

# Gaseous Pollutant Monitoring Standard Operating Procedure (CO, SO<sub>2</sub>, NO<sub>X</sub>, NO<sub>Y</sub>, NO<sub>2</sub>)

Ву

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For the

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# Gaseous Pollutant Monitoring Standard Operating Procedure

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# **Definitions and Acronyms**

AQS	Air Quality System
CFR	Code of Federal Regulations
СО	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 <sub>2</sub>	Nitrogen dioxide
NO <sub>X</sub>	Nitrogen oxides
ΝΟγ	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 <sub>2</sub>	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  $(NO_X \text{ and } NO_Y)$ , 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<sub>2</sub>, CO, and NO<sub>2</sub>) are either Federal Reference Method (FRM) or Federal Equivalent Method (FEM) designated monitors. NO, NO<sub>X</sub> and NO<sub>Y</sub> 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.

Equipment Type	Pollutant	Trace-Level Equipment	Ambient-Level Equipment	Designation
Analyzer	SO <sub>2</sub>	100EU, T100U	100E, T100	FEM
	СО	300EU, T300U	300E, T300	FRM
	NO/NO <sub>X</sub> /NO <sub>2</sub>	200EU, T200U	200E, T200	FRM for $NO_2^*$
	NO/NO <sub>Y</sub>	T200U-NO <sub>Y</sub>		
	NO <sub>2</sub>	T500U		FEM
Calibrator	All**	700EU, T700U***	700E, T700	
Zero Air Supply	All	701H	701	

 Table 1-1: Supported analyzers and required calibration equipment

\* The 200EU and T200U NO/NO<sub>X</sub>/NO<sub>2</sub> analyzers are FRM designated only for NO<sub>2</sub>.

\*\* Calibrators used for NO<sub>X</sub> and NO<sub>Y</sub> monitoring must be equipped with an ozone generator module. See Chapter 6 for additional information on calibration requirements.

\*\*\* Trace-level CO and SO<sub>2</sub> 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<sub>X</sub> and NO<sub>Y</sub> 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<sub>2</sub>, CO, and NO<sub>2</sub>;
- representative levels of gaseous pollutant concentrations in populated areas;
- background concentrations of gaseous pollutants in rural areas;
- maximum concentrations of NO<sub>x</sub> and CO in the urban near-road environment; and
- peak SO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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. Fivepound CO2 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<sup>®</sup>).
- 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 (<sup>5</sup>/<sub>32</sub>" inner diameter) PFA. Gas cylinder-to-calibrator lines are typically ½" outer diameter. All fittings that connect calibration gases and zero air to regulators, manifolds and analyzers must be made of FEP Teflon<sup>®</sup>, stainless steel, or brass. Kynar<sup>®</sup> 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

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

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<sub>X</sub> and NO<sub>Y</sub>), 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.

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

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

## 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.

Quality Control Check	EPA Minimum Required	Ecology Minimum
Туре	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

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

\* When running NO<sub>2</sub> as part of PAMS, primary QC checks every 2 days are recommended.

### 2.3.1.2. Timing

**Note**: For NAAQS compliance at SO<sub>2</sub> sites, operators will not conduct any QC checks or analyzer / sample train maintenance when the most recent 1-hour SO<sub>2</sub> concentration is  $\geq$  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 99<sup>th</sup> 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 99<sup>th</sup> percentile by 1.5 to establish the calibration scale (3000 ppb in this example). If the 99<sup>th</sup> percentile value is below 100 ppb for SO<sub>2</sub>, NO, NO<sub>X</sub>, NO<sub>Y</sub>, or NO<sub>2</sub> 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<sub>2</sub> and NO<sub>2</sub> 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).





#### 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  $\frac{3}{5}$ " 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.

Parameter	Zero Limits	Primary/Secondary QC Check Point Limits
SO <sub>2</sub>	< ± 1.1 ppb	< ± 10.1% or < ± 1.51 ppb, whichever is greater
СО	< ± 50.1 ppb	< ± 10.1%
NO, NO <sub>X</sub> , NO <sub>Y</sub> and NO <sub>2</sub>	< ± 1.51 ppb	< ± 15.1% or < ± 1.51 ppb, whichever is greater
NO <sub>2</sub> (PAMS)	< ± 0.21 ppb	< ± 10.1%

Table 2-4: QC check acceptance criteria

# 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.

816	3   <del>-</del>			Envida	s Ultimate	Viewer				- • X
File	Dynamic	Operational	Traces	Tools	Setups	Views	Help			
Sequ	Phase Fr Sequence	rom Stop/Start Collection +	EUL Hyper Terminal	 Command Terminal →						
0	Neph_2pt		nunication							
0	Auto_Ozone_	2pt								
0	Manual_Calibr	ration_2Z1SP		Chann	el	Unit	s	Raw Val.	Instant.	St
Ø	Manual_Ozon	e_3pt	1	RTem	p	Deg	F	0.766	76.6	1
٢	2-pt_NO_Seq		1 1	WindSpe	edS	mph	٦	1.9	1.9	
٧	Multi-pt_NO2_	Seq	I W	indDirec	tionS	degre	ees	12	12	
6	2-pt_NO2_Se	q	1	VindSpe	edV	mph	n	1.9	1.9	
10	Multi-pt_NO_S	Seq	I W	indDirec	tionV	degre	es	12	12	
T/	ACS36ST	7:37:50 A	м	TempAr	nb	Deg	F	0.538	57.6	1
T/	ACS36ST	7:37:50 A	М	NO		ppb	)	40.397	40.397	
T/	ACS36ST	7:37:50 A	м	NO2		ppb	)	23.039	23.039	<u> </u>
	ACCOUCT	7. 27. 50 4		NO				C2 420	62.426	•
🔶 Ca	onnected 🚨	User:DrDas 🛯 🖳 V	er :1.2.27					3	9/26/2016 7:37	:51 AM 🔐

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:

- 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<sub>2</sub>, 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<sub>cyl</sub> 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<sub>2</sub> is produced for every mole of O<sub>3</sub> added, assuming all O<sub>3</sub> 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<sub>2</sub> is recommended over the method of dilution of NO<sub>2</sub> from a cylinder, as NO<sub>2</sub> 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<sub>2</sub>, NO, NO<sub>2</sub>, O<sub>3</sub>, H<sub>2</sub>S, 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.

Category	Equipment	Purchase Schedule
Tools and Equipment	Two-stage stainless steel (SO <sub>2</sub> , NO <sub>x</sub> , NO <sub>Y</sub> ) or brass (CO) regulator	Once
	Flexible fluoropolymer tubing (¼" and ½")	Yearly or as needed
	Fluoropolymer and stainless steel fittings ( $\frac{1}{4}$ " and $\frac{1}{8}$ ")	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 $\mu$ m, for SO2, CO, O3, and 5 $\mu$ m, for NO <sub>Y</sub> and NO <sub>X</sub> )	Monthly or as needed
	Compressed cylinder of EPA Protocol gas (SO <sub>2</sub> , 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 <sup>®</sup>	Yearly or as needed

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

### 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.

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

 Table 3-6: Summary of required calibrator system maintenance

## 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 <sub>3</sub> generator UV lamp.
REG PRES	Measures the gas pressure at the pressure regulator on the O <sub>3</sub> 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 <sub>3</sub> gas flow rate (Ipm).
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<sup>®</sup> 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<sub>2</sub> 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.

<u>©} </u>	Envidas (	Ultimate Setup	- 8 %
File Operational Configuration H	lelp		
Save 2 Point Calib Display Calibration			
View Settings Analyzer	Channel Digital Monitor Status Validation I	/0 Validation Alarms	+
Sites TACS36ST Channels	Name     ACTCONC       Ch. Address     20       Unit     ppb       Serial #     135       Low Range     0       High Range     500       Threshold %     75       24Hr Thresh %     75       Pollutant Type     [None]       View Format     #.###       State     On       Average     Mean	Analyzer API-700-EU  Channel ACTCONC EU Conversion Low Volt High Volt Linear Correction A B 1 ×+ 0 V Web Display V V	Validation Limits  Validation Limits  Range Deviation  By Value Low High  Change as Percent of Range Percentage  Unipolar (Set Negative Value to 0)  Constant Constant By Percentage By Value to Samples Value CBy Timebase By Instant
	Channels for Average Calculation           Role         Channel           Extra Data For Average         Role         Value	✓ Value Manipulation     ✓ Value Manipulation     ✓ Enable     ✓     Formula Basic C     Return The Value: return     End function: ;     Display function, command and value s     Select a chanel: <ch.name> or <ch. (a,b,c,)<="" :="" function="" fx(),="" parameter="" td=""><td>Formula ommands election Box: <ctrl><space> Name_SiteName&gt;</space></ctrl></td></ch.></ch.name>	Formula ommands election Box: <ctrl><space> Name_SiteName&gt;</space></ctrl>
🚨 DrDas 👔 Local 🐼 EnvidasConfig 矚	Unlimited 🔼 1 😞 64 📰 Protocols: 436 📃 Ve	r: 1.2.1.487 🛃 Logs	9/26/2016 7:43:40 AM 🛒

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<sub>3</sub> generator module for NO<sub>X</sub> and NO<sub>Y</sub> 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.

unication	Collect Every 10 On Minutes			
Post 1	Index	<ul> <li>Command</li> </ul>	Name	Units
Port 5		ALTLADIUW	Act Call flow	UM .
Port 6	-	IAHISLALFLUW	Larg Lai Flow	LPM
Pot 7	3	ACTOLIFLOW	Act DE Flow	LPM
Port 11 Revt 12	4	TARIGULFLOW	Tag Di Flow	LPM
26. 12. 12.	5	U3UENHEP	03 Gen Hel	MV
B Charnels	6	03GENFLOW	03 Gen Flow	LPM
🕀 🚓 33. A-GAS_700 (35)	7	03GENDRIVE	03 Gen Dr/Out	MV
10 - CAL_700 [36]	8	O3GENTEMP	03Gen Temp	C
1	9	CALPHESS	Cal Press	PSIG
- 37 A-03 TABG 200 (55)	10	DILPRESS	Dil Press	PSIG
T API-700EU	11	REGPRESS	Reg Press	PSIG
Port 13	12	ACTCONC	ACT Conc	PPS
Pot 14	13	TARGONC	TARG Conc	PPS
Pot 15 Pot 16	14	BOXTEMP	Bax temp	C
Port 17	15	ACT03	Actual 03	PP9
Port 18	16	TARG03	Target 03	PPB
Port 19	17	TESTCHAN	Test Chan	MV
dem	18	PHOTOMEAS	PH Meas	MV
external and a second se	19	PHOTOREF	PH Bel	MV
ce	20	PHOTOFLOW	PH Flow	LPM
ettings	21	PHOTOLTEMP	PH LTemp	C
9-01	22	PHOTOSPRESS	PH SPiece	InHGA
Record	23	PHOTOSTEMP	Sample temp	C
lecord (	24	PHOTOSLOPE	PH Slope	
	25	PHOTOOFFSET	PH Offset	
	26	O3GENMODE	03 GEN FRAC	

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<sub>2</sub>) Monitoring

# 4.1. Introduction

This chapter describes Ecology's procedures for monitoring trace- and ambient-level SO<sub>2</sub> 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<sub>2</sub> measurement is based on the principle of characteristic fluorescence released by excited SO<sub>2</sub> when exposed to ultraviolet (UV) light. The SO<sub>2</sub> analyzer collects ambient samples and detects the decaying radiation emitted by SO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> at near zero concentrations and is required for trace-level SO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> sites, operators will not conduct any QC checks or analyzer / sample train maintenance when the most recent 1-hour SO<sub>2</sub> concentration is  $\geq$  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<sub>2</sub> action levels

### 4.5.2. Maintenance

The maintenance schedule for the Teledyne API T100 and T100U SO<sub>2</sub> analyzers is summarized in Table 4-1 below.

Table 4-8: Summary of required SO<sub>2</sub> 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<sup>th</sup> percentile of hourly concentrations at the site over the previous 3 years multiplied by 1.5. If the 99<sup>th</sup> 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<sub>2</sub> analyzer:

- 1. Ensure that the pressures of zero air and cylinder gas to the calibrator are between 25 and 30 psi.
- 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.

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	<ul><li>Flow path is clogged:</li><li>Check critical flow orifice</li><li>Replace particulate filter</li></ul>
	Sample gas	Constant with atm. changes	Slowly decreasing	Developing leak in pneumatics to vacuum.
DARKPMT	Output when UV lamp shutter closed	<u>+</u> 20 of check out value	Increasing	PMT cooler failure. Shutter failure.
SO <sub>2</sub>	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	<ul> <li>Flow path is clogged:</li> <li>Pump diaphragm has worn out and needs replacing (more common)</li> <li>Critical flow orifice/ sintered filter is clogged and needs replacing (rare)</li> <li>Replace particulate filter</li> </ul>

Table 4-2: Teledvne A	PI T100 and T100U	l diagnostic data	(Teledvne API 2016)
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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 <u>+</u> 0.3	Outside normal range	Poor calibration/Incorrect span gas concentration/Light leak/ UV lamp output decay.
	UV Source Filter Contaminated	1.0 <u>+</u> 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  $\pm$  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<sup>®</sup>) 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<sub>2</sub> monitoring sites must be configured to collect 1-minute, 5-minute, and 1hour 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<sub>2</sub> 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<sub>2</sub> concentration

The correct configuration for the SO<sub>2</sub> concentration channel is shown in Figure 4-4 below.

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Figure 4-10: SO<sub>2</sub> 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).

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Figure 4-11: SO<sub>2</sub> primary QC sequence properties

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Figure 4-12: SO<sub>2</sub> primary QC sequence configuration part 1

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Figure 4-13: SO<sub>2</sub> primary QC sequence configuration part 2



Figure 4-14: SO<sub>2</sub> primary QC configuration of validation limits

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Figure 4-15: SO<sub>2</sub> 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.

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<u>⊕</u> - <del>{</del> <b> </b> <del>}</del> <del>/</del>	API-300-EU			5		SAMPFLOW	Sample flow rate	CC/M		
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	API-700-EU			8		LAMPRATIO	UV Ratio	MV		
	API-703E			9		STRAYLIGHT	StrayLight	PPB		
±-₹/	Adam 5069			10		DARKPMT	Dark PMT	MV		
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				12		SLOPE	Slope	none		
				13		OFFSET	Offset	none		
				14		HVPS	HVpower	MV		
				15		RCELLDUTY	Duty Cycle	MV		
				16		RCELLTEMP	Reaction Cell	deg		
				17		BOXTEMP	BoxTemp	deg		
				18		PMTTEMP	PMTtemp	deg		
				19		IZSDUTY	IZS Duty	sec		
				20		IZSTEMP	IZS Temp	sec		
				21		NORMPMTDET	Normal PMT	deg		
			*							

Figure 4-16: Configuration of SO<sub>2</sub> 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  $\mu$ m 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<sub>2</sub>) fills the measurement cell and the reference cell contains N<sub>2</sub> 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<sub>2</sub> 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<sup>®</sup> 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<sup>®</sup> dryer is located upstream of the CO scrubber and consists of a bundle of Nafion<sup>®</sup> tubes housed within a single shell. The Nafion<sup>®</sup> 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.

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.
		<ul> <li>≥ 10 m away from an intersection; preferably at a midblock location.</li> </ul>

Table 5-10: Summary of CO siting criteria

# 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 99<sup>th</sup> 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.
- 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.

Diagnostic Parameter	Condition	Behavior	Interpretation
STABILITY	Zero Cal	Increasing	<ul><li>Pneumatic leaks in instrument &amp; sample system.</li><li>Detector deteriorating.</li></ul>
CO MEAS	Zero Cal	Decreasing	<ul> <li>Source aging.</li> <li>Detector deteriorating.</li> <li>Contaminated optics.</li> </ul>
MR RATIO	Zero Cal	Increasing	<ul> <li>Source aging.</li> <li>Detector deteriorating.</li> <li>Contaminated zero gas (H<sub>2</sub>O).</li> </ul>
	Zero Cal	Decreasing	<ul> <li>Source aging.</li> <li>Detector deteriorating.</li> <li>GFC Wheel leaking.</li> <li>Pneumatic leaks.</li> <li>Contaminated zero gas (CO).</li> </ul>
	Span Cal	Increasing	<ul> <li>Source aging.</li> <li>Pneumatic leaks in instrument &amp; sample system.</li> <li>Calibration system deteriorating.</li> <li>GFC Wheel leaking.</li> </ul>
	Span Cal	Decreasing	<ul><li>Source aging.</li><li>Calibration system deteriorating.</li></ul>
PRES	Sample	Increasing > 1"	<ul><li>Leaks between sample inlet and sample cell.</li><li>Change in sampling manifold.</li></ul>
	Sample	Decreasing > 1"	<ul> <li>Dirty particulate filter.</li> <li>Pneumatic obstruction between sample inlet and sample cell.</li> <li>Obstruction in sampling manifold.</li> <li>Pump diaphragm has worn out.</li> </ul>
PHT DRIVE	Any, with Bench Temp at 48 °C	Increasing	<ul> <li>Poor mechanical connection between IR- photodetector and sample cell.</li> <li>IR-photodetector deteriorating.</li> </ul>

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

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  $\pm$  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<sup>3</sup>/min and stable, there are no large leaks in the instrument's pneumatics.
  - If the pressure is near or  $\geq 10$  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  $\leq$  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<sup>®</sup>) 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).

<b>፼</b>    <u>  </u>   =	Envidas Ultimate Setup	- • ×
File Operational Configuration	Help	
View         Settings         Analyzer           Sites         10th & Weller         Channels	Channel     Digital Monitor Status Validation     I/O Validation     Alarms       Name     CO	Validation Limits Range Deviation By Percentage  By Value Low -50 High
	Low Range 0 High Volt High Volt Linear Correction A B 11 X + 0 Pollutant Type CO View Format #.## V State On View Format Average	Change as Percent of Range Percentage  Unipolar (Set Negative Value to 0) Constant By Percentage  By Value # of Samples Value D Linches  D Linches
	Mean       Channels for Average Calculation       Role       Channel       Extra Data For Average       Role       Value       Role       Value       Role       Value       Role       Value       Role       Value       Channel       Formula Bas       Return The Value: return       End function: ;       Display function, command and value       Select a channel:        Ch.Name> or <	E Commands
26. UV [28]     27. DeltaCarbon [29]     28. Bam_PM25_Conc [3]     30. 03GENFLOW [32]     30. 03GENFLOW [32]     31. COREF [33]     32. Sequence     Output List     Sequence     Output List     Users     Sound Record     Video Record	FTP AQCSV EPA       Directive         PDC       1         ELV       ELV         Method Code       000         Daily ELV	lo) xor) ,! (not), << (shift left),>>(shift a may take some time

Figure 5-19: CO channel configuration for NAAQS compliance

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File 🔻	Operational	Configuration	Help					
View	Settings	Analyzer	Channel Dig	gital Monitor Status Validation I/C	) Validatio	n Alarms		*
BA Sit	les		-		1			Validation Limits
8	10th & Weller		Name	WAQA_CO		Analyzer	API-300EU 👻	Range Deviation
B	Channels		Ch. Address	20 👻		Channel		By Percentage By Value
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	B G 3 Gast	725 [2] Value [3]	Unik	ppm		EU Conver	sion	
	0 0 4. RTe	mp [4]	Serial #	058		Low Volt		High
	. S. USV	VindSpdS [7]	Low Range	0		LEab Val		
	😥 🥎 6. USV	VindDirS [8]	High Bange	100		rign vok	-	Change as Percent of Hange
	🕀 🌎 7. USV	√indSpdV [9]	71 1.119	76		Linear Correctio	n	Percentage -
	0 0 USV	VindDirV [10]	I hreshold %	75 <b>•</b>		A	В	Unipolar (Set Negative Value to 0)
	9. Amb	enp [11]	24Hr Thresh.%	75 👻		0.001	X+ 0	Constant
		633 [12]	Pollutant Type	(None) 👻				By Percentage  By Value
	E _ 12. CO	[14]	View Format			Veb Displ	sv	tt of Samples
	E-La Ca	librations	State					+ or Samples
	🕀 🥎 13. NO	[15]	A	Un 👻				Value
	🕀 🌎 14. NO	2 [16]	Average	Mean 👻				By Timebase   By Instant
	15. NU	IX [17]	Channels for Aug	rage Calculation		Value Manipula	tion	
	17 AC		Channels for Ave	Rage Calculation		Enable		Formula
	E . 18. WA	AQA_CO [20]		Charmer				
	L Ca	librations						
	🕀 🥎 19. AC	TCALFLOW [2				-		
	🕀 🌍 20. Am	bPress [22]					Formula Basic	Commands
	1. FD	MS_ADD [23]	Extra Data For A	/erage		Return The V	/alue: return	
	1 22. FD	MS_BASE [24]	F	lole Value		End function	; ; ion: command and value	celection Box: CTRL>CSpace>
	23. FD	MS_FEM [26]				Select a chai	nnel: <ch.name> or <c< td=""><td>h.Name_SiteName&gt;</td></c<></ch.name>	h.Name_SiteName>
	0 0 25. BC	[27]				Function : Fx Math operato	(), Parameter (a,b,c)	2)
	1 - C 26. UV	[28]				Logic operation	ors: & (and),   (or), ^ (x	or) ,! (not), << (shift left),>>(shift
	🖻 🥎 27. De	ItaCarbon [29]				right) *In large sta	tions uploading formula i	may take some time
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1		•						
C DrDas	R Local	EnvidasConfig	Unlimited A 1	128 Protocols: 344	er: 1.2.1.4	61 Logs		9 12/11/2019 4:24:48 PM

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).

<u>¶i</u>	Envidas U	Jltimate Setup	- (	e 83
File  Operational Configuration	Help			
View <u>Settings</u> Analyzer	Properties Sequence			
Communication Sequence 2-pt CD Sequence Multi-point CD Sequence Multi-point ND Sequence NO2_CONV_MultiPt	Name: State: D0 Inhibit Sequence: DI/D0 Trigger: Stop Sequence when Diff	2-pt CD Sequence On (None) (None) Run Manual Start Sequence Immediately		•
NO_NOx_5X_Verification	Change Diagnostics Collection 1	Time During Calibration To 1 On Minutes		
Alerts Settings     Jeffs Users     Sound Record	Schedule Type:	Daily	•	
⊕- <u>©</u> Video Record	Start Time:	8/21/2018 01:01		
	Run Only on These Days:	<ul> <li>✓ Sunday</li> <li>Monday</li> <li>Friday</li> <li>Tuesday</li> <li>Saturday</li> <li>✓ Wednesday</li> </ul>		
	Run Only Between These Times:	01:01	A V	
	Calibrator     Send Analyzer Calibration Comm     Send Calibrator Command	mands Make sure Send Analyzer Calibration Commands is not checked		
	Calibrator	AP1703	-	

Figure 5-21: CO QC sequence properties

<b>\$</b>				Envidas Ultimate Setup	
File Operational Configuration Help	Prope	uties Sec	quence		
B-A Sites					_
Communication     Sequence     Neph2Pt     Sequence     Multipoint CO Sequence     Multipoint NO Sequence     No_NOX_SX_Verification     Sequence     Sequen	•	00:00:00	Mode Calibrator Command Digital Output Mode Calibrator Command Digital Output	Zero Zero C GENERATE ZERO Site 10th & Weller Digital Output C GENERATE 500 PP8 C0 Site 10th & Weller Digital Output C GENERATE 500 PP8 C0 Site 10th & Weller Digital Output	
	Mode     Calibrator       00:55:00     Digital Out       00:58:00     Mode       00:58:00     Digital Out       01:00:00     Digital Out	00:55:00	Mode Calibrator Command Digital Output	Czero     Span     NOCal     NO2Cal     NO2Cal       Purge       C GENERATE ZERO       Site 10th & Weller Digital Output	н
		00:58:00	Mode Calibrator Command Digital Output	Cero Ospan ONUCal OUCal ONUCCal ONUCCal  Purge C STANDBY Site 10th & Weller Digital Output	
		Mode Calibrator Command Digital Dutput	Cero         Span         NULai         CLULai         NULai         NULai           Sample         C         C         StANDBY         Site 10th & Weller Digital Output         OZero         OSpan         ONOCal         ONO2Cal         ONO2CAL </td <td></td>		
		Add Phase		Coff Cont Care Dek	≠ ete Phase

Figure 5-22: CO QC sequence configuration

en la la	Envidas Ultimate Setup					
File  Operational Configuration	Help					
View         Settings         Analyzer           Sites         10th & Weller         ▲           Channels         1. neph [1]         ▲         2. NPM25 [2]           3. GasValue [3]         ▲         4. RTemp [4]           5. USWind5pdS [7]         ▲         6. USWindDirS [8]           ■         7. USWind5pdS [7]         ▲           ■         9. AmbTemp [1]         ■           ■         9. AmbTemp [1]         ■           ■         10. BC_633 [12]         ■           ■         10. UV_633 [13]         ■           ■         Calibrations         ■           ■         13. N0 [15]         ■           ■         15. N0X [17]         ■	Initial Calibration       Validation Limits         Enable Calibration Correction       Span Diff(% Of Ref.)       10         Zero Offset       9.95383132530       Top Confit (% Of Range)       50         Factor       0.97785966010       Factor Low       0.7         Factor       0.97785966010       Factor Low       0.7         Factor Low       0.7       Factor Low       0.7         Factor Set Monitor Status ToOutCall Dutside a Validation Limit       1.3       Set Monitor Status ToOK_CalibFail" And "DutCal" If Outside 2× the Validation Limit         Must Enable OK_XXX Status Under Options)       Digital Output       CCal       Image: Control Cont					
⊕ ∽ 17. ACTOILFLOW [15 ⊕ ∽ 17. ACTOILFLOW [15 ⊕ ∽ 18. WAQA_CO [20]	Add Calibration					
B ← 19. ACTCALFLOW [2' B ← 20. AmbPress [22] B ← 21. FDMS_ADD [23] B ← 22. FDMS_BASE [24]	Select Sequence Neph2Pt  Add Calibration					

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.

🧐 🔡 I 🗢		Envidas U	lltimate Setup		- Ξ Σ
File Operational Configuration	Help				
View Settings <u>Analyzer</u>	Propert	ies Device <mark>Diagnostics</mark>	Digital Status Spare Pa	arts	
□-2 10th & Weller □-3 Adam 5017		ollect Every 10 (	On Minutes		Get Default
Adam 5069     Adam 5069     Adam 5069		Indeu	Command	Nama	Unite
		Index	co	Name CO Cono	DDM
		2		Chability	
🖻 🧼 Channels		2			rrm edd
in ∞ 12. CO [14]		3			IIIY
		4 E			
API-700EU		0	AUTUZENU		
🛓 🝝 API-200EU		b	SAMPPRESS	Pres	IN-HG-A
🖶 🍝 FDMS		/	SAMPFLUW	Sample flow rate	LL/M
API703		8	BENCHTEMP	Bench Iemp	
⊞.≪S Bam1U2U		9	WHEELTEMP	Wheel Temp	
		10	BOXTEMP	Box Temp	C
		11	PHOTOTEMP	PHT Drive	mV
		12	COSLOPE	Slope	
		13	COOFFSET	Offset	
		14	COREF	Detector Reference	mV
		15	RANGE	Instrument Range	PPM
		16	RESPONSE	Instrument Response	
		17	REF	CO Reference	mV
		18	OVENTEMP	Oven T	C
		19	BOXTEMP2	box T 2	С
		20	TESTCHAN		mV
	•	21	CLOCKTIME	instru time	
	*				

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

# 6. Nitrogen Oxides (NO<sub>X</sub>) and Reactive Nitrogen (NO<sub>Y</sub>) 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<sub>Y</sub> 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<sub>X</sub> and NO<sub>z</sub>, 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<sub>x</sub> and NO<sub>Y</sub> analyzers described here detect the chemiluminescence that occurs when NO reacts with O<sub>3</sub>. As ambient air is drawn through the analyzer's reaction cell, the analyzer introduces O<sub>3</sub> to the reaction cell. The NO in the ambient air reacts with the O<sub>3</sub> to form NO<sub>2</sub> and O<sub>2</sub>, with a portion of the newly formed NO<sub>2</sub> retaining excess energy in an excited energy state (denoted as NO<sub>2</sub><sup>\*</sup>). The NO<sub>2</sub><sup>\*</sup> 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<sub>2</sub> 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<sub>2</sub> concentrations for the NO<sub>x</sub> analyzers. The analyzer calculates the NO<sub>2</sub> concentration in the sample by subtracting the NO concentration measured when the sample bypasses the molybdenum converter from the NO<sub>x</sub> concentration (NO<sub>2</sub> = NO<sub>x</sub> – NO). The NO<sub>Y</sub> analyzer differs from the NO<sub>x</sub> analyzer in that it places the molybdenum converter very close to the probe inlet. The very reactive NO<sub>z</sub> 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<sub>x</sub> 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<sub>X</sub>/NO<sub>Y</sub> 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<sub>X</sub>/NO<sub>Y</sub> monitoring. To the extent practical, the NO<sub>Y</sub> external molybdenum converter should be mounted approximately 10 m above ground and as close as possible to the point of sampling.

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.

Table 6-13: Summary	of NO/NO <sub>2</sub> /NO <sub>X</sub> /NO <sub>Y</sub>	siting criteria
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## 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<sub>2</sub>/NO<sub>X</sub>/NO<sub>Y</sub> 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<sub>Y</sub> is described in the TAPI T200U NO<sub>Y</sub> 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.

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 $\leq 96\%$ or $\geq 104\%$	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

Table 6-14:	Summary of	of required	NO <sub>2</sub> /NO <sub>2</sub>	analvzer	maintenance
	Summary	orrequired		anaiyzei	maintenance

Procedure	Frequency	Section
Replace external pump NO <sub>X</sub> 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 <sub>X</sub> slope exceeds $1.0 \pm 0.3$ 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<sup>th</sup> percentile of hourly concentrations at the site over the previous 3 years multiplied by 1.5. If the 99<sup>th</sup> 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<sub>X</sub>/NO<sub>Y</sub> 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  $\leq$  10 LPM, and 35 psi for total flows between 10 and 20 LPM.
- 2. Select TST to display the current NO and NO<sub>X</sub> 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<sub>X</sub> and change the concentration displayed to the value of the calibration scale calculated for NO<sub>X</sub> 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<sub>x</sub>. 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.
- 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<sub>x</sub> 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<sub>X</sub> 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<sub>X</sub> slope falls outside 1.0  $\pm$  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<sub>Y</sub> analyzers use different filters from ozone, SO<sub>2</sub>, 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 <sup>3</sup> /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 <sub>3</sub> air filter cartridge is exhausted. Change chemical.
NO <sup>2</sup> (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	Decreasing	Drift of instrument response. Clean RCEL
	concentrations	over time	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<sub>Y</sub> analyzers have two sample ports, one for NO and one for NO<sub>Y</sub>. 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  $\pm$  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  $\geq$ 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<sup>®</sup>) 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<sub>X</sub> 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<sub>Y</sub> requires familiarity with the T200 manual and T200U and T200U NO<sub>Y</sub> 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<sub>2</sub>/NO<sub>x</sub> concentration channels are shown in Figure 6-3 through Figure 6-5. Three data channels must be configured to record NO, NO<sub>2</sub> and NO<sub>x</sub> concentrations in ppb for NAAQS compliance evaluation, to support modeling and other applications and for display on Ecology's public website. For the NO<sub>Y</sub> analyzer these channels are NO, NO<sub>Y</sub> and DIF, where DIF is the difference measurement between NO<sub>Y</sub> and NO.

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Figure 6-28: NO channel configuration

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Figure 6-29: NO<sub>2</sub> channel configuration

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Figure 6-30: NO<sub>x</sub> channel configuration

There are two separate QC check sequences run for NO/NO<sub>X</sub>/NO<sub>Y</sub> chemiluminescence instruments. The first is a QC check for the NO/NO<sub>X</sub>(NO<sub>Y</sub>) channels, and the second is a QC check for the NO<sub>2</sub> (DIF) channel and converter efficiency. The NO/NO<sub>X</sub>(NO<sub>Y</sub>) QC check is a dilution calibration where NO gas is used to QC the NO and NO<sub>X</sub>(NO<sub>Y</sub>) channels. The NO<sub>2</sub> QC check uses GPT to generate different concentrations of NO<sub>2</sub> through the reaction of NO and O<sub>3</sub>.

### 6.6.1.1. NO/NO<sub>X</sub>(NO<sub>Y</sub>) QC check sequence

The configuration for a multi-point QC check for NO and NO<sub>x</sub> 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<sub>x</sub>. 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).

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Figure 6-31: NO/NO<sub>X</sub> QC sequence properties

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Figure 6-32: NO/NO<sub>X</sub> QC sequence configuration
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#### Figure 6-33: NO/NO<sub>X</sub> QC validation limits configuration

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Figure 6-34: NO/NO<sub>X</sub> QC configuration of phases and reference values

#### 6.6.1.2. NO<sub>2</sub> QC check sequence (converter efficiency check)

The configuration for a multi-point NO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>, respectively. During GPTZ, NO gas is generated in the same manner as a GPT calibration, but the O<sub>3</sub> generator lamp is un-energized, thus producing no O<sub>3</sub>. The GPTZ phase is used for obtaining the baseline NO and NO<sub>X</sub> readings. The GPTZ readings are referred to as [NO]<sub>original</sub> and [NO<sub>X</sub>]<sub>original</sub>. The GPT phases subsequent to the GPTZ phase generate 40 and 80 ppb of O<sub>3</sub>, which generate 40 and 80 ppb NO<sub>2</sub>. The GPTZ and GPT phases must have the same flowrate and NO concentration. During the GPT phase the NO and NO<sub>X</sub> readings are referred to as [NO]<sub>remaining</sub> and [NO<sub>X</sub>]<sub>remaining</sub>. 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<sub>X</sub> and NO<sub>2</sub> 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<sub>x</sub> 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<sub>2</sub> channel and converter efficiency using equations 6-1 through 6-3. Appendix A3 shows an example of the NO<sub>2</sub> converter efficiency QC excel worksheet. This must be filled out when an NO<sub>2</sub> 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:  $[NO_2]_{impurity} = [NO_2]_{actual} - [NO]_{actual} during the GPTZ phase. [NO]_{actual} and [NO_2]_{actual} are calculated from the dilution calibration flowrates ACTDILFLOW, ACTCALFLOW, and O3GENFLOW, and the NO and NO<sub>X</sub> cylinder concentrations.$ 

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<sub>2</sub> Actual concentrations are calculated as [NO]<sub>original</sub>-[NO]<sub>remaining</sub>, and therefore are not reliant on the ActO3 matching the Target O<sub>3</sub>. To ensure consistency, if the NO<sub>2</sub> Actual is greater than 10 ppb from the target NO<sub>2</sub> in the GPT sequence, manually run a GPTPS using the same concentrations and flowrates.

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Figure 6-35: NO<sub>2</sub> converter efficiency QC sequence properties

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Figure 6-36: NO<sub>2</sub> converter efficiency QC sequence configuration

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Figure 6-37: NO<sub>2</sub> converter efficiency QC configuration of phases & reference values for NO channel

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Figure 6-38: NO<sub>2</sub> converter efficiency QC configuration of phases & reference values for NO<sub>X</sub> channel

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

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

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Figure 6-41: NO<sub>2</sub> converter efficiency QC configuration of phases and reference values for the O<sub>3</sub> gen flow channel



Figure 6-42: Time series of NO, NO<sub>x</sub>, and NO<sub>2</sub> during a NO<sub>2</sub> converter efficiency QC using GPTZ and GPT

#### 6.6.1.3. NO<sub>Y</sub> converter efficiency check

The NO<sub>Y</sub> 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<sub>Y</sub> 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<sub>Y</sub>] 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<sub>Y</sub>] channels should be a 2-minute average of the ACTCONC channel as seen in Figure 6-20 and Figure 6-21.

The [NO]<sub>remaining</sub> and [NO<sub>Y</sub>]<sub>remaining</sub> during IPN/NPN phase of the QC check are used to converter efficiency offline using the NO<sub>Y</sub> 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.

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Figure 6-43: NO<sub>Y</sub> converter efficiency QC sequence properties

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	Add Phase		Delete Pha	sse

Figure 6-44: NO<sub>Y</sub> converter efficiency QC sequence configuration



Figure 6-45:  $\ensuremath{\text{NO}_{\text{Y}}}$  converter efficiency QC configuration of phases and reference values for the NO channel

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Figure 6-46: NO $_{\rm Y}$  converter efficiency QC configuration of phases and reference values for the NO $_{\rm Y}$  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.

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Figure 6-47: Configuration of NO/NO<sub>X</sub>/NO<sub>2</sub> analyzer diagnostic parameter collection

## 7. Nitrogen Dioxide (NO<sub>2</sub>) Monitoring by Cavity Attenuation Phase Shift (CAPS)

## 7.1. Introduction

This chapter describes the standard operating procedure for "true" nitrogen dioxide (NO<sub>2</sub>) monitoring by cavity attenuation phase shift (CAPS) spectroscopy within the Washington Network. A "true" NO<sub>2</sub> measurement is a requirement for Photochemical Assessment Monitoring Stations (PAMS). The QC requirements for NO<sub>2</sub> as part of the PAMS network are more stringent than NO<sub>2</sub> measured at near-road sites.

This chapter includes procedures for installation, operation, quality control, maintenance, and data acquisition for CAPS NO<sub>2</sub> 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<sub>2</sub> measurements.

## 7.2. Principles of operation

The cavity attenuation phase shift (CAPS) spectroscopy NO<sub>2</sub> 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<sub>2</sub> prominently absorbs light at 450 nm, so the presence of NO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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 <u>Air Monitoring Project Approval, Site Selection, and Installation Procedure</u> for further information on site selection.

#### Quality control and maintenance 7.5.

#### **Quality control checks** 7.5.1.

No additional quality control is required beyond the steps described in Section 2.3. The action levels and acceptance limits for NO<sub>2</sub> 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<sub>X</sub>/NO<sub>Y</sub> limits for NCore or near-road sites. When running NO<sub>2</sub> as part of PAMS, primary QC checks every other day are recommended.

Table 7-16: CAPS NO <sub>2</sub> QC check acceptance criteri	Table 7-16:	CAPS NO <sub>2</sub> C	C 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.

able 7-17: Summary of required CAPS NO <sub>2</sub> 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 <sup>3</sup> /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<sub>2</sub> instrument in the field.

The reference NO<sub>2</sub> 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<sub>2</sub> 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.

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 <sup>-1</sup> of check-out value	Significantly increasing	Developing AREF valve failure. Replace valve.
	Constant within ±100 Mm <sup>-1</sup> of check-out value	Significantly increasing	Developing leak in pneumatic system. Check for leaks.
	Constant within ±100 Mm <sup>-1</sup> of check-out value	Significantly increasing	Debris on mirrors. Replace charcoal scrubber.
NO <sub>2</sub> (Concentration)	Constant for constant concentrations	Slowly decreasing signal for same concentration	Developing leak in pneumatic system. Check for leaks.

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

#### 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  $\pm$  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 handheld 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<sup>®</sup>) 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<sup>3</sup>/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<sub>2</sub> 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<sub>2</sub> concentration channels are shown in Figure 7-1. The data channel must be configured to record NO<sub>2</sub> concentrations in ppb for NAAQS compliance evaluation, PAMS compliance where applicable, to support modeling and other applications, and for display on Ecology's website.

	Envidas Ultimate Setu	ip.	- • ×
File Operational Configuration Help			
View Settings <u>Analyzer</u>	Channel Digital Monitor Status Validation I/O Validation Alarm	16 )	
B-A SEABEACO		Validation I	Limits
🗄 🍜 Adam 5017	Name N02_CAPS	Analyzer API-T500-U 👻 🗌 Range f	Deviation
M903 Nephelometer	Ch. Address 33 🗸	Channel no2 - O By Perc	entage 🔘 ByValue
Adam 5080 Counter	Unit ppb	Low	
E TOMS	Carid #	EU Conversion	
🕀 🚳 API-700-EU		Low Volt	1
API-T100U	Low Range 0	High Volt Change	as Percent of Range
E - API-300-EU	High Range 100	Percentane	
⊕ - → API-400E	Threshold % 75 🔹	Linear Correction	(Cat Magative ) (alue to (I)
- 4PI-700-EU	24Hr Thresh % 75		(Servegarive value to 0)
🕀 🍜 Adam 5069	Pollutant Type (None)	Consta	ant Constant
⊕ -≪ Adam 5069	View Format	2 Mak Disks	pentage 🥥 By Value
API-T500-U		web Display # of Sampl	les
E- Channels	On •	Value	
29. NO2_CAPS [33]	Average Mean 👻	📃 By Tim	ebase 🧿 By Instant
Calibrations	Channals for Australia Calculation	Value Manipulation	
API-T703	Pole Channel	Enable	Formula
API-703	The Chainer		
		Earmula Basia Commando	
		rormula Basic Commands	
	Extra Data For Average	Return The Value: return End function: :	
	Role Value	Display function, command and value selection Box: <ctrl>+</ctrl>	Space>
		Select a channel: <ch.name> or <ch.name_sitename> Function : Fx(), Parameter (a,b,c)</ch.name_sitename></ch.name>	
		Math operators: +, -, /, *, % (modulo) Logic operators: & (and),   (or), ^ (xor) ,! (not), << (shift left)	),>>(shift right)
		*In large stations uploading formula may take some time	
	PIPAULSV EPA Directive		
	Method Code 000		
	Daily ELV		

Figure 7-48: CAPS NO2 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<sub>3</sub> concentration into the reaction cell, and thus the NO<sub>2</sub> 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<sub>2</sub> monitoring at the site. It will take about 20-30 minutes for the GPTPS to lock in the O<sub>3</sub> value the first few times it is run. The calibrator should be preconditioned until it locks in the specified O<sub>3</sub> value in the time set in the automated sequence, which is 10 minutes in the example below. NO<sub>2</sub> 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<sub>2</sub> GPT phases should last at least 20 minutes, not including the GPTPS phase. The dilution calibrator does not provide a channel average NO<sub>2</sub> value as is done with CO, SO<sub>2</sub>, 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<sub>2</sub> channel average that does not include the last minute of the phase.

**Note**: This is a different method than for NO<sub>2</sub> QC checks conducted on a NO/NO<sub>x</sub> instrument. CAPS NO<sub>2</sub> singularly measures NO<sub>2</sub> without NO<sub>x</sub> or NO, so there is no way to determine NO<sub>2</sub> through the method described in Section 6.6.1.2.

nali= Eler Overational Configuration Help		Envidas Ultimate Setup	- e z	
Wew         Soltings         Analyzer         Properties           ID: Association         Properties         Name:         Name:	Sequence	2,2m	1	
100         TraceCO_3P1         State:           100         000         P00         P00           11         taceKO_3p1         D00         P00           11         taceKO_3p1         D000F         State	On bit Sequence: (None) Trigger: (None)	Dn None) [None] [None] Run Manual Start Sequence Immediately		
CAPS_NO2_set     TraceSO2_set     Schedul     New_CAPS_NO2_set     New_CAPS_NO2_set     Schedul     New_CAPS_NO2_set     Schedul     New_CAPS_NO2_set     Schedul     New_CAPS_NO2_set     Schedul     New_CAPS_NO2_set     New-CAPS_NO2_set     New-CAPS_NO2_se	e Interval Interval me 9/ 6/2019 03:01 t Every 02 Days 00 dy on These Days: Sunday Monoday Toenday Wedeneday	Hours and 00 Minutes Hours Solution Kinday Solution Kinday Solution Kinday		
Riun Dri Cabbato Sen (7) Sen	Ny Between These Times: 00.00 W nd Analyzer Calibration Commands nd Calibrator Command	Make sure Send Analyzer Calibration Commands is not checked	]	
Calibrate	or API-700-EU	•		

Figure 7-49: CAPS NO<sub>2</sub> QC sequence properties configuration

				Envidas Ultimate Setup	- • ٤	
Here         Operational         Contiguration         Help           View         Settings         Analyzer         Image: Contiguration         Help	Prope	arties Sec	uence			
B Sites B Sequence TraceOQ_3Pt D Cone_3pt TraceOQ_3pt TraceSQ2_3pt TraceSQ2_3pt NEW_CAPS_NO2_2pt NEW_CAPS_NO2_3pt NEW_CAPS_NO2_3pt Surger CaPS_NO2_3pt Surger CaPS_NO2_3pt NEW CAPS_NO2_3pt Surger CaPS_NO2_3pt Video Record Surger Sites Surger Sites Surger Sites Surger Sites Surger Sites Surger Sites Surger Sites Sit		HH:mm:ss		- Olafigð		
	► 00:	00:00:00	Mode Calibrator Command Digital Output	Zero c generate zero Site SEABEACO Digital Output ONDy OSO2 ONO2 OTraceNOdiffCal OTraceNOCal		
		00:20:00	Mode Calibrator Command Digital Output	Purge         GPTZ and GPT sequences programmed in need to be in quotation marks           Site SEABEACO Digital Output         Site SEABEACO Digital Output	nto the calibrator	
	01:00.00		Mode Calbrator Command D0:30:00 Digital Output	NDy SD2 CD ØND2 OTraceNOdiffCal OTraceNOCal		
		00:30:00		c execseq "GPT_40PPB" Site SEABEACO Digital Output ONDy OS02 OD OND2 TraceN0diffCal OTraceN0Cal		
		01:00:00	Mode Calibrator Command Digital Dutput	Purge c generale zero Site SEABEACO Digital Output ONDy OSO2 OCO ONO2 OTraceNOdiffCal OTraceNOCal		
		01:05:00	Mode Calibrator Command Digital Output	Purge c standby Site SEABEACO Digital Output ONDy OSO2 OC0 ONO2 OTraceNOdiffCal OTraceNOCal		
		01:05:00 Add Phase	Calibrator Command Digital Output	c standby Site SEABEACO Digital Output ONDy OSO2 ONO2 OTraceNOdiffCal OTraceNOCal	Telete Phase	

Figure 7-50: CAPS NO<sub>2</sub> QC sequence configuration part 1

<b>4</b> 12 -	Envidas Ultimate Setup				
File Operational Configuration Help					
View Settings Analyzer Properties Sequence					
HH:mm:ss		digitalIO		^	
-10 Auto_Ozone_2pt Mode	Span				
TraceCU_SPT Dzone_3pt Calibra	Command c execseq "GPT_40PPB"				
1         TraceND_3pt         00.30.00         Digital           1         TraceND2_3pt         00.30.00         Digital           1         TraceND2_3pt         00.30.00         Digital           1         TraceND2_3pt         00.30.00         Digital	site SEABEACO Digital Output	€C0  €N02	CTraceNOdifCal CTraceNOCal		
- NEW_CAPS_N02_zpt Mode	Purge				
DiPN_Moly_check Calibra	Command c generate zero				
Digital 01:00:00 Digital 01:00:00:00 Digital 01:00:00 Digital 01:00:00 Digital 01:00:00 Digital 01:00:00 Digital 01:00:00 Digital 01:00:00:00 Digital 01:00:00:00:00 Digital 01:00:00:00:00:00:00:00:00:00:00:00:00:0	Site SEABEACO Digital Output	€C0 €N02	CTraceNOdifiCal		
Mode	Purge	Puge			
Calibra	Command c standby	c standby			
01-05:00 Digital	put Site SEABEACO Digital Output	€C0 €N02	CTraceNOdifCal CTraceNOCal	E	
Mode	Sample				
Calibre	Command c standby				
01-06-00 Digital	Site SEABEACO Digital Output	©C0 ©N02	©TraceN0difCal ©TraceN0Cal		
Add Phase		💽 On Cott Care		Delete Phase	

Figure 7-51: CAPS NO<sub>2</sub> QC sequence configuration part 2

<b>Ø</b> \$1 [] =	Envidas Ultimate Setup						
File Operational Configuration Help							
View Settings <u>Analyzer</u>	Initial Calibration	Validation Limits		Make sure Calibration Correction is not			
E-2 SEABEACO	Enable Calibration Correction	Span Diff(2 Of Bef )	10	spabled			
🕀 💿 Adam 5017		opar bill(re of fici.)		enabled			
M903 Nephelometer	Zero Urrset	Zero Drift (% Of Range)	0.2				
Calculated Channels	Factor 1	Factor Low	0.7				
Adam 5080 Counter		Factor High	1.3				
+							
API-780-20	Collection Coll & New						
APL-T1001	Calibration Fail Action	CARDING MADE IN 1999					
API-300-EU	Set Monitor Status ToDutcair Outside	a validation Limit					
TEI-42C	Set Monitor Status ToDK_CalibFail" Ar	nd "OutCal" If Outside 2× the Validation	in Limit				
API-703E	(Must Enable OK XXX Status Under D	(ptions)					
⊕ - 🐼 API-400E	Digital Output (None)	1	-				
-3 API-700-EU							
-3 703	Use EPA Part 60/75 00C Rules						
🕣 🚳 Adam 5069	- Set Channel Status to DDC (Dut of C	ontroll After the Zero or Span Limit is Ev	readed				
🗈 🐟 Adam 5069	for this number of consecutive calibra	tions.	5				
Adam 5017			-				
	Set Channel Status to ODC if this num	ber of hours has elapsed since the last	calibration.				
			29				
Calib NEW CAPS ND2 2pt	Add Calibration			Select Sequence from dron down menu and			
Lalib NEW CAPS NO2 3pt	Select Sequence NEW CAPS N	02 2pt	•	"Add Calibration" to add accusate the			
				Add Calibration to add sequence to the			
		Add C	Calibration	channel			

Figure 7-52: CAPS NO<sub>2</sub> QC validation limits configuration



Figure 7-53: CAPS NO<sub>2</sub> 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.

		annuas energias secon		
Propert	ties Device Diagnostics Digital Status	Spare Parts		
20	ollect Every 10 On Minutes			Get
	Index	Command	Name	Units
•	LP CONTRACT	N02	N02	PP6
	2	RANGE	RANGE	PP8
	3	PHASE	PHASE	DEG
	4	MEAS	MEAS	MM-1
	5	AREF	AREF	MM-1
	6	SAMPLEPRIS	SAMPLEPRES	InHG
	7	SAMPTEMP	SAMPTEMP	C
	8	BOXTEMP	BOXTEMP	c
	9	SLOPE	SLOPE	
	10	OFFSET	OFFSET	PPB
	11	STABILITY	STABILITY	PPB .
	12	OVENTEMP	OVENTEMP	c
		0.00000000		
	Property Control of Co	Properties         Derive         Composition         Digital Status:           Image: Status         Image: Status         Image: Status         Image: Status           Image: Status         Image: Status         Image: Status         Image: Status         Image: Status           Image: Status         Image: Status         Image: Status         Image: Status         Image: Status         Image: Status           Image: Status         Image: Status         Image: Status         Image: Status         Image: Status         Image: Status         Image: Status         Image:	Properties         Direct Status:         Space Parts           Collect Every         10         On Minutes           Index         NO2         Parkade           2         Parkade         A           3         Parkade         A           4         MEASE         A           5         APEF         6           5         APEF         0           9         SLOPE         0           11         OFSET         0           12         OVENTEMP         0	Propertie         Direct Status         Space Parts           Context Every         10         On Mendes           Index         No2         MAGE           2         PANGE         PANGE           3         PANGE         PANGE           4         MEAS         MEAS           5         AREF         AREF           6         SAMPLEPPIS         SAMPLEPPES           7         SAMPLEPPIS         SAMPLEPPES           8         DOCKEMP         OCHEMP           9         SLOPE         SLOPE           11         STABILTY         STABILTY           12         OVENTEMP         OVENTEMP

Figure 7-54: Configuration of CAPS NO<sub>2</sub> analyzer diagnostic parameter collection

## 8. References

Ambient Air Monitoring Reference and Equivalent Methods" <u>Code of Federal Regulations</u> Title 40, Pt. 53, 2020 ed.

"Interpretation of the Primary National Ambient Air Quality Standards for Oxides of Nitrogen (Nitrogen Dioxide)" <u>Code of Federal Regulations</u> Title 40, Pt. 50, Appendix S, 2017 ed.

"Measurement Principle and Calibration Procedure for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence)" <u>Code of Federal Regulations</u> Title 40, Pt. 50, Appendix F, 2017 ed.

"National primary and secondary ambient air quality standards for oxides of nitrogen (with nitrogen dioxide as the indicator)" <u>Code of Federal Regulations</u> Title 40, Pt. 50.11, 2017 ed.

"Network Design Criteria for Ambient Air Quality Monitoring" <u>Code of Federal Regulations</u> Title 40, Pt. 58, Appendix D, 2017 ed.

"Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring." <u>Code of Federal</u> <u>Regulations</u> Title 40, Pt. 58, Appendix E, 2017 ed.

"Quality Assurance Requirements for Monitors used in Evaluations of National Ambient Air Quality Standards." <u>Code of Federal Regulations</u> Title 40, Pt. 58, Appendix A, 2016 ed.

State of Alaska Department of Environmental Conservation. Division of Air Quality. <u>Standard Operating</u> <u>Procedures for Sulfur Dioxide (SO<sub>2</sub>) Monitoring by Ultraviolet Fluorescence</u>. Anchorage, 2012 (Revision 2).

\*\* Teledyne API's manuals and addenda listed below are sorted by the instrument type, then by year

Teledyne API (2014). Operation Manual: Models T701, T701H, 701, and 701H Zero Air Generators. San Diego, 2014.

Teledyne API (2011). Operation Manual: Model 701 Zero Air Generator. San Diego, 2011.

Teledyne API (2010). Operation Manual: Model 701H High Performance Zero Air Generator. San Diego, 2010.

Teledyne API (2009). Addendum for Model 701H Zero Air Module with Internal Dewpoint Sensor. San Diego, 2009.

Teledyne API (2015). Operation Manual: Model T700 Dynamic Dilution Calibrator. San Diego, 2015.

Teledyne API (2015). <u>Addendum: Model T700U Calibrator</u>. San Diego, 2015.

Teledyne API (2015). <u>Manual Addendum: Model 700EU Calibrator</u>. San Diego, 2015.

Teledyne API (2009). Operator's Manual: Model 700E Dynamic Dilution Calibrator. San Diego, 2009.

Teledyne API (2016). Operation Manual: Model T100 UV Fluorescence SO<sub>2</sub> Analyzer. San Diego, 2016.

Teledyne API (2011). Operation Manual: Model 100E UV Fluorescence SO<sub>2</sub> Analyzer. San Diego, 2011.

Teledyne API (2011). Addendum: Model T100U Trace Level UV Fluorescence SO<sub>2</sub> Analyzer. San Diego, 2011.

Teledyne API (2009). Addendum: Model 100EU Trace Level SO<sub>2</sub> Analyzer-Addendum. San Diego, 2009.

Teledyne API (2015). Operation Manual: Model T200 NO/NO<sub>2</sub>/NO<sub>X</sub> Analyzer. San Diego, 2015.

Teledyne API (2013). Manual Addendum: Ultra Sensitivity Model T200U NO/NO<sub>2</sub>/NO<sub>X</sub> Analyzer. San Diego, 2013.

Teledyne API (2013). <u>Addendum: T200U NO<sub>Y</sub> Analyzer</u>. San Diego, 2013.

Teledyne API (2010). Technical Manual: Model 200E Nitrogen Oxide Analyzer. San Diego, 2010.

Teledyne API (2010). Manual Addendum: Ultra Sensitivity Model M200EU NO/NO<sub>2</sub>/NO<sub>X</sub> Analyzer. San Diego, 2010.

Teledyne API (2010). <u>Addendum: M200EU-NO<sub>Y</sub> Converter</u>. San Diego, 2010.

Teledyne API (2015). Operation Manual: Model T500U NO<sub>2</sub> Analyzer. San Diego, 2015.

Teledyne API (2012). Operation Manual: Model T300 Gas Filter Correlation CO Analyzer. San Diego, 2012.

Teledyne API (2012). Manual Addendum: Model T300U Ultra-Sensitive Gas Filter Correlation CO Analyzer. San Diego, 2012.

Teledyne API (2011). Operation Manual: Model 300E/EM CO Analyzer. San Diego, 2011.

Teledyne API (2008). Operation Addendum: Model 300EU CO Analyzer. San Diego, 2008.

U.S. Environmental Protection Agency (2016). National Exposure Research Laboratory. <u>List of Designated Reference and Equivalent Methods</u>. Research Triangle Park, 2016 (https://www3.epa.gov/ttn/amtic/criteria.html).

U.S. Environmental Protection Agency (2017. Office of Air Quality Planning and Standards. <u>Quality</u> <u>Assurance Handbook for Air Pollution Measurement Systems Volume II: Ambient Air Quality</u> <u>Monitoring Program</u>. Research Triangle Park, 2017 (EPA-454/B17-001).

U.S. Environmental Protection Agency (2012). National Risk Management Research Laboratory.

EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards. Research Triangle Park, 2012 (EPA-600/R-12/531).

U.S. Environmental Protection Agency (2012). Office of Air Quality Planning and Standards. <u>Near-road</u> <u>NO<sub>2</sub> Monitoring Technical Assistance Document</u>. Research Triangle Park, 2012 (EPA-454/B-12-002).

U.S. Environmental Protection Agency (2005). Office of Air Quality Planning and Standards. <u>Technical</u> <u>Assistance Document (TAD) for Precursor Gas Measurements in the NCore Multi-Pollutant Monitoring</u> <u>Network, version 4</u>. Research Triangle Park, 2005 (EPA454/R-05-003).

U.S. Environmental Protection Agency (2019). Office of Air Quality Planning and Standards. Technical Assistance Document (TAD) for Sampling and Analysis of Ozone Precursors for the Photochemical Assessment Monitoring Stations Program – Revision 2. Research Triangle Park, 2019 (EPA-454/B-19-004).

## **Appendices**

## Appendix A. Quality Control Check Forms Appendix A1. SO<sub>2</sub> CO, CAPS NO<sub>2</sub> QC form

Pr	Washingto ecursor Pol	on State De lutant Oua	partment o lity Control	f Ecology Check Form			
Revised 0 305 2021		<b>-</b>	,				
QC Form Type				Parameter			
AQS No			I	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			M	aintenance La	st Performed:		
				Analyzer			
Gas Cylinder Serial No			.	Calibrator			
Gas Cylinder Exp. Date				Zero Air			
Cylinder Conc. (ppm)				Probe & Lines			
Cylinder Pressure (psi)			Room Temp Device				
Conditions since las	t QC:						
Any failed QCs sin	ce last visit?			Min Room	Temp (°F)		
Calibration	Performed?			Max Room Temp (°F)			
Diagnosti	cs normal*?		Pa	Particulate Filter Changed?			
*within normal range per Gas	eous SOP. If No, s	pecify below					
			1.0		I		
	As	s-Left					
Slope							
	0	nset					
QC Check Results:							
	Target	Actual	Indicated	Difference	Results		
Zero	0						

	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

	V	Vashington	1 State Depa	rtment of Eco	logy
	Prec	ursor Polli	utant Qualit	y Control Che	CKFORM
Revised 03 05 20 21					
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			Ma	aintenance La	st Performed:
				Analyzer	
Gas Cylinder Serial No				Calibrator	
Gas Cylinder Exp. Date				Zero Air	
Cylinder Conc (ppm)				Probe & Lines	
Cylinder Pressure (psi)			Room	n Temp Device	
Conditions since las	t QC:		I		
Any failed QCs sin	ce last visit?			Min Room	Temp (*F)
Calibration	Performed?		_	Max Room	lemp (°F)
Diagnosti	cs normal*?	and the last	Pa	rticulate Filter	Changed?
within normai range per ua	seous sor: ij no,s	specify below.			
Calibration	Factors (N	D)	Ca	libration Fact	ors (NOx.NOy)
Slope				Slope	
Offset				Offset	
Conversion Efficien	ey:	. 1		Y/N	Most recent CE
Near-Road NOx	Any CE failu	re since las	tQC?		
NCore NOy	CE performe	ed during ti	us 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:

	Fill in the white cells							
	NO <sub>2</sub> / Conversion Efficiency Calculations							
		,	* Fill in white cells	*				
Control # 082019						Results		
S	ite	Entry from"All Cal	ibrations" Rep	ations" Report GPT7 (Orig)				PASS/FAIL
Site Name	SEA10WEL	Calibration Report Date	10/3/2019		[NO out] NO Actual NO Indicated		NO Diff %	<15%
Site AQS ID	530330030	Calibration Report Time	3:05		100.11	99.642	-0.47	PASS
Operator	JL		Meas		[NO <sub>x</sub> out] NOx Actual	NO <sub>x</sub> Indicated	NOx Diff%	<15%
Analyzer S/N	223	Zero Measured NO	-0.28	ppb	100.41	99.967	-0.44	PASS
Calibrator S/N	124	NO(Orig)Span Level 1	99.642	ppb	,			
Zero Air S/N	577	NO(Rem)Span Level 2	17.842	ppb	Primary			
Tank NO(Rem)Sp		NO(Rem)Span Level 3	0.123	ppb	[NO <sub>2</sub> out] NO <sub>2</sub> Actual	NO <sub>2</sub> Indicated	NO <sub>2</sub> Diff%	<15%
Cyl Serial #	JB03058	Zero Measured NOX	0.076	ppb	82.09	82.96	1.05	PASS
Exp Date	7/3/2021	NO <sub>x</sub> (Orig)Span Level 1	99.967	ppb	NO <sub>2</sub> Impurity	NO <sub>2</sub> Converted	Conv Eff%	>96%-104%<
NO Conc.	10.20	NO <sub>x</sub> (Rem)Span Level 2	100.8	ppb	0.29	82.93	101.01	PASS
NO <sub>x</sub> Conc.	10.23	NO <sub>x</sub> (Rem)Span Level 3	96.898	ppb				
GPT 1	Targets	Dil_Flow	6.938	LPM		Secondary		
Orignal NO	100	ACTCALI_Flow	69	cc/m	[NO <sub>2</sub> out] NO <sub>2</sub> Actual	NO <sub>2</sub> Indicated	NO <sub>2</sub> Diff%	<15%
Primary NO <sub>2</sub>	40	O3GENFLOW	23.2	cc/m	99.81	96.78	-3.04	PASS
Secondary NO <sub>2</sub>	80	Total Flow	7.0302	LPM	NO <sub>2</sub> Impurity	NO <sub>2</sub> Converted	Conv Eff%	>96%-104%<
Total Flow LPM	7				0.29	96.74	96.93	PASS
	$NO_{2,Out}\{"X"\} =$	[NO] <sub>Original</sub> - [NO] <sub>Remainder</sub> + [	[NO <sub>2</sub> ] <sub>Impurity</sub>		NO <sub>2 Conv</sub> {"Y"} =	[NO <sub>2</sub> ] <sub>Out</sub> - {[NO <sub>x</sub> ] <sub>Original</sub> -	[NO <sub>x</sub> ] <sub>Remainder</sub> ]	•

## Appendix A3. NO<sub>X</sub> converter efficiency QC form

Revised 092419	
<b>IPN/NPN Conversion F</b>	Efficiency Calculation Sheet
Start Time (PST)	End Time (PST)
Target NPN (ppb)	
IPN/NPN CE check:	Nor
NO_rem	NOy_rem
NO2 =	NOx loss =
Conversion Efficiency =	
Must be≥ 96% an	$d \leq 104\%$ to pass
$CE(\%) = 1 - \left(\frac{N}{2}\right)$	$\left(\frac{NOX \ loss}{NO2}\right) \times 100\%$

### Appendix A4. NO<sub>Y</sub> converter efficiency QC form

## Appendix B. Linearity check form

Revised 08/06	Post-calibration linearity check									
	Location			¥	Date					
	AQS No				Operator					
Anal	lyzer Serial No									
Anal	lyzer State Tag_				QC Start Time		PST			
					QC Stop Time		PST			
Ga	s Cylinder S/N				Calibrator S/N	S/N				
Gas Cyliı	nder Exp. Date				[Gas Cylinder]					
	Pollutant				*Grey cells only o	apply to NOxy				
Cali	bration Point									
	Pre-Cali	bration	Post-Cali	bration	Pre-Calib	oration	Pre-Calib	e-Calibration		
Slope										
Offset										
			Linea	ity Check F	loculte					
	Actual	Indicated	ated Difference* Re		Actual	Indicated	Difference*	Results		
Zero										
	*Within 2% of the	e calibration ran	ige							
	Natas									
	Notes:									