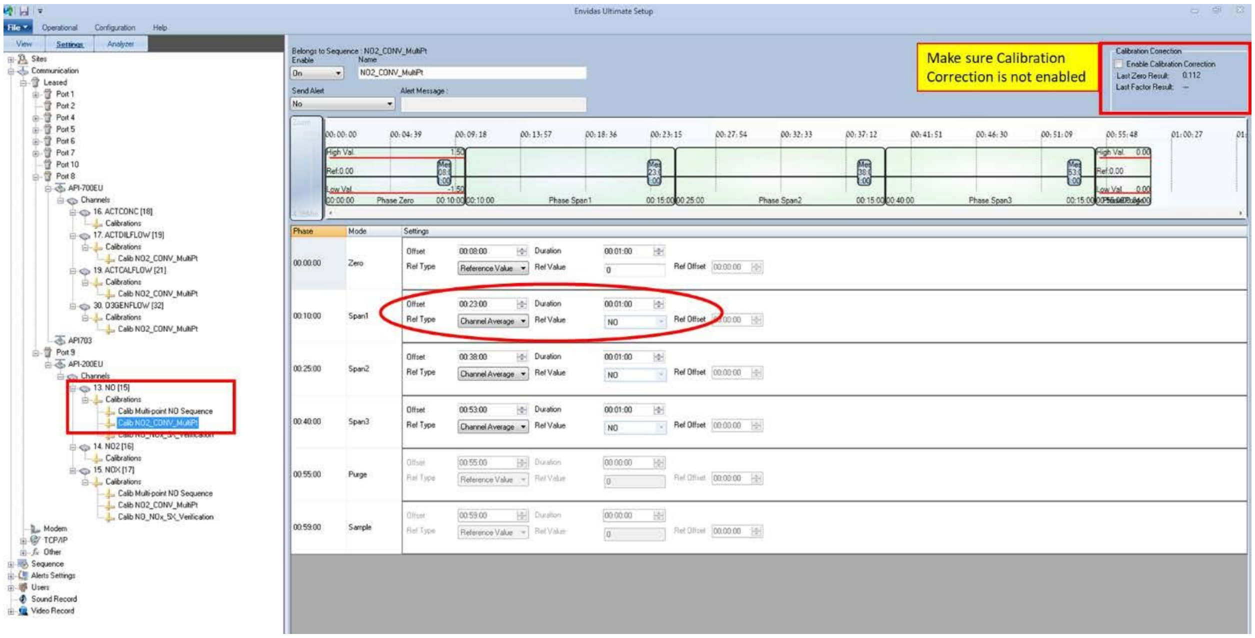

Figure 6-37: NO_2 converter efficiency QC configuration of phases & reference values for NO channel

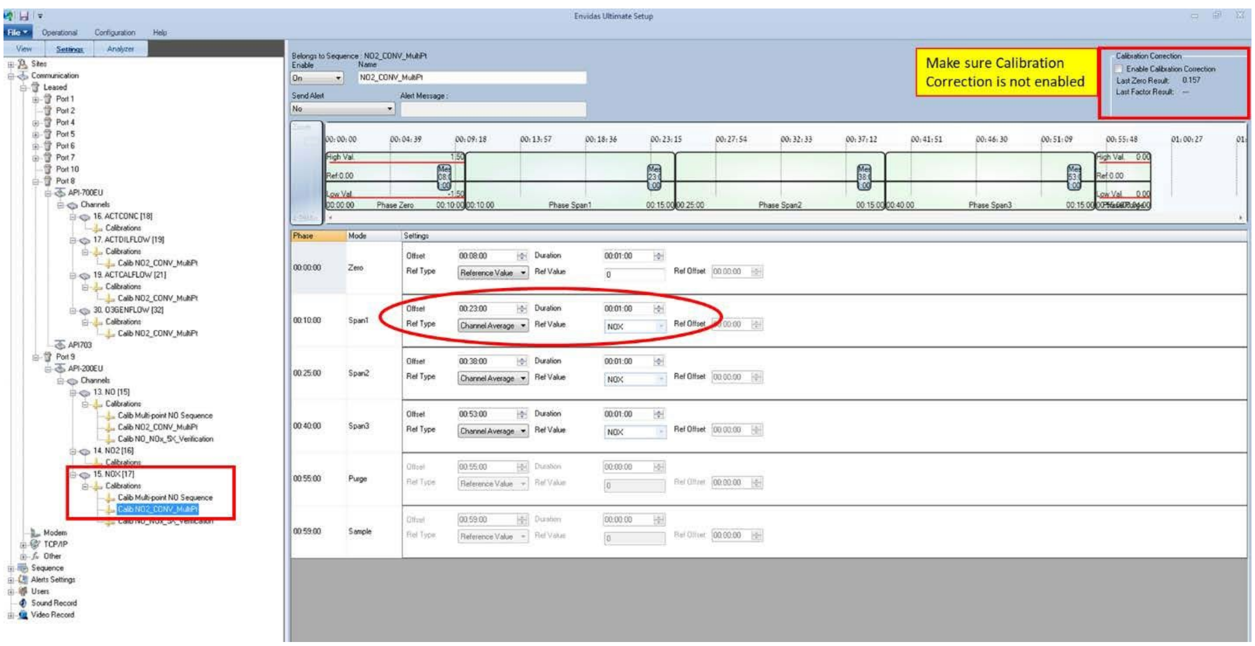

Figure 6-38: NO_2 converter efficiency QC configuration of phases & reference values for NO_X channel

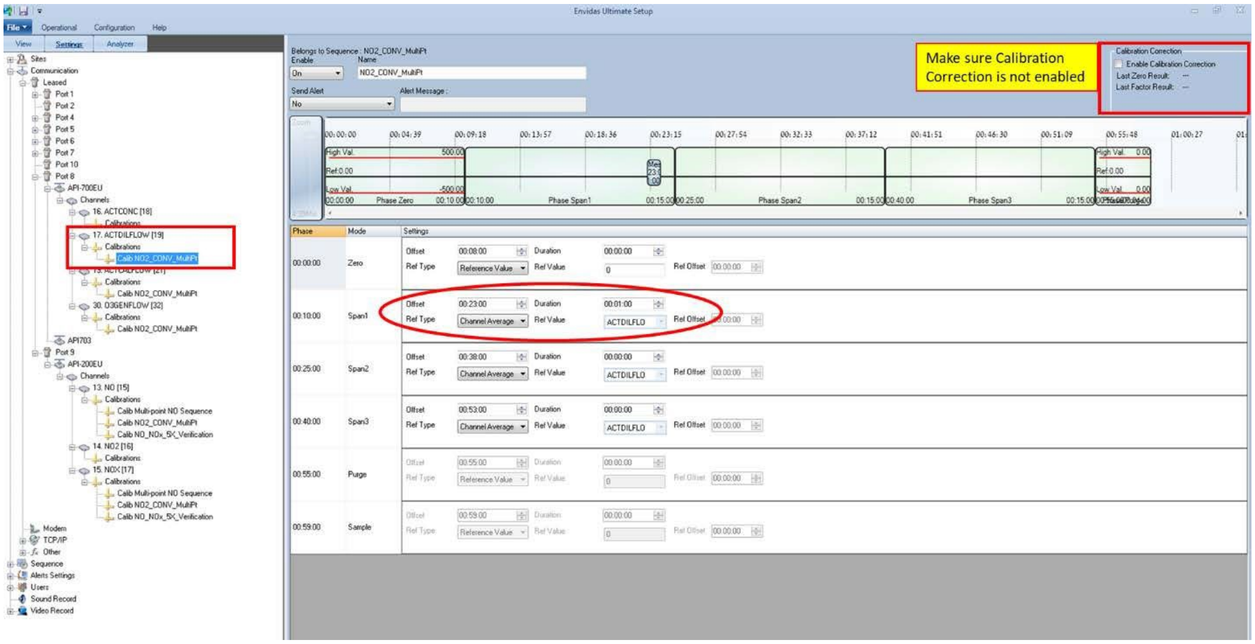

Figure 6-39: NO_2 converter efficiency QC configuration of phases and reference values for the ACTDILFLOW channel

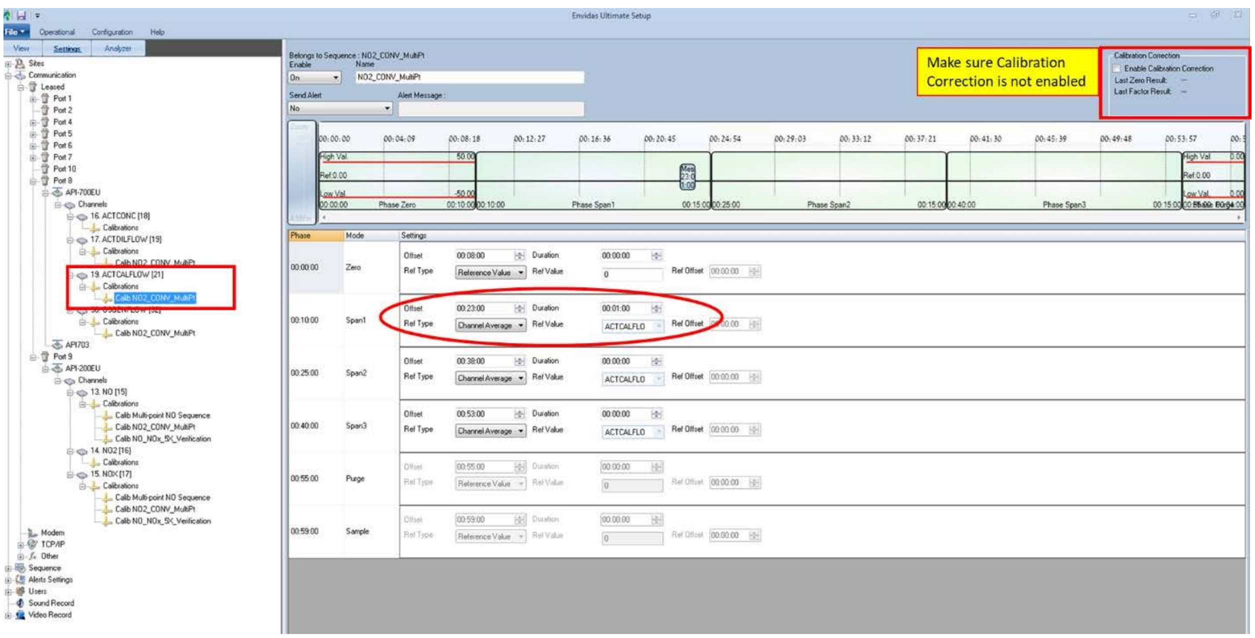

Figure 6-40: NO_2 converter efficiency QC configuration of phases and reference values for the ACT CAL Flow channel

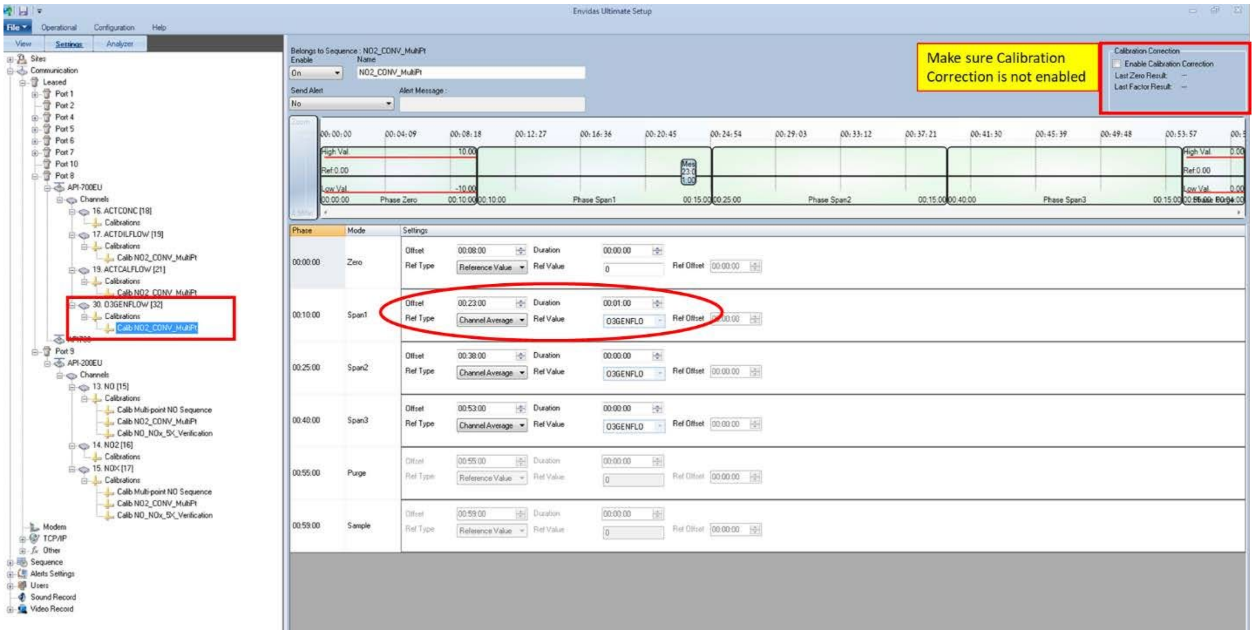

Figure 6-41: NO$_2$ converter efficiency QC configuration of phases and reference values for the O$_3$ gen flow channel

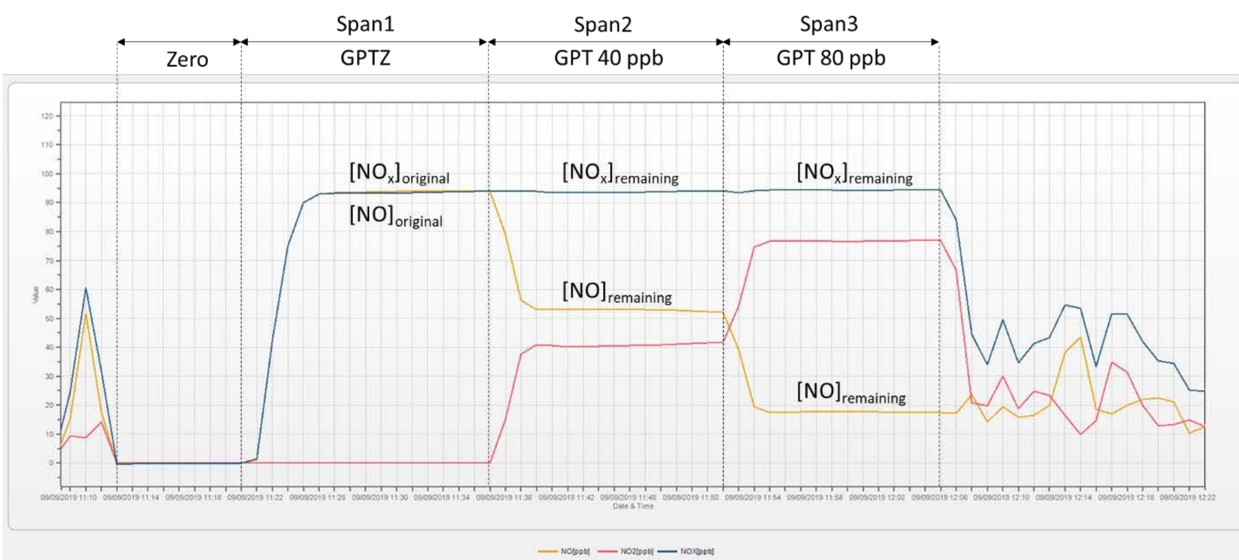

Figure 6-42: Time series of NO, NO$_X$, and NO$_2$ during a NO$_2$ converter efficiency QC using GPTZ and GPT

6.6.1.3. NO_Y converter efficiency check

The NO_Y converter efficiency can be checked using direct dilution of Isopropyl Nitrate (IPN) or N-Propyl Nitrate (NPN). IPN and NPN are interchangeable for the remainder of this section. The configuration for a NO_Y converter efficiency QC check using IPN is shown in Figure 6-18 through Figure 6-22. The IPN/NPN span point phase should last a minimum of 60 minutes as the concentration can take a long time to equilibrate. The calibration sequence must be run simultaneously on both the [NO] and [NO_Y] channels. The reference value for the [NO] channel should be a 2-minute average of the NO channel, and the reference value for the [NO_Y] channels should be a 2-minute average of the ACTCONC channel as seen in Figure 6-20 and Figure 6-21.

The $[NO]_{remaining}$ and $[NO_Y]_{remaining}$ during IPN/NPN phase of the QC check are used to converter efficiency offline using the NO_Y converter efficiency QC form found in Appendix A4. Contact the Calibration and Repair Laboratory or Quality Assurance Unit to obtain the latest version of a QC form.

Note: The GPT sequence for NO_2 converter efficiency (Section 6.6.1.2) can also be used to check NO_Y converter efficiency.

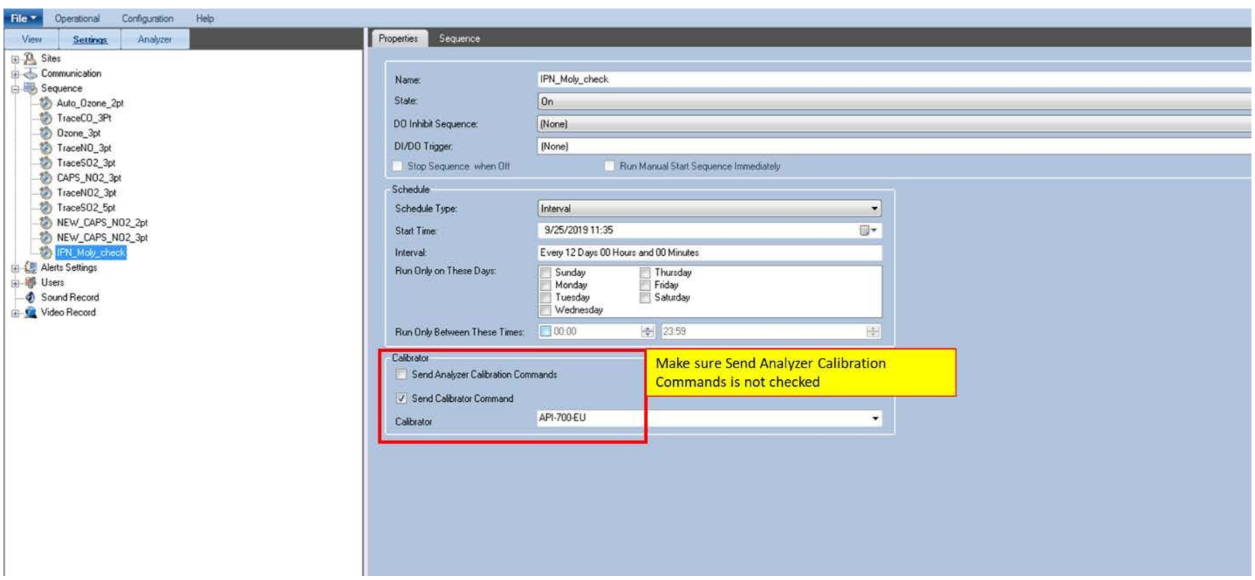

Figure 6-43: NO_Y converter efficiency QC sequence properties

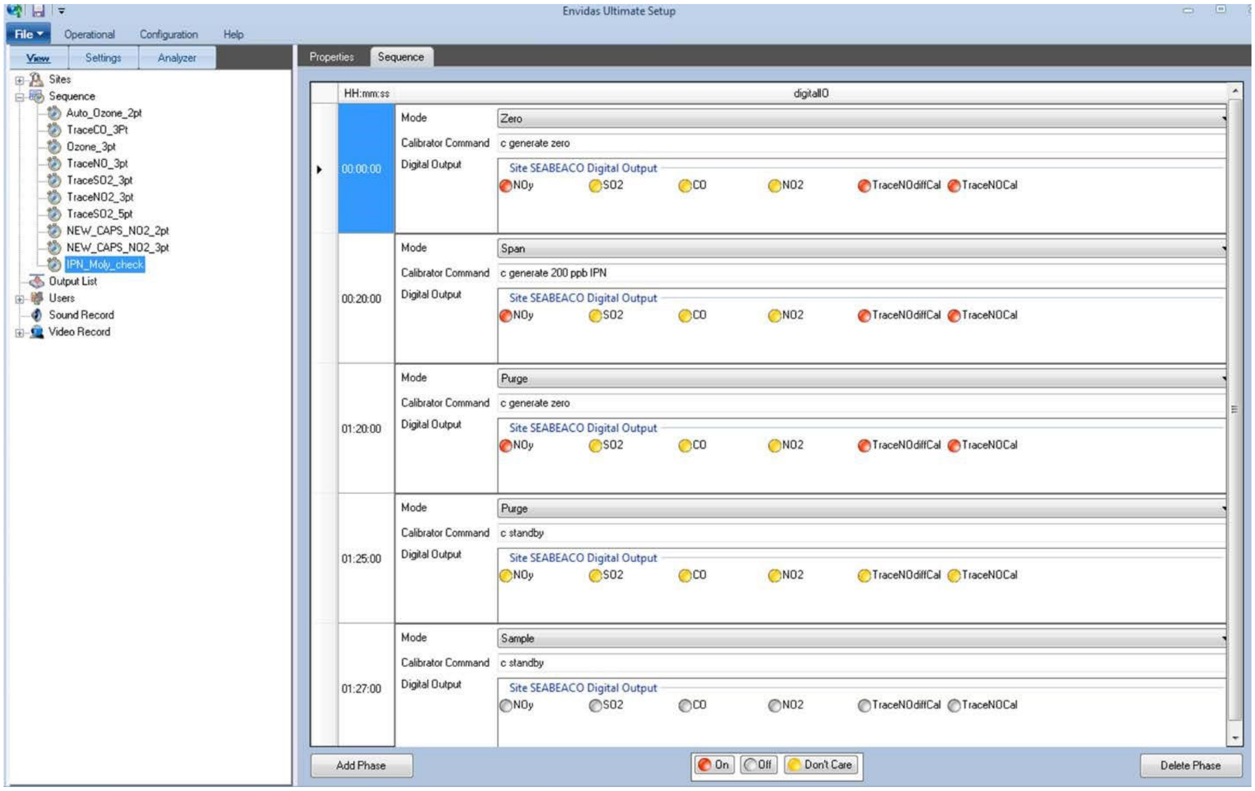

Figure 6-44: NO_Y converter efficiency QC sequence configuration

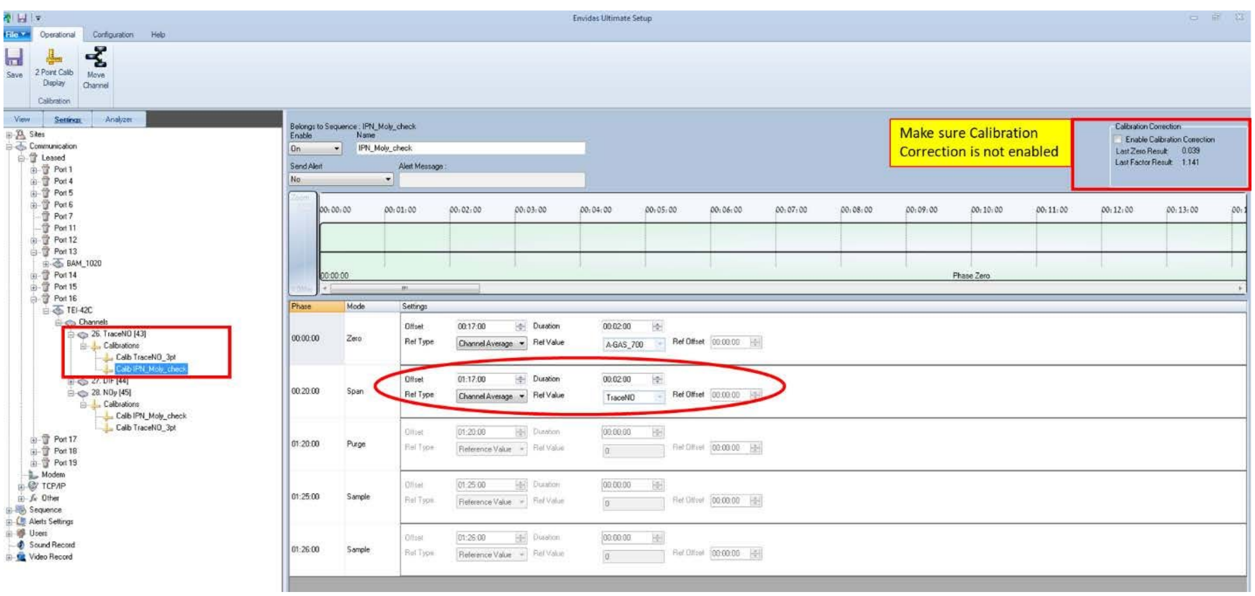

Figure 6-45: NO_Y converter efficiency QC configuration of phases and reference values for the NO channel

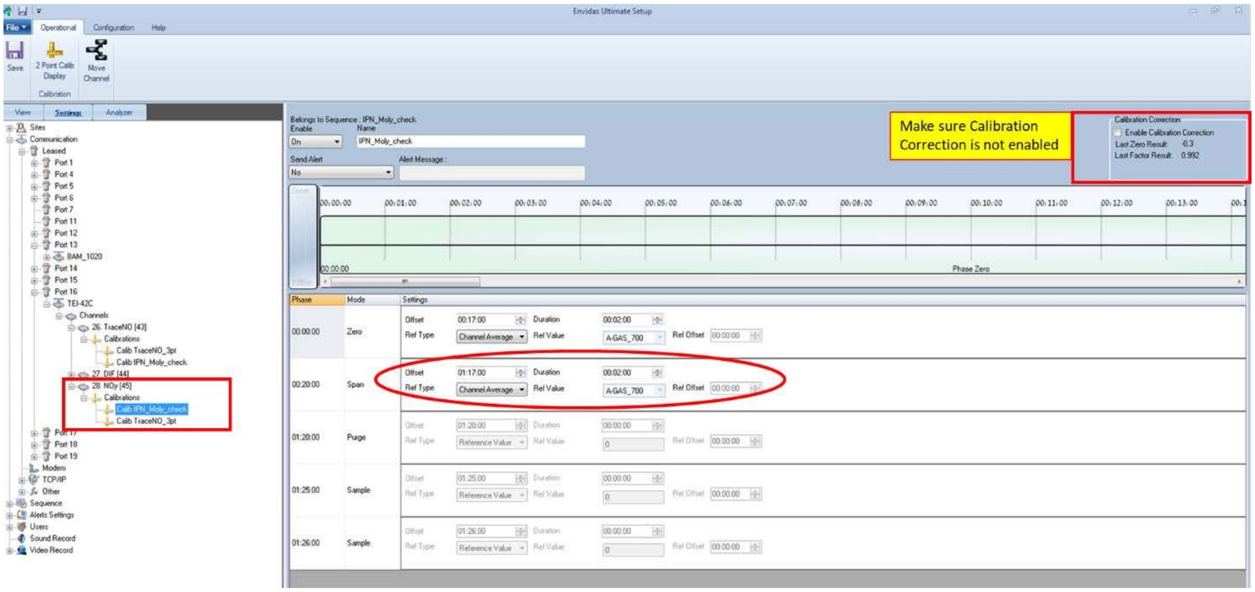

Figure 6-46: NO_Y converter efficiency QC configuration of phases and reference values for the NO_Y channel

6.6.2. Diagnostic data collection

At a minimum, the data logger must be configured to collect the diagnostic parameters listed in Table 6-3 at least every 30 minutes. Operators may elect to collect additional diagnostic parameters. The configuration for collection of a complete set of diagnostic parameters is shown in Figure 6-22.

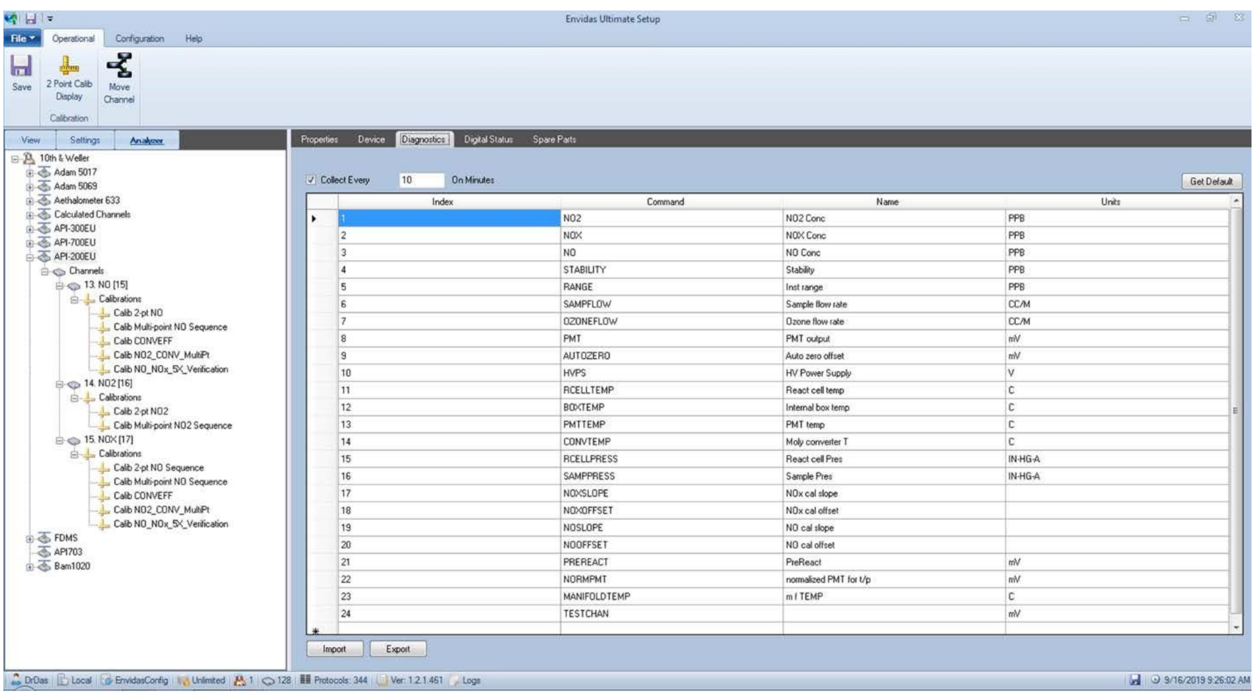

Figure 6-47: Configuration of $NO/NO_X/NO_2$ analyzer diagnostic parameter collection

7. Nitrogen Dioxide (NO_2) Monitoring by Cavity Attenuation Phase Shift (CAPS)

7.1. Introduction

This chapter describes the standard operating procedure for "true" nitrogen dioxide (NO_2) monitoring by cavity attenuation phase shift (CAPS) spectroscopy within the Washington Network. A "true" NO_2 measurement is a requirement for Photochemical Assessment Monitoring Stations (PAMS). The QC requirements for NO_2 as part of the PAMS network are more stringent than NO_2 measured at near-road sites.

This chapter includes procedures for installation, operation, quality control, maintenance, and data acquisition for CAPS NO_2 analyzers. It is applicable to analyzer model T500U manufactured by Teledyne Advanced Pollution Instrumentation (Teledyne API) and is intended to be used with the model-specific operation manual and Sections 2 and 3, which describe general procedures for gaseous pollutant monitoring and associated calibration systems. The T500U is an EPA FEM monitor (Designation number EQNA-0514212) for NO_2 measurements.

7.2. Principles of operation

The cavity attenuation phase shift (CAPS) spectroscopy NO_2 analyzer operates as an optical absorption spectrometer, where absorption of light at 450 nm is directly proportional to the concentration of the absorbing gas. A sample of particle free ambient air is drawn into the sample cell. The sample cell has highly reflective mirrors located at either end, with a light emitting diode (LED) centered at 450 nm behind one mirror, and a detector behind the other mirror. The mirrors create an extensive optical path length in the cell, so when the LED is on in a zero-air environment the intensity of the light builds exponentially. NO_2 prominently absorbs light at 450 nm, so the presence of NO_2 decreases the mean path length traveled by the light in the cell, and thus the average time of light spent in the cell. This reduction in time spent in the cell by the 450 nm light absorbed is proportional to the concentration of NO_2 in the sampled air. The sample cell is heated to a constant 45 degrees Celsius to mitigate the formation of moisture on the surfaces of the mirrors while also minimizing changes in the absorption coefficient due to temperature fluctuations.

7.3. Equipment and supplies

In addition to the standard equipment in Table 3-1, operators should purchase a pump rebuild kit or contact the Calibration and Repair Laboratory to obtain a rebuilt pump or pump rebuild kit.

7.4. Installation

In addition to the siting criteria described in Section 2.2.1, the NO_2 sample probe must be located according to the monitoring site's spatial scale, as summarized in Table 6-1. Operators should refer to 40 CFR Part 58 Appendices D and E for extensive siting criteria. Operators should also refer to Ecology's [Air Monitoring Project Approval, Site Selection, and Installation Procedure] for further information on site selection.

7.5. Quality control and maintenance

7.5.1. Quality control checks

No additional quality control is required beyond the steps described in Section 2.3. The action levels and acceptance limits for NO_2 as part of PAMS are in Table 7-1. Note that these limits come from the PAMS TAD and are more stringent than the $NO/NO_X/NO_Y$ limits for NCore or near-road sites. When running NO_2 as part of PAMS, primary QC checks every other day are recommended.

Table 7-16: CAPS NO_2 QC check acceptance criteria

Quality Control Check	Action Level	Acceptance Limits
Zero Point	< 0.21 ppb	< 0.21 ppb
Span Point	< ±7.1%	< ±10.1%

7.5.2. Maintenance

The maintenance schedule for the Teledyne API T500U analyzer is summarized in Table 7-2 below (Table 11-1 in the T500U manual). Additional questions regarding maintenance schedules should be directed to the Calibration and Repair Laboratory.

Table 7-17: Summary of required CAPS NO_2 analyzer maintenance

Procedure	Frequency	Section
Analyzer calibration	Contact the Calibration Lab	7.5.2.1
Verify diagnostic data	Weekly	7.5.2.2
Flow check	Every 6 months	7.5.2.3
Pressure leak check	Annually or after pneumatic repairs	7.5.2.4
Replace pump diaphragm	Annually or when measured flow less than 800 cm^3/min	7.5.2.5
Change particulate filter	Annually (may need more frequently in a high dust load environment)	7.5.2.6
Change AREF filter and charcoal filter	Annually	7.5.2.6
Clean Spectrometer mirrors	As necessary due to excessive Measured Loss	Contact Calibration Lab

7.5.2.1. Analyzer calibration

Note: Do not calibrate the CAPS NO_2 instrument in the field.

The reference NO_2 concentration used in QC checks is generated via chemical reaction inside the dilution calibrator's reaction cell. Upon a failed QC there is the possibility of an error occurring with the O_3 generator or reaction cell in the calibrator. For these reasons, the CAPS NO_2 analyzer should not be calibrated in the field. Contact the Calibration and Repair Laboratory for guidance if there are unresolved failed QCs or it is suspected that the instrument is out of specifications and needs a calibration.

7.5.2.2. Verify diagnostic data

At a minimum, operators should review the diagnostic data weekly to identify any problems with the analyzer's operation. Table 7-3 below shows the diagnostic parameters available and their interpretation.

Table 7-18: Teledyne API T500U diagnostic data (Teledyne API 2015)

Diagnostic Parameter	Expected	Actual	Interpretation and Action
SAMP (pressure)	Constant within atmospheric changes (Typically 2 in Hg below ambient)	Fluctuating	Developing leak in pneumatic system. Check for leaks
	Constant within atmospheric changes (Typically 2 in Hg below ambient)	Slowly increasing	Developing leak in pneumatic system prior to the sample restrictor. Check for leaks. Sample pump requires replacement. Check flow rate.
	Constant within atmospheric changes (Typically 2 in Hg below ambient)	Slowly decreasing	Kink in tubing. Check and adjust tubing. Flow path is clogging up. Run a flow check to determine whether to replace the flow restrictor or the sample filter.
AREF	Constant within ±100 Mm^{-1} of check-out value	Significantly increasing	Developing AREF valve failure. Replace valve.
	Constant within ±100 Mm^{-1} of check-out value	Significantly increasing	Developing leak in pneumatic system. Check for leaks.
	Constant within ±100 Mm^{-1} of check-out value	Significantly increasing	Debris on mirrors. Replace charcoal scrubber.
NO_2 (Concentration)	Constant for constant concentrations	Slowly decreasing signal for same concentration	Developing leak in pneumatic system. Check for leaks.

7.5.2.3. Flow check

Note: Do not exceed 10 psi when performing a flow check

In addition to reviewing the analyzer's reported flow via diagnostics, operators should verify the analyzer's flow every 6 months using a NIST-traceable flow meter certified to 1000 sccm.

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a flow meter to the sample inlet port on the rear panel. Ensure that the inlet to the flow meter is at atmospheric pressure.
3. The sample flow measured with the external flow meter should be 900 sccm ± 10%.
4. If needed, adjust the internal flow sensor according to the procedures in the instrument manual.

Low flows indicate that the pneumatic pathways are blocked. Refer to the manufacturer's operation manual or contact the Calibration and Repair Laboratory for troubleshooting assistance.

7.5.2.4. Pressure leak check

Note: Do not do a vacuum leak check on this instrument. Do not exceed 10 psi when performing a pressure leak check

To perform a pressure leak check, pressurize the instrument to **7** psi for 10 minutes. Use either a hand-held pressure pump with pressure gauge or with a tank of pressured gas (ultrapure air or nitrogen) with a two-stage regulator adjusted to <10 psi, a shutoff valve and a pressure gauge.

1. Turn off the analyzer and remove the instrument cover.
2. Install the pressure source on the SAMPLE inlet on the rear panel of the instrument.
3. Pressurize the instrument to approximately **7** psi, allowing enough time for full pressurization through the critical orifice. Do not exceed **10** psi.
4. Turn off pressure to the instrument and allow to sit for 10 minutes. If the pressure gauge measures a loss exceeding 2 psi during that time, there is a leak in the pneumatics.
5. If the leak check fails, use a liquid leak detector (e.g. Snoop®) to search for leaks. Pressurize the instrument to 7 psi and check each tube connection (fittings, hose clamps) with solution and look for bubbles. Wipe off all leak detection fluid before reconnecting sample lines to ensure that fluid is not sucked into the instrument.
6. Reconnect the sample and exhaust lines and replace the instrument cover.

7.5.2.5. Replacing the internal pump/ Replace pump diaphragm

Low flow or no flow can be a sign of worn-out seals in the pump. Pumps should be rebuilt annually or if the measured flowrate is less than 800 cm^3/min using the Teledyne API pump rebuild kit. Instructions are included with the rebuild kit. Always perform a flow and leak check after the pump is rebuilt.

7.5.2.6. Annual maintenance and repair

Many of the required annual maintenance procedures are best performed in a laboratory environment; please contact the Calibration and Repair Laboratory to obtain parts and supplies and to coordinate annual maintenance items. Follow procedures in the Model T500U NO_2 Analyzer Operation Manual for the following activities:

- Changing the particulate filter
- Replacing the AREF filter and charcoal filter

7.6. Data collection and storage

7.6.1. Envidas channel configuration

The correct configurations for CAPS NO_2 concentration channels are shown in Figure 7-1. The data channel must be configured to record NO_2 concentrations in ppb for NAAQS compliance evaluation, PAMS compliance where applicable, to support modeling and other applications, and for display on Ecology's website.

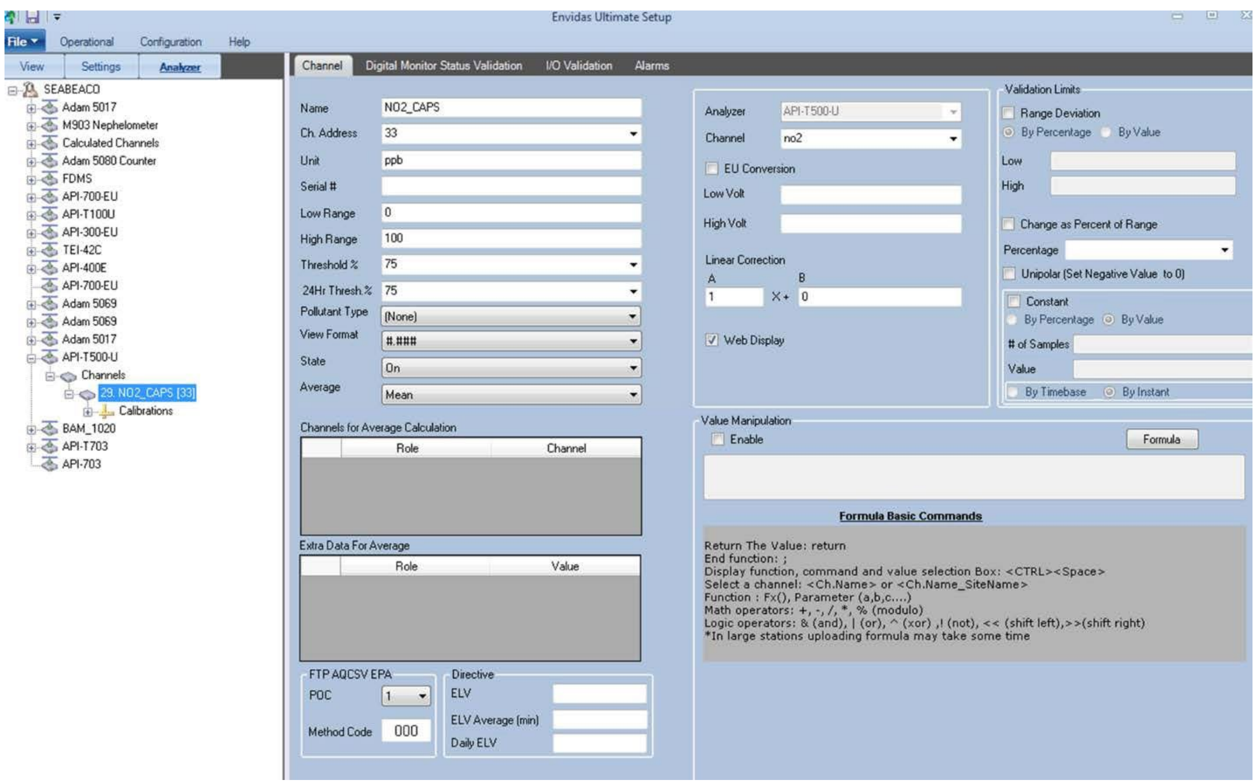

Figure 7-48: CAPS NO_2 channel configuration

The configuration for a two-point QC check set to run every two days is shown Figure 7-2 through Figure 7-6. This sequence can be modified with an additional point for a secondary QC point. A GPT preset (GPTPS) phase is required before all GPT phases. The GPTPS step allows the calibrator to adjust the ozone generator to ensure that the O_3 concentration into the reaction cell, and thus the NO_2 concentration out of the reaction cell, is equal to the reference value. More detailed information on GPT and GPTPS can be found in Section 3.2.1.1. and the dilution calibrator manual. The GPTPS phase and subsequent GPT phase must have the same flow rates and concentration settings. A GPTPS using the same settings to be used in the sequence should be performed manually several times during initial setup of the calibrator for NO_2 monitoring at the site. It will take about 20-30 minutes for the GPTPS to lock in the O_3 value the first few times it is run. The calibrator should be preconditioned until it locks in the specified O_3 value in the time set in the automated sequence, which is 10 minutes in the example below. NO_2 span point GPT and GPTPS phases must be programmed into the site calibrator following procedures in this SOP and analyzer manual. The GPT and GPTPS calibrator sequences are initiated by Envidas using the EXECSEQ command in the Envidas QC sequence (Figure 7-3).

The NO_2 GPT phases should last at least 20 minutes, not including the GPTPS phase. The dilution calibrator does not provide a channel average NO_2 value as is done with CO, SO_2, and NO QC checks. The reference value is the target value the calibrator is set to deliver, circled in Figure 7-6. This value is compared to a 2-minute NO_2 channel average that does not include the last minute of the phase.

Note: This is a different method than for NO_2 QC checks conducted on a NO/NO_X instrument. CAPS NO_2 singularly measures NO_2 without NO_X or NO, so there is no way to determine NO_2 through the method described in Section 6.6.1.2.

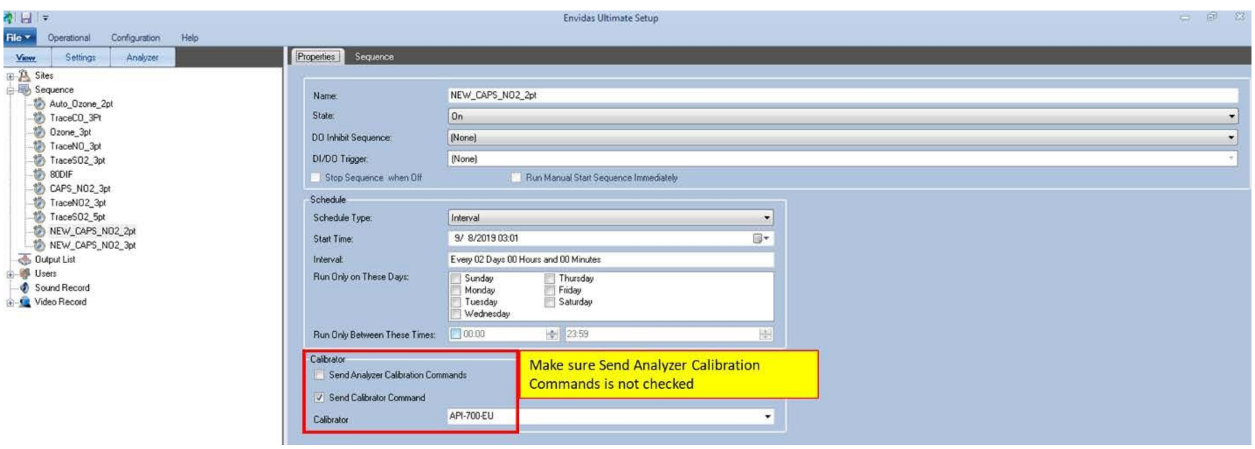

Figure 7-49: CAPS NO_2 QC sequence properties configuration

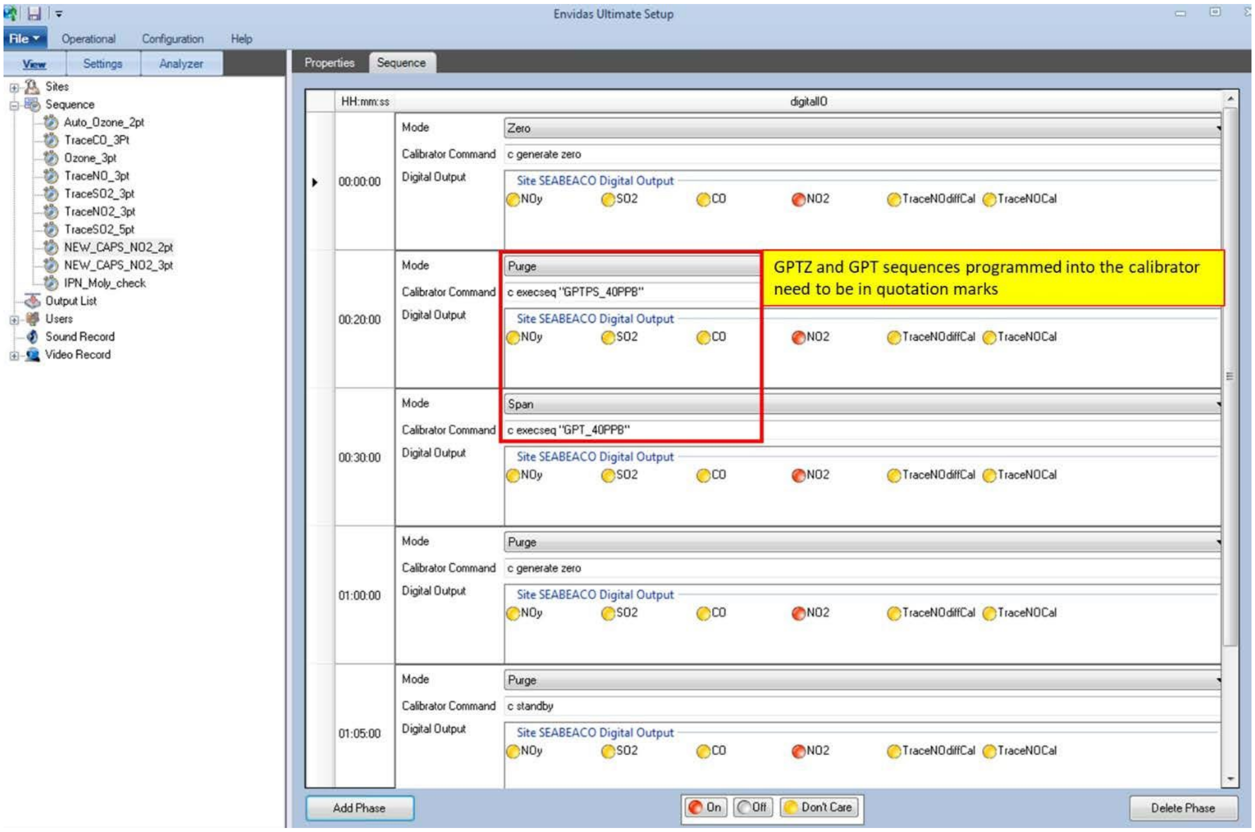

Figure 7-50: CAPS NO_2 QC sequence configuration part 1

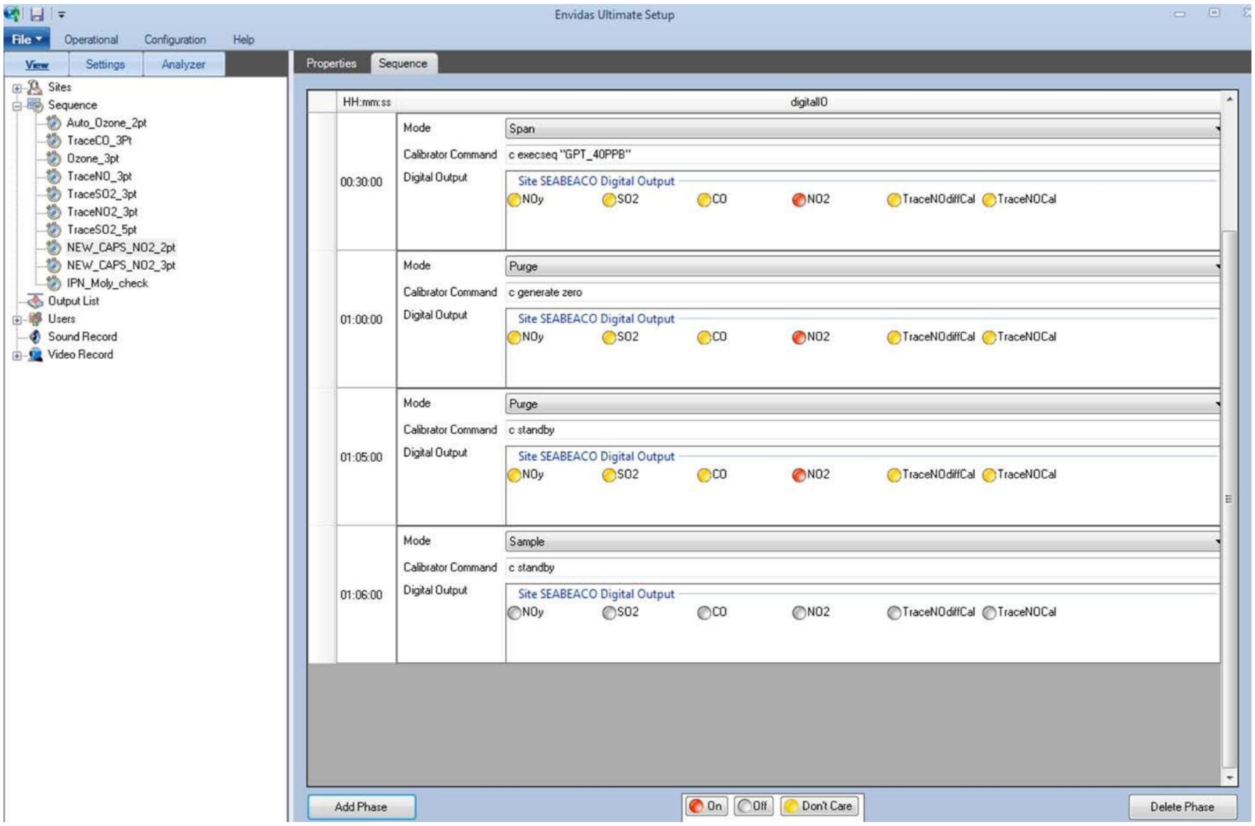

Figure 7-51: CAPS NO_2 QC sequence configuration part 2

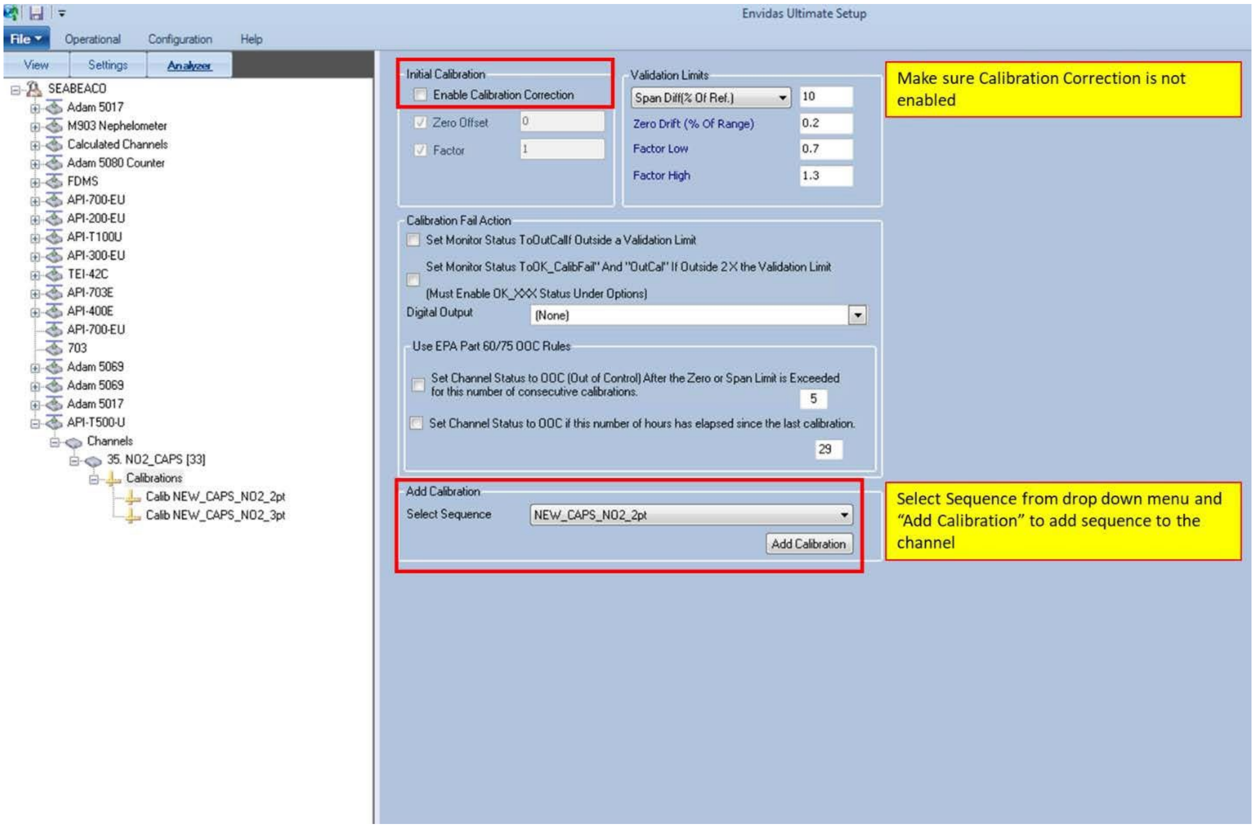

Figure 7-52: CAPS NO_2 QC validation limits configuration

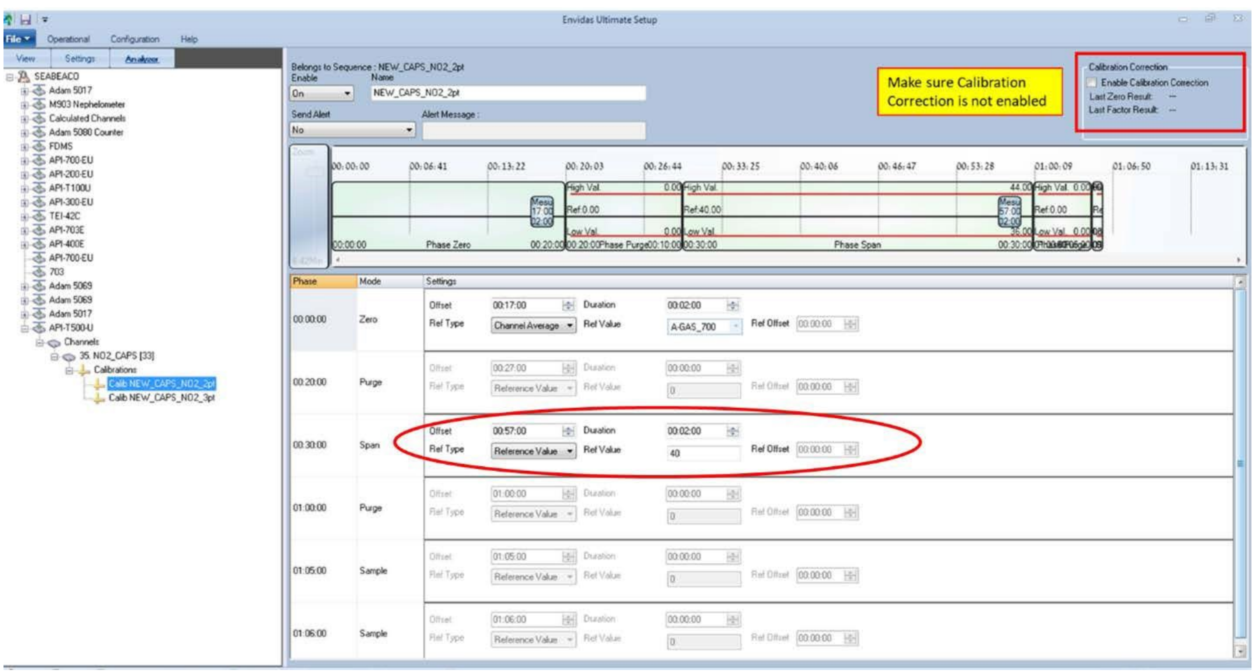

Figure 7-53: CAPS NO_2 QC configuration of phases and reference values

7.6.2. Diagnostic data collection

At a minimum, the data logger must be configured to collect the diagnostic parameters listed in Table 7-3 at least every 30 minutes. Operators may elect to collect additional diagnostic parameters. The configuration for collection of a complete set of diagnostic parameters is shown in Figure 7-7.

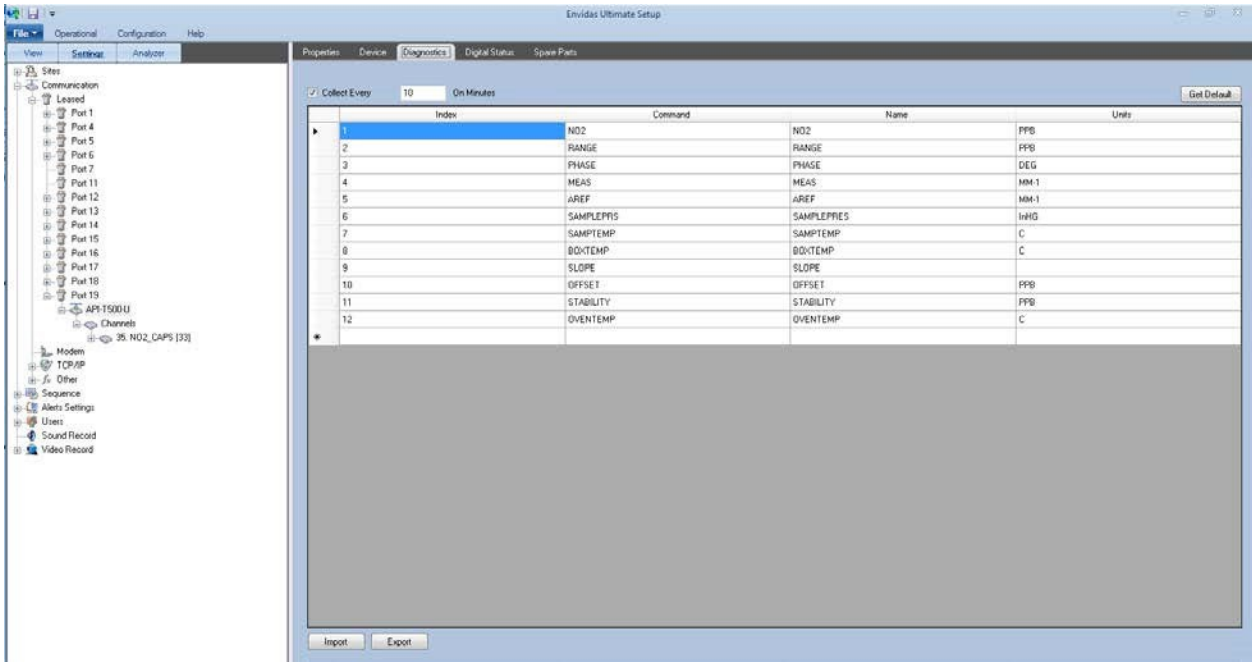

Figure 7-54: Configuration of CAPS NO_2 analyzer diagnostic parameter collection

8. References

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Appendices

Appendix A. Quality Control Check Forms

Appendix A1. SO_2 CO, CAPS NO_2 QC form

Washington State Department of Ecology
Precursor Pollutant Quality Control Check Form

Revised 0305 2021

QC Form Type		Parameter	
AQS No		Date	
Location		Operator	
Analyzer Serial No		QC Start Time	PST
Analyzer State Tag		QC Stop Time	PST
Calibrator Serial No		Room Temp	°F
Calibrator State Tag			
Zero Air Serial No			
Gas Cylinder Serial No			
Gas Cylinder Exp. Date			
Cylinder Conc. (ppm)			
Cylinder Pressure (psi)			

Maintenance Last Performed:	
Analyzer	
Calibrator	
Zero Air	
Probe & Lines	
Room Temp Device	

Conditions since last QC:

Any failed QCs since last visit?		Min Room Temp (°F)	
Calibration Performed?		Max Room Temp (°F)	
Diagnostics normal*?		Particulate Filter Changed?	

*within normal range per Gaseous SOP. If No, specify below.

As-Left	
Slope	
Offset	

QC Check Results:

	Target	Actual	Indicated	Difference	Results
Zero	0				
Primary QC Point					
Secondary QC Point					
Optional QC Point 3					
Optional QC Point 4					

Notes:

Appendix A2. NO_X and NO_Y QC form

Washington State Department of Ecology
Precursor Pollutant Quality Control Check Form

Revised 03052021

QC Form Type		Parameter	
AQS No		Date	
Location		Operator	
Analyzer Serial No		QC Start Time	PST
Analyzer State Tag		QC Stop Time	PST
Calibrator Serial No		Room Temp	°F
Calibrator State Tag			
Zero Air Serial No			
Gas Cylinder Serial No			
Gas Cylinder Exp. Date			
Cylinder Conc. (ppm)			
Cylinder Pressure (psi)			

Maintenance Last Performed:	
Analyzer	
Calibrator	
Zero Air	
Probe & Lines	
Room Temp Device	

Conditions since last QC:

Any failed QCs since last visit?		Min Room Temp (°F)	
Calibration Performed?		Max Room Temp (°F)	
Diagnostics normal*?		Particulate Filter Changed?	

*within normal range per Gaseous SOP. If No, specify below.

Calibration Factors (NO)	
Slope	
Offset	

Calibration Factors (NOx.NOy)	
Slope	
Offset	

Conversion Efficiency:

		Y/N	Most recent CE
Near-Road NOx	Any CE failure since last QC?		
NCore NOy	CE performed during this QC?		

QC Check Results:

NO	Target	Actual	Indicated	Difference	Results
Zero	0				
Primary QC Point					
Secondary QC Point					
Optional QC Point 3					

NOx . NOy	Target	Actual	Indicated	Difference	Results
Zero	0				
Primary QC Point					
Secondary QC Point					
Optional QC Point 3					

Notes:

Appendix A3. NO_X converter efficiency QC form

Fill in the white cells

NO_2 / Conversion Efficiency Calculations

** Fill in white cells **

Control # 082019

Site

Site Name	SEA10WEL
Site AQS ID	530330030
Operator	JL
Analyzer S/N	223
Calibrator S/N	124
Zero Air S/N	577

Tank

Cyl Serial #	JB03058
Exp Date	7/3/2021
NO Conc.	10.20
NO_x Conc.	10.23

GPT Targets

Orignal NO	100
Primary NO_2	40
Secondary NO_2	80
Total Flow LPM	7

Entry from"All_Calibrations" Report

Calibration Report Date	10/3/2019	
Calibration Report Time	3:05	
	Meas	
Zero Measured NO	-0.28	ppb
NO(Orig)Span Level 1	99.642	ppb
NO(Rem)Span Level 2	17.842	ppb
NO(Rem)Span Level 3	0.123	ppb
Zero Measured NOX	0.076	ppb
NO_x (Orig)Span Level 1	99.967	ppb
NO_x (Rem)Span Level 2	100.8	ppb
NO_x (Rem)Span Level 3	96.898	ppb
Dil_Flow	6.938	LPM
ACTCALI_Flow	69	cc/m
O3GENFLOW	23.2	cc/m
Total Flow	7.0302	LPM

Results

GPTZ (Orig)

[NO out] NO Actual	NO Indicated	NO Diff %	PASS/FAIL <15%
100.11	99.642	-0.47	PASS
[NO_x out] NOx Actual	**NO_x Indicated**	**NOx Diff%**	<15%
100.41	99.967	-0.44	PASS

Primary

[NO_2 out] NO_2 Actual	NO_2 Indicated	NO_2 Diff%	<15%
82.09	82.96	1.05	PASS
NO_2 Impurity	**NO_2 Converted**	**Conv Eff%**	>96%-104%<
0.29	82.93	101.01	PASS

Secondary

[NO_2 out] NO_2 Actual	NO_2 Indicated	NO_2 Diff%	<15%
99.81	96.78	-3.04	PASS
NO_2 Impurity	**NO_2 Converted**	**Conv Eff%**	>96%-104%<
0.29	96.74	96.93	PASS

$NO_{2\,Out}$ {"X"} = $[NO]_{Original} - [NO]_{Remainder} + [NO_2]_{Impurity}$

$NO_{2\,Conv}$ {"Y"} = $[NO_2]_{Out} - \{[NO_x]_{Original} - [NO_x]_{Remainder}\}$

Appendix A4. NO_Y converter efficiency QC form

Revised 092419

IPN/NPN Conversion Efficiency Calculation Sheet

Start Time (PST) ____________________ End Time (PST) ____________________

Target NPN (ppb) ____________________

IPN/NPN CE check:

NO_rem ____________________ NOy_rem ____________________

NO2 = ____________________ NOx loss = ____________________

Conversion Efficiency = ____________________

Must be ≥ 96% and ≤ 104% to pass

$$CE\ (\%) = 1 - \left(\frac{NOx\ loss}{NO2}\right) \times 100\%$$

Appendix B. Linearity check form

Revised 08/06/2019

Post-calibration linearity check

Location		Date	
AQS No		Operator	
Analyzer Serial No			
Analyzer State Tag		QC Start Time	PST
		QC Stop Time	PST
Gas Cylinder S/N		Calibrator S/N	
Gas Cylinder Exp. Date		[Gas Cylinder]	
Pollutant		**Grey cells only apply to NOxy*	
Calibration Point			

	Pre-Calibration	Post-Calibration	Pre-Calibration	Pre-Calibration
Slope				
Offset				

Linearity Check Results

	Actual	Indicated	Difference*	Results	Actual	Indicated	Difference*	Results
Zero								

**Within 2% of the calibration range*

Notes: