Ozone Monitoring Standard Operating Procedure

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Olympia, Washington

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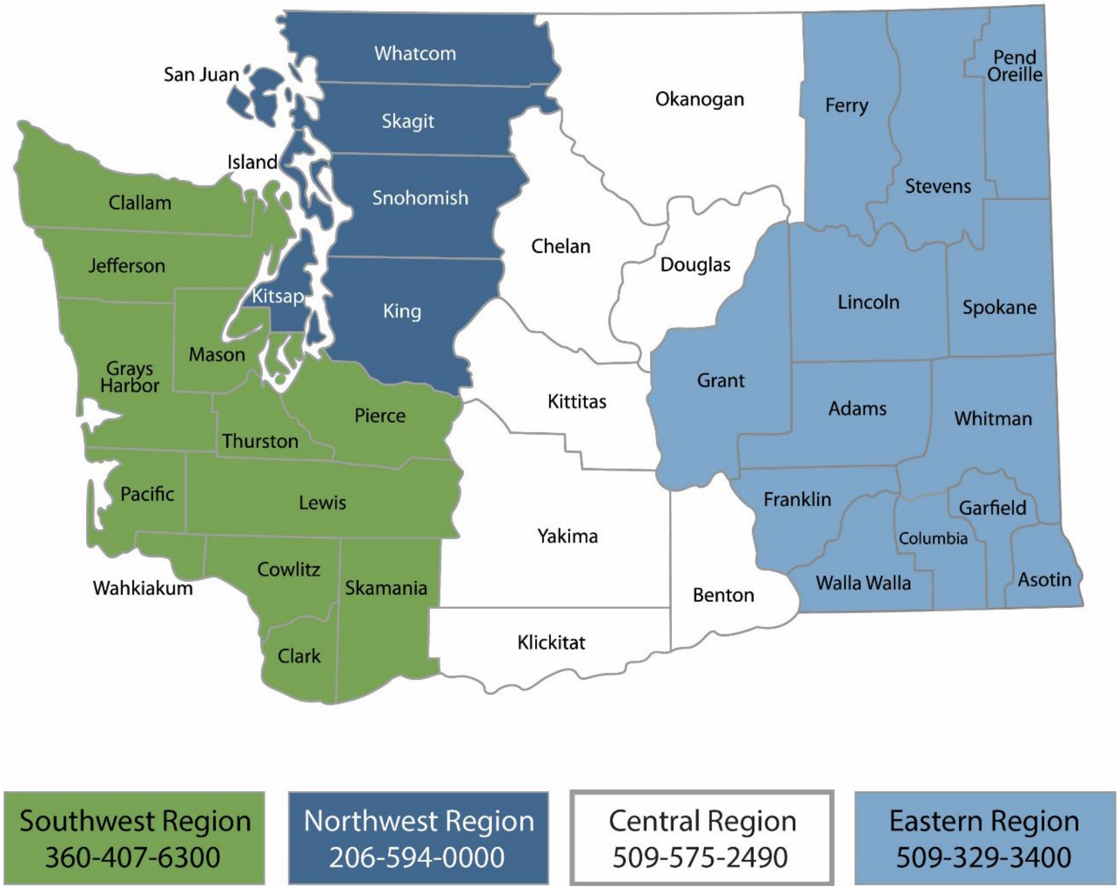

Region	Counties served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline,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

Air Quality Program

Washington State Department of Ecology
Olympia, WA

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Revision History

Revision Date	Revision Number	Summary of Changes	Revised Sections	Revised By
04/29/2025	1.0	Updated transfer standard certification guidance based on latest TAD. Misc. updates to content, figures, and structure. Removed discussion of Envidas.	1, 5, 6, 7	Cameron Richards

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Acronyms and Definitions

AC	Alternating current
AMTIC	EPA's Ambient Monitoring Technology Information Center
AQP	Washington State Department of Ecology Air Quality Program
AQS	EPA's Air Quality System database
cc/min	Cubic centimeters per minute
DQO	Data quality objective
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
LPM	Liters per minute
mV	Millivolts
NIST	National Institute of Standards and Technology
O_3	Ozone
ppb	Parts per billion
PST	Pacific Standard Time
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
SOP	Standard operating procedure
SRP	Standard reference photometer
TAD	Technical assistance document
TAPI	Teledyne Advanced Pollution Instrumentation
VOC	Volatile organic compound

Level 1 Ozone Calibration Standard: The highest-authority primary standard, typically a Standard Reference Photometer (SRP), which set the standard point of comparison for other photometers.

Level 2 Ozone Calibration Standard (Bench Standard): A transfer standard directly verified against a Level 1 standard, used in laboratory or stationary "bench" settings to certify Level 3 standards.

Level 3 Ozone Calibration Standard (Field Standard): A field-portable transfer standard verified against a Level 2 standard, used for routine calibration and quality control checks of ambient ozone analyzers.

Transfer standard: A transportable device or apparatus which, together with associated operational procedures, is capable of accurately reproducing pollutant concentration standards or of producing accurate assays of pollutant concentrations which are quantitatively related to an authoritative standard. In this document this term will be used to describe field and bench ozone transfer standards.

Teflon^(R): Type of material, can include FEP, PFA, or PTFA.

Verification: The process used to relate a candidate transfer standard output to a standard of higher authority (to confirm adequate functionality?)

Washington Network: The Washington Ambient Air Monitoring Network of air monitoring sites operated as part of Ecology's Primary Quality Assurance Organization.

1. Introduction

1.1. Purpose and scope

This document describes the standard operating procedure for ozone monitoring within the Washington Ambient Air Monitoring Network (Washington Network) as part of the Washington State Department of Ecology's Primary Quality Assurance Organization.

It covers installation, quality control and maintenance for ozone analyzers, verification process on authoritative ozone calibrators called transfer standards, as well as data acquisition and review of ambient ozone monitoring data. All ozone analyzers currently used in the Washington Network are designated as Federal Equivalent Method (FEM). This document is applicable to Teledyne Advanced Pollution Instrumentation (Teledyne API) ozone analyzers (Model 400E/T400) and ozone calibrators (Model 703E/T703/T703U/T753U) and is intended to be used with the model-specific operation manual.

1.2. Data quality objectives

Data Quality Objectives (DQOs) are a set of systematic planning goals established for data collection to ensure that representative data is collected for its intended use. The DQOs for ozone monitoring within the Washington Network are to determine:

- attainment with primary and secondary National Ambient Air Quality Standards;
- representative ozone levels in populated areas;
- background concentrations in rural areas; and
- the extent of regional pollutant transport.

1.3. Health and safety

Ozone is a pale blue gas with pungent odor and is a strong oxidant due to its reactivity. Ground-level ozone is typically formed as a result of complex photochemical reactions involving volatile organic compounds (VOCs), oxides of nitrogen (NO, NO_2) and solar radiation. Prolonged or substantial exposure to ozone can lead to irritation of the respiratory system, reduced lung function and long-term damage to lung tissues.

When handling instruments that generate ozone or while working in an ozone-concentrated environment, the generated gas and exhaust must be properly vented to prevent a health hazard. If you feel any discomfort (e.g. chest pain, irritation in the eyes, nose, or throat) due to ozone exposure, leave the room or shelter immediately.

2. Principles of Operation

The ozone analyzer operates on the principles of ultraviolet (UV) absorption by ozone. A sample of ambient air is drawn into the instrument and illuminated at one end of the optical bench by a UV lamp. The UV intensity remaining at the opposite end of the bench is then measured by a UV detector. To calculate the amount of UV absorbed by ozone, the measurement/reference cycle is used to alternately obtain the reference and measurement UV intensity values by sending ozone-free air and sampled air to the optical bench, respectively. The cycle takes about 6 seconds and repeats every 6 seconds; it also effectively rejects interference from sources like SO_2, NO_x, and H_2O. A microprocessor uses the reference and measurement UV signals, sample temperature and pressure, and the calibration factors to calculate the final ozone concentrations using the Beer-Lambert law.

For the transfer standard, an ozone generator located upstream of the photometer (optical bench) is included in addition to all the components described above. The photometer continuously sends feedback to the ozone generator to adjust the lamp intensity to supply accurate ozone concentrations.

3. Equipment and Supplies

The diagnostic tools, parts and supplies necessary to operate and maintain an ozone monitoring site are summarized in Table 3-1 below.

Table 3-1: Summary of required equipment and supplies

Category	Equipment	Purchase schedule
Tools and equipment	Flexible Teflon® tubing (¼”)	Yearly or as needed
	Teflon® or stainless steel fittings (¼”)	Once, replace as needed
	Sampling funnel	Once, replace as needed
	Charcoal column	Once
	NIST-traceable flow meter	Once
	Various hand tools (screwdriver, volt meter, etc.)	Once
Consumables	PTFE particulate filter (47 mm diameter, pore size 5 µm)	Monthly or as needed
	Extra charcoal	Yearly or as needed

4. Installation Procedure

4.1. Siting

4.1.1. Siting criteria

Siting requirements for ozone monitoring probes are summarized in Table 4-1. The most common spatial scales for ozone monitoring within the Washington Network are urban, regional and neighborhood. Operators should refer to 40 CFR Part 58 Appendix E for additional siting criteria on ozone monitoring.

Operators should also refer to Ecology's Air Monitoring Project Approval, Site Selection, and Installation Procedure for further information on site selection.

Table 4-1: Summary of O_3 siting criteria

Parameter	Category	Siting requirement
Inlet height	General	2 - 15 m above ground level
Inlet radius clearance	General	≥ 1 m vertically and horizontally away from supporting structure
	Near obstructions (building, walls, etc.)	≥ 2x height of the obstruction extended above the probe
	Near overhanging trees	≥ 10 m from the drip line
	Arc of air flow	Unrestricted, continuous 270° arc that includes prevailing direction of high concentrations
Distance from roadways	≤ 1,000 vehicles per day	≥ 10 m from nearest traffic lane
	1,000-10,000 vehicles per day	≥ 20 m from nearest traffic lane
	> 10,000 vehicles per day	Refer to 40 CFR Part 58 Appendix E, Table E-1
Distance from minor sources (e.g. incineration flues)	General	As far away as possible

4.1.2. Shelter conditions

Ozone analyzers and transfer standards 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°C and 30°C year-round. Room temperature must also be thermostat-controlled such that the standard deviation of daily room temperature hourly averages over 24 hours is less than 2.1°C. Analyzers and transfer standards must not be positioned directly under the output vent of the air conditioner.

4.2. Probe configuration

Ozone monitoring sites contain an analyzer, transfer standard and data logger to collect, calibrate and store ambient ozone concentration and calibration data. The system should be configured as shown in Figure 4-1. Contact the Calibration and Repair Lab if there are any challenges with achieving this setup at a site.

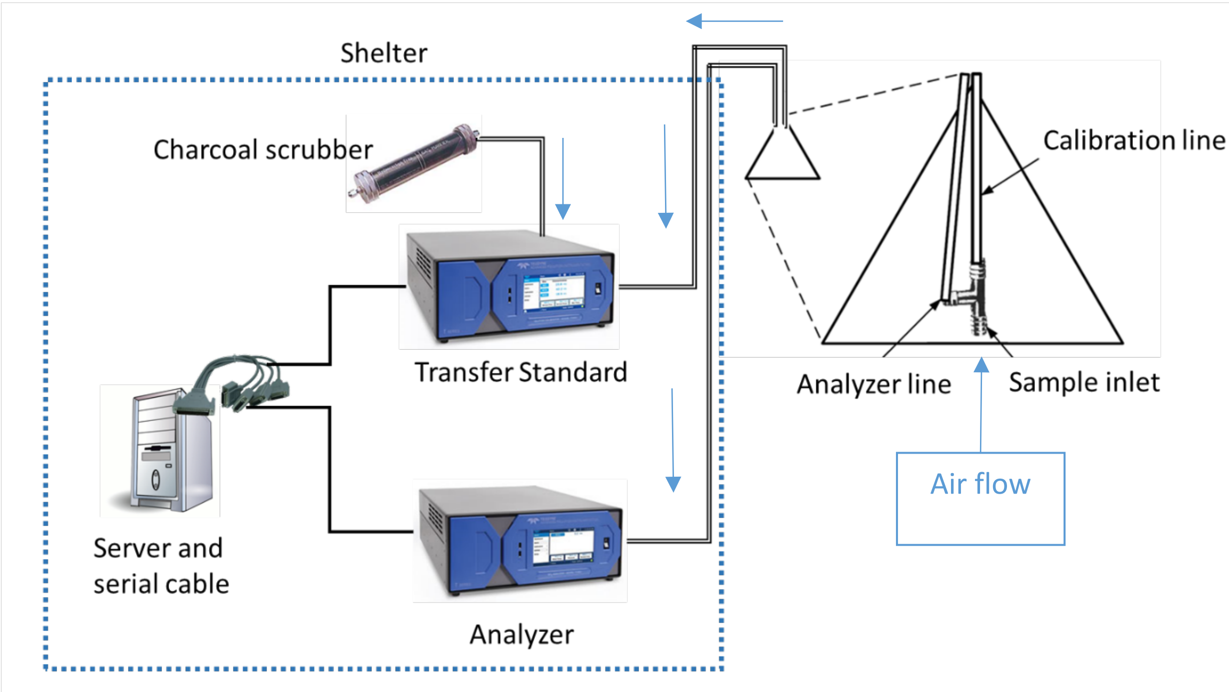

Figure 4-1: Configuration of station probes and instruments (photos from Teledyne API)

Inside the shelter, the analyzer and transfer standard are connected serially to the data logger via a 9-pin cable. A sample line runs from the analyzer to the outside of the shelter where it meets the calibration line that is connected to the transfer standard. An exhaust line should be connected to the exhaust port of the analyzer and vented to the exterior of the shelter to prevent ozone build-up during span checks and filter burn-outs. Ecology requires the use of an external active charcoal scrubber on the Dry Air port of the transfer standard to supply ozone-free air.

Outside the shelter, a tee must be used to connect the calibrator output line with the sample inlet line. This “through the probe” configuration allows calibration gas to be run through the full sample path to verify the complete sampling train. The tee is sheltered under a funnel to protect the probe from precipitation and debris.

All Washington Network ozone monitoring sites must use Teflon® tubing throughout the sampling train (from inlet probe to the back of the analyzer). The standard probe size is ¼” outer diameter. The only acceptable materials to be used for fittings in the sampling train are Teflon®, borosilicate glass, or their equivalent for all state and local monitoring stations, per 40 CFR Part 58 Appendix E, Section 9. Kynar® is not an acceptable material for surfaces in contact with the ambient air sample.

The length and size of the inlet tubing and flow rate must be selected and configured such that the residence time is less than 20 seconds. Residence time is defined as the amount of time for an air sample to travel from the opening inlet probe to the inlet of the analyzer, and can be calculated using Equation 4-1:

$$RT = (L\pi(d/2)^2)/flow$$

Where:

RT = Residence Time (min); multiple by 60 to convert to seconds
L = length of sample inlet (cm)
d = inner diameter of sample inlet (cm)
flow = instrument flow rate (cc/min)

Equation 4-1. Residence time calculation

Note: The inner diameter of a ¼" sample inlet is typically 0.396 cm. Verify the actual value with the manufacturer.

5. Calibration Standards

5.1. Standard hierarchy

Due to ozone's strong reactivity and instability, concentrated ozone cannot be practically stored and transported in compressed cylinders like other gases. In order to generate accurate ozone concentrations when calibrating or evaluating the analyzers onsite, EPA requires that precise ozone calibrators, called **transfer standards,** must be certified for traceability to other standards with higher authority and accuracy, as summarized in Figure 5-1, listed in order of descending accuracy.

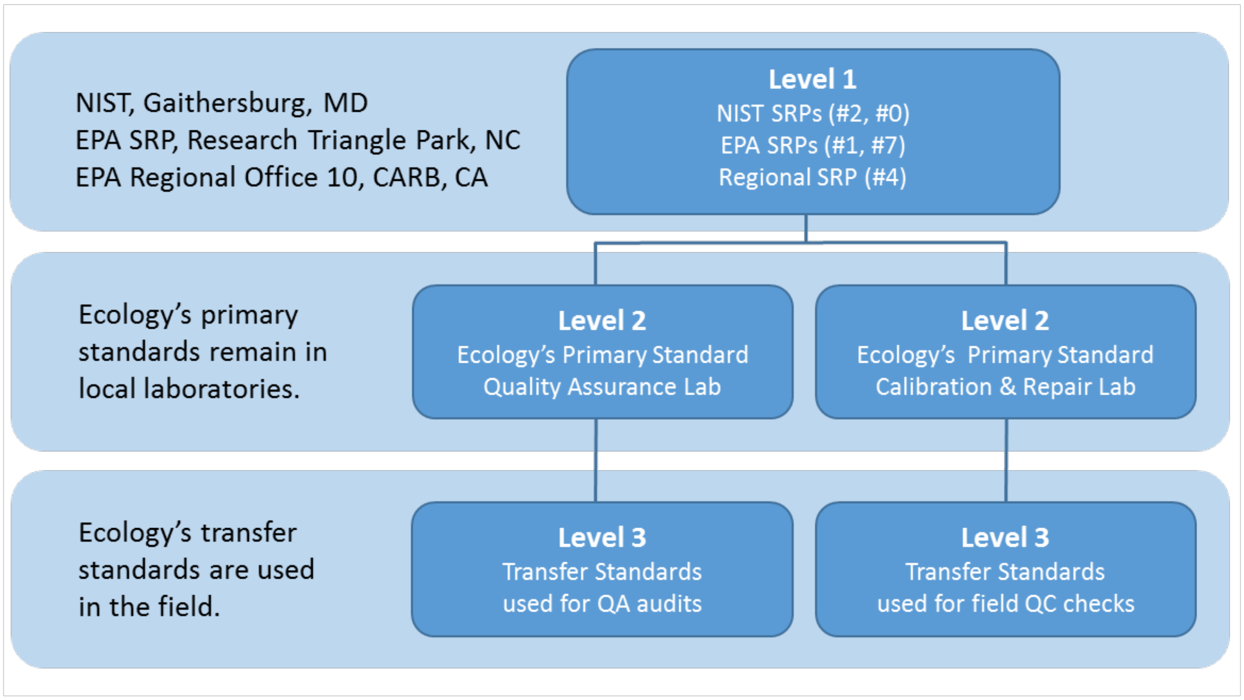

Figure 5-1: Washington network ozone standard hierarchy chart.

- **Level 1 - Standard Reference Photometer (SRP):** The National Institute of Standards and Technology (NIST) maintains national Level-1 SRPs. EPA also maintains SRPs that are compared against the NIST SRPs every two years. The California Air Resources Board (CARB) maintains regional SRPs that are compared against the EPA SRPs annually.
- **Level 2 - Ecology's Primary Ozone Standards:** Ecology's primary standards are kept in the Quality Assurance Lab and the Calibration & Repair Lab and are only used for recertifying the Level-3 transfer standards. Under the 2023 version of EPA's *Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone Technical Assistance Document* (TAD), they are designated as bench standards. The Level-2 standards are sent to CARB for comparison against the Regional SRP annually.

- **Level 3 - Transfer Standard:** All Level-3 transfer standards are certified against Ecology's Level-2 primary standards. Under the 2024 TAD, stationary standards at sites are designated as bench standards. Standards used in performance audits are designated as field standards since they are transported regularly, which impacts the minimum required reverification frequency. At a minimum, Level-3 standards are verified before each ozone season (May 1 – September 30) for seasonal monitoring sites, annually for year-round monitoring sites, and every 6 months for those used in performance audits.

Transfer standards deployed at monitoring stations are maintained by the Calibration & Repair Lab, and those used during performance audits are maintained by the Quality Assurance Lab to ensure assessment independency.

Annual maintenance of the onsite and auditing transfer standards is performed by the Calibration & Repair Lab and Quality Assurance Lab, respectively. The most current Verification Report and Maintenance Worksheet for the transfer standard must be kept onsite with the instruments, except for those maintained by the QA team. An example Verification Report and Maintenance Worksheet can be found in Appendix A.

5.2. Transfer standard verification

This section is intended for individuals responsible for transfer standard verification in the Calibration & Repair Lab and Quality Assurance Lab. Operators are encouraged to read through and understand the verification process but shall not use this section to make any adjustment on the instruments.

All transfer standards used in the Washington Network must be designated as a Federal Reference Method (FRM) or Federal Equivalent Method (FEM) under 40 CFR Part 50 Appendix D.

Verification must be established for Level-3 (field) transfer standards against a Level-2 (bench) primary standard. The specific requirements are:

1. At least six comparison points between the transfer standard and primary standard, and a zero. The points must be evenly spaced intervals over the concentration range of the transfer standard, including 0 and (90 ±5) % of the upper range limit.
2. Three individual comparison sets of six or more comparison points elected in step 1
3. For each comparison set, compute the slope (m) and intercept (I) by the least squares linear regression of the transfer standard and the primary standard.
4. When the three comparison sets are completed, calculate the average slope ($\overline{\mathrm{m}}$) and average intercept ($\overline{\mathrm{I}}$).
5. Determine the standard deviation of the three intercepts (S_I) using Equation **5-1**, with one degree of freedom (N=6, N-1=5).

$$S_I = \sqrt{\frac{1}{3}\left[\sum_{\mathrm{i}=1}^{3}(I_i - \bar{I})^2\right]}$$

Where I_i is the individual intercept from each comparison set.

Equation 5-1. Standard deviation calculation

6. Determine the standard deviation of the three slopes (S_m) using Equation **5-2**, with one degree of freedom (N=3, N-1=2). The relative standard deviation measures the degree of variation among the dataset relative to the mean.

$$S_m = \frac{100}{\bar{m}} \sqrt{\frac{1}{3}\left[\sum_{i=1}^{3}(m_i - \bar{m})^2\right]} \ \%$$

Where m_i is the individual slope from each comparison set.

Equation 5-2. Relative standard deviation calculation

7. To maintain verification, the value of S_I in step 5 must be < 1 **and** value of S_m in step 6 must be < 0.0075. Additionally, each point difference must be < ±3.1% (or ±1.5 ppb for concentration points < 50 ppb), all 3 regression slopes must be, 1 ±0.03, and all 3 regression intercepts = 0 ±3 ppb.

Reverification involves one periodic six-point comparison cycle between the primary standard and the transfer standard. Each point difference must be ±3.1% (or ±1.5 ppb for concentration points < 50 ppb). In relation to the most recent verification test, the regression slope must be ±0.015 of the mean slope, and the regression intercept must be ±1.5 ppb of the mean intercept. The regression slope from the reverification test cycle must be 1.00 ±0.03, and the regression intercept must be 0 ±3 ppb. If the transfer standard meets the specification, a new slope and intercept are computed using the 6 most recent running averages. The new slope becomes the average slope for comparison in future verification process. The new calibration relationship is computed as:

$$\text{Standard } O_3 \text{ Concentration } = \frac{1}{\bar{m}}\left(\text{Indicated } O_3 \text{ concentrations} - \bar{I}\ \right)$$

Equation 5-3. Standard ozone calculation

Should the transfer standard fail to meet reverification specifications, it loses its verification and the problem must be investigated and corrected. Reverification requires repeating one comparison set of the of the initial verification steps described above. Refer to EPA's *Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone*, available on the virtual Ambient Monitoring Technology Information Center (AMTIC), for extensive requirements and instructions.

6. Quality Control and Maintenance

To ensure proper operation of ozone monitors, automated and manual QC checks must be conducted at routine intervals at all seasonal and year-round sites. All QC checks must be initiated through the data logger to ensure consistency in QC checks between sites and to ensure results are captured by the data acquisition system.

Multiple terms for various QC checks and challenge points exist throughout EPA literature and documentation from other agencies. For clarification, this SOP adopts the uniform terminology of Primary QC Check Point and Secondary QC Check Point. These terms are paired with their corresponding EPA terms in Table 6-1 below.

Table 6-1: Ecology and EPA quality control check terms

Ecology term	EPA term	Must include in	Ecology target (ppb)
Primary QC Point	One-Point QC Value; Precision Check	Primary QC Check; Secondary QC Check	70
Secondary QC Point	Span Check Value	Secondary QC Check	150
Upscale Points	Multi-Point Calibration Upscale Points	Verification check after calibration	240, 180, 120, 60
Zero Check	Zero/span check	All other checks	0

The timing of QC checks and maintenance is important. Depending on the hours of the day, as little as three hours of analyzer downtime can lose a day for establishing a valid design value. Ecology recommends following these guidelines:

1. Schedule automated QC checks during early morning hours (0100 – 0359 PST)
2. Schedule and complete any maintenance work before 1000 PST to avoid missing critical sampling period of high ozone concentrations
3. Schedule QCs taking longer than an hour to start after 15 minutes to the hour, and end before 15 minutes after. An hour is considered complete if at least 45 minutes of valid data are collected.
4. Keep the work within 2 hours

6.1. Automated quality control checks

6.1.1. Frequency

Automated QC checks must meet the minimum frequencies specified in "Automated" means both initiation and sequence are automatic; "automatic" refers to the sequence only. Due to their low cost and minimal data loss, more frequent checks are recommended to identify analyzer issues, improve data completeness, and provide precision information.

For ease of bi-weekly inspection, schedule one check early in the week (e.g., Monday) and another later (e.g., Thursday).

Table 6-2. "Automated" means both initiation and sequence are automatic; "automatic" refers to the sequence only. Due to their low cost and minimal data loss, more frequent checks are recommended to identify analyzer issues, improve data completeness, and provide precision information.

For ease of bi-weekly inspection, schedule one check early in the week (e.g., Monday) and another later (e.g., Thursday).

Table 6-2: Minimum required and recommended quality control check frequencies.

Quality control check point	Acceptance Criteria	Corrective Action Levels	Ecology minimum frequency
Primary QC Point	±7%	±5%	Once every 3 days
Secondary QC Point	±7%	±5%	Once every 14 days
Zero Check	±3 ppb	±2 ppb	With any QC check

6.1.2. Timing

Schedule automated QC checks during hours of typically lowest concentrations (e.g., 0100-0359 PST) to minimize data loss. Avoid losing more than 15 minutes of data per hour.

- **Primary QC checks (under 60 minutes):** Start at the top of the hour to lose only one hour of data.
- **Secondary QC checks (up to 88 minutes):** Start 46 minutes after the hour to lose only the middle hour (e.g., a 0146 PST start loses only the 0200 PST hour).

Ensure primary and secondary QC check schedules do not conflict (e.g., primary checks every 2 days on odd-numbered days; secondary every 12 days on even-numbered days).

6.1.3. Concentrations and calibration scale

All Washington Network ozone monitoring sites must use 70 ppb as the primary QC point and 150 ppb as the secondary QC point. The analyzer's calibration range should be 300 ppb. Contact the Calibration & Repair Lab for assistance with additional QC points or different calibration ranges.

6.1.4. Flow requirements

To maintain FEM designation (EQOA-0992-087), Models 400E or T400 analyzers must have a sample flow of 800±80 cc/min (volumetrically measured at local conditions). The transfer standard's output flow must exceed the analyzer's requirement by at least 1 LPM to prevent ambient air intrusion during calibration and QC checks.

6.1.5. Acceptance criteria

As shown in Table 6-2, critical acceptance levels are ±7% for non-zero QC points (compared to actual 2-minute average transfer standard readings) and ±3 ppb for zero points.

If a QC check fails, first confirm the analyzer is the source, not other components (e.g., pump failure, shelter temperature, probe blockage). Check diagnostic parameters, verify site conditions, and confirm calibration system function. An "as-found" QC check may be needed. If the analyzer is confirmed to be at fault, calibrate it per Section 6.4.

6.1.6. Corrective action limits

Corrective action is required if non-zero QC points exceed ±5% of the reference value or a zero QC point is greater than ±2 ppb. This involves checking and adjusting analyzer and calibrator diagnostics and components, as detailed in Sections 6.4 and 6.5.

6.2. Manual quality control checks

Occasionally, operators will need to manually initiate a primary or secondary QC check. This is necessary:

- When an automated QC check fails to run properly;
- Before and after calibration; and
- Upon installation of an analyzer, prior to sampling.

Operators must initiate the QC check from the data logger and not from the transfer standard itself. This ensures that all results are captured by the data acquisition system and are reportable to EPA's Air Quality System (AQS).

Operators should avoid conducting manual QC checks when conditions favorable to high ozone formation occur, such as when ambient temperatures are expected to exceed 85 degrees. In regions where high temperatures are unavoidable during ozone season, such as eastern Washington, perform any QC checks in the morning, optimally before 1000 PST.

6.3. Site visits and QC check form

Operators must visit the site every month to confirm good operation of instrumentation. An electronic QC check form must be completed during the monthly site visit and emailed to the QA team no later than the 10th day of the following month. Operators must fill out a logbook entry when they are on-site. An example of the QC check form is shown in Appendix A. Contact the Calibration & Repair Lab or QA team to obtain the latest version.

Operators **must** check the following during each site visit, in addition to the verifications listed in the form:

1. Investigate any warning messages or unusual behaviors of the analyzer and transfer standard
2. Visually inspect the inlet to ensure that the cone and tee are in good condition and configured appropriately
3. Inspect the sample and calibration lines to ensure that they are clean and free of moisture
4. Verify that shelter conditions meet the requirements specified in Section 4.1.2
5. Verify that the shelter temperature device is checked against a certified NIST-traceable temperature standard every 180 days (see Section 6.5.5)
6. Verify that the standard deviation of daily shelter temperature (1-hr average) since last site visit is less than 2.1 °C

7. Inspect the particulate filter; replace as needed per requirements (see Section 6.5.2)
8. Ensure the most current ozone SOP and model-specific operation manuals for the analyzer and transfer standard are present either in hard copy in the shelter or in electronic form on the logger
9. Ensure the latest Certification Report of the transfer standard against Ecology's primary standard from the Calibration & Repair Lab is present in the shelter

6.4. Calibration and verification

When a QC check fails, operators must first diagnose the cause by reviewing diagnostic parameters. An "as-found" QC check may be necessary to confirm the issue. If the analyzer is definitively identified as the source of the failure (ruling out other components like the ozone transfer standard or telemetry), the analyzer requires calibration as per this SOP and the manufacturer's manual.

Following calibration, a post-calibration verification is mandatory to confirm the analyzer's linear response. This verification uses zero and specific upscale points, distinct from the routine primary and secondary QC points listed in Table 6-1. In accordance with 40 CFR Part 50 Appendix D Section 4.5.5.6, the analyzer's readings at each point must be within 2% of the calibration scale (refer to Section 6.1.3) when compared to the transfer standard.

Upon completion, an electronic Analyzer Calibration Verification Form must be filled out and submitted to both the QA team and the Calibration & Repair Lab. A copy should remain with the analyzer onsite and be returned to the Calibration & Repair Lab at the end of the ozone season for seasonal sites, or during semi-annual maintenance for year-round sites.

Steps for Linearity Verification:

1. Record the analyzer's as-found slope and offset.
2. Record traceability information for temperature and pressure standards used.
3. Set the ozone channel to off-scan.
4. Calibrate the analyzer following the manufacturer's operational manual.
5. Begin an automatic sequence for the linearity check. Each upscale point should be sampled for a minimum of 15 minutes.
6. Readings should be recorded as a 2-minute average, taken immediately one minute before the end of each concentration phase.
7. Record all required diagnostic parameters displayed during the verification on the form.
8. Verify that all tested points meet the established criteria.
9. Note the analyzer's as-left slope and offset.
10. Set the ozone channel to on-scan.
11. Record all performed activities in the electronic logbook.

An example of the form is provided in Appendix A. Contact the Calibration & Repair Lab or Quality Assurance Team to obtain an electronic version.

The upscale linearity verification is crucial as it comprehensively assesses the analyzer's accuracy across various concentration points, ensuring a linear relationship with the transfer standard and reliable measurements of ambient pollution. Despite this, operators must ensure a routine automated QC check, including a primary QC point, is scheduled within three days post-calibration and linearity verification to continuously confirm measurement accuracy.

Linearity verification is required at a minimum frequency of every 180 days, regardless of whether slope and offset adjustments were made. For year-round sites, this is often incorporated into the semi-annual maintenance service performed by the Calibration & Repair Lab. For seasonal ozone monitoring sites, the Calibration & Repair Lab conducts this multi-point verification using the analyzer's paired transfer standard before the ozone season begins, providing operators with a Calibration Report (see Figure A-5 for an example). If there are any concerns about the analyzer's performance, contact the Calibration & Repair Lab for assistance.

6.5. Maintenance

Major maintenance and repairs on the analyzers, such as those involving the photometer or major circuit boards, are performed in the Calibration & Repair Lab. However, the station operator performs the routine maintenance listed in Table 6-3. Record all maintenance activities in the electronic logbook. An example of the Maintenance Worksheet for the analyzer (Model 400E/T400) is included in Appendix A.

Table 6-3: Summary of required O_3 analyzer and transfer standard maintenance

Procedure	Minimum required frequency	Section
Verify diagnostic data in analyzer & transfer standard	Every 30 days and after any maintenance	6.5.1
Inspect/replace particulate filter	Inspect every 30 days. Replace every 90 days, or more frequently if filter is noticeably dirty	6.5.2
Adjust output flow rate	When *Output Flow* < 3.0 LPM	6.5.3
Adjust UV source lamp	When *Photo Ref* (transfer standard) or *O_3 Ref* (analyzer) < 3000 mV	6.5.4
Verify shelter temperature device	Every 180 days	6.5.5
Clean/replace sample and calibration lines	Before ozone season at seasonal sites and every 180 days at year-round sites	6.5.6
Analyzer linearity verification	When a (confirmed) QC check failure occurs or every 180 days, whichever occurs first	6.4

6.5.1. Verify diagnostic data

At a minimum, operators must review diagnostic data every 30 days during their monthly site visit. However, to identify potential problems early and prevent data loss, it is recommended that operators review diagnostic data on a more frequent basis. The acceptable operating ranges for several analyzer and transfer standard diagnostic parameters are listed in Table 6-4, Table 6-5, and Table 6-6.

Note that photo pressure and sample pressure readings, as well as photo flow, may be lower than the listed range for sites at higher elevation. Both pressure readings should be checked and recorded during a QC check to verify they are below ambient pressure. This verifies that there is a slight vacuum inside the photometer of each unit. The fundamental diagnostic data in the ozone analyzer is summarized in Table 6-4.

Troubleshooting instructions regarding specific diagnostic data may be available in the model-specific operation manual. Otherwise, contact the Calibration & Repair Lab for technical assistance.

Table 6-4: Summary of diagnostic data (adopted from Teledyne API Manual 400E)

Test function	Diagnostic relevance and interpretation
STABIL	Indicates noise level of instrument or stability of the O_3 concentration of Sample Gas.

O3 MEAS and O3 REF	If the value is:
	• **Too high:** UV Source has become brighter. Adjust the variable gain potentiometer (pot), see Section 6.5.4.
	• **Too low**:
	  o < 3000 mV: Lamp output has dropped, adjust UV preamp board or replace lamp.
	  o < 100 mV: Bad UV lamp or UV lamp power supply.
	• **Unstable:** Bad UV lamp, Defective UV lamp power supply, Failed I^2C Bus
	• **Showing O3 REF changes by more than 10 mV between zero and span gas:** Defective/leaking switching valve

PRES	Sample pressure. See Table 6-6.
SAMPLE FL	Sample flow. If outside range, it may indicate sample pump failure, blocked sample inlet, dirty PM filter, leak downstream of the orifice, or flow sensor failure.
SAMPLE TEMP	Photometer sample temperature. If outside range or unstable, it may indicate sample temperature sensor or relay board failures. See warning message table in the operation manual.
PHOTO LAMP	Photometer lamp temperature. If outside range, it may indicate issues from the bench, relay board, lamp heater, lamp temperature sensor, or I^2C Bus.
BOX TEMP	Box temperature, typically ~7 °C > ambient temperature. If outside range, it may be due to poor ventilation to the analyzer or a bad exhaust fan.
SLOPE	Values outside range indicate: • Contamination of the zero air or calibration gas supply, • Instrument is out of calibration, • Blocked gas flow, • Faulty sample pressure sensor or circuitry, or • Bad/incorrect calibration gas concentration.
OFFSET	Values outside range indicate contamination of the zero air supply.

Table 6-5: Acceptable operating range of transfer standard

Test function	Expected
Photo Flow	0.72 - 0.88 LPM*
Photo Pressure	27.0 - 29.9 inHg-A
Box Temp	20 - 40 °C
Photo Ref	3000 - 4800 mV
Output Flow	3.0 - 4.0 LPM
Slope & Offset	Must match Certification Report

**Flow should be measured volumetrically at local temperature and pressure.*

Table 6-6: Acceptable operating range of analyzer

Test function	Expected
Sample Flow	720 - 880 cc/min*
Sample Pressure	> -2 inHg-A of the ambient pressure and < ambient pressure
Box Temp	20 - 40 °C
O3 Ref	3000 - 4800 mV
Slope	1.0 ±0.15
Offset	0.0 ±3.0 ppb

**Flow should be measured volumetrically at local temperature and pressure.*

6.5.2. Inspect/replace particulate filter

A PTFE filter is used to keep dirt from entering the analyzer. The filter must be inspected every 30 days and must be replaced every 90 days or when noticeably dirty. Slow analyzer response during a calibration check may indicate a dirty filter.

The PTFE filter is in the filter holder mounted inside the front panel of the analyzer. Depending on the model, pull the front panel open by pulling either the two snap-in fasteners or the two hollow corners at the top of the front panel.

Important: Wear clean, laboratory-grade, powder-free gloves when handling all the parts in the following procedure to avoid contamination.

1. Turn the analyzer OFF to prevent drawing debris into the instrument.
2. Open the hinged front panel. Unscrew the black rim around the glass piece and remove the glass cover. Be careful not to contaminate the inside surface.
3. The large O-ring may adhere to the glass, if so, be careful to invert the glass and place on a clean surface without dropping or contaminating the O-ring. If it stays in the groove in the chamber, leave it there and be careful not to contaminate the retaining ring or filter with silicone grease from the O-ring in the following steps.
4. Using a clean stainless-steel tweezer, remove the retaining ring with cut-outs that holds the filter in place, remove the old filter and install a new filter. Make sure the filter is centered in the holder.

5. As shown in Figure 6-1, re-install the parts in order. Make sure the ring with cut-outs has notches facing up. Screw on the retaining ring and hand tighten.
6. Lift the front cover to close the instrument and turn the analyzer ON.

After changing the filter, the operator should perform a leak check to make sure that the filter is sitting well in its housing:

1. Turn the analyzer ON and allow enough time for flows to stabilize.
2. Cap the sample inlet port with a FEP cap (Do not use a metal cap).
3. When the pressures have stabilized (approximately 2 minutes), note the SAMP FL test function reading on the front panel (toggle the TST keys until SAMP FL appears on the screen).
4. If SAMP FL < 10 cc/m then the analyzer is free of large leaks.

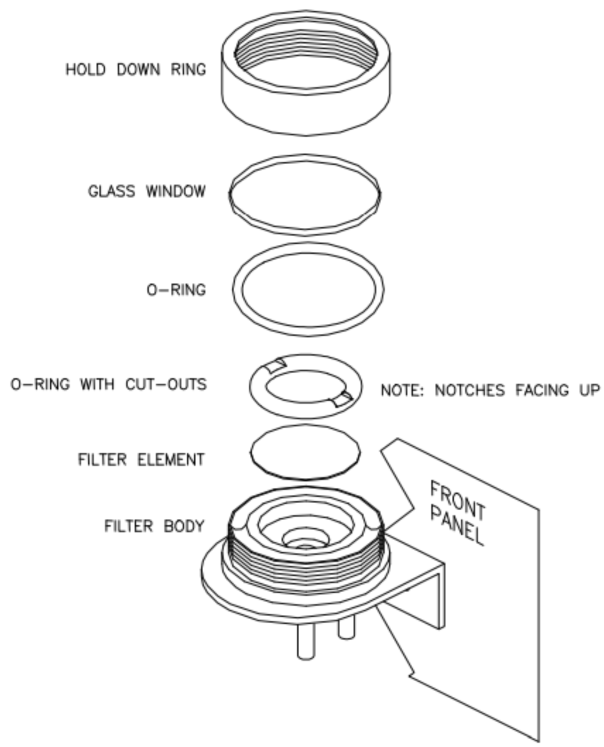

Figure 6-1: Particulate filter assembly (Teledyne API Manual 400E)

To ensure that **no** contaminants remain to impact the particulate filter and sampling, perform the following steps. Operators may also condition the filter (i.e. step 2) before testing the analyzer against the transfer standard.

1. Use the transfer standard or configured sequence from the data logger to generate a concentration of 150 ppb to confirm that the analyzer and transfer standard agree within 3% when the readings on the analyzer are stable (STABIL ≤ 0.3).
2. If the instruments do not agree within 3 %, the filter must be conditioned. Generate a concentration of 800 ppb using the transfer standard and allow it to run for at least 30 minutes and when the readings on the analyzer are stable (STABIL ≤ 0.3). Ensure the analyzer is properly vented to the outside when generating high concentrations.

3. Repeat step 1 to confirm that the filter has been properly conditioned, and the analyzer and transfer standard agree within 3 %.

6.5.3. Adjust output flow rate

The output flow of the transfer standard should be at least 1.0 LPM greater than the sample flow of the ozone analyzer. If the flow rate is outside of range, adjust the output flow rate.

1. Open the front panel of the transfer standard by pulling either the two snap-in fasteners or the two hollow corners at the top of the front panel.
2. Pull out the regulator knob (Figure 6-2) and adjust the regulator until the desired flow (~2.5 LPM) is achieved. (Clockwise: increase flow rate; Counterclockwise: decrease flow rate).
3. Push the regulator knob back in to lock.
4. Close the front panel.

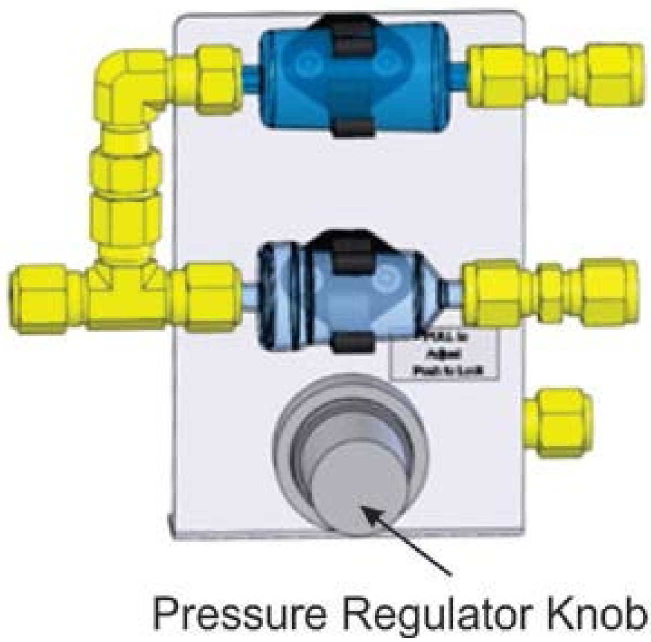

Figure 6-2: Output pressure regulator assembly (Teledyne API Manual T703/T703U)

6.5.4. Adjust UV source lamp

The UV source lamp should be adjusted whenever the O3 REF (Models 400E/T400 analyzers) or Photo Reference (Models 703E/T703/T703U/T753 transfer standards) value drops below 3000 mV.

1. Make sure the analyzer or transfer standard is warmed up and has been running for at least 30 minutes before proceeding.
2. Remove the cover from the analyzer or transfer standard.
3. Locate the Optical Bench Assembly inside the analyzer or transfer standard and the UV DETECTOR GAIN ADJUST POT shown in Figure 6-3 (applicable to all Teledyne API models).

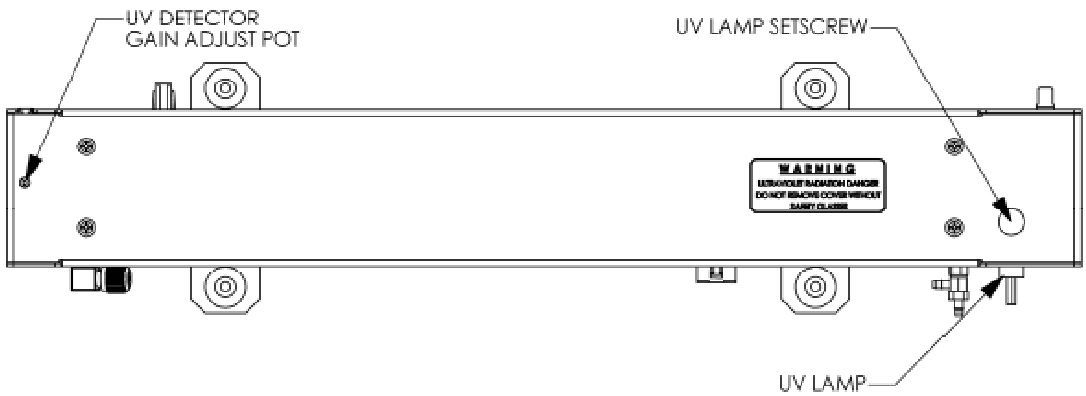

Figure 6-3: Optical bench assembly (Teledyne API Manual 400E)

4. Perform the following procedures to bring PHOTO_DET to the front screen: **SETUP** > **MORE** > **DIAG** > Toggle keys to password **818** > **ENTER** > **ENTER** (to SIGNAL I/O) > **JUMP** > Toggle keys to **31** (400E) or **27** (T400) or **42** (703E and T703) > **ENTER**. PHOTO_DET should be on display.
5. Using an insulated pot adjustment tool, turn the UV DETECTOR GAIN ADJUST POT counterclockwise to increase the PHOTO_DET signal. The target is to adjust PHOTO_DET as high as possible within the range of 3500-4600 mV.
6. If necessary, additional adjustment can be made by physically rotating the lamp in its housing. To do this, slightly loosen the UV LAMP SETSCREW. Next, slowly rotate the lamp up to ¼ turn in either direction while watching the PHOTO_DET signal. To finish, re-tighten the LAMP SETSCREW.
7. If the 3500-4600 mV range cannot be reached by either of the adjustment methods in step 5 and 6, then the lamp must be replaced. Please call Calibration & Repair Lab for the lamp replacement assistance.
8. Replace the instrument cover and press **EXIT** to return to the main menu.

6.5.5. Verify shelter temperature device

At a minimum, operators must verify the shelter temperature device performance using a certified NIST-traceable temperature standard every 180 days. The acceptable difference between actual and indicated room temperature is 2.1°C. Operators must perform a single-point ambient temperature check and document the results on the appropriate QC form. The ozone monthly QC check form allows operators to keep track of when the shelter temperature probe was last verified. This requirement applies to all FRM/FEM monitoring stations, and the procedure is described in the [Ecology Air Quality Program Quality Assurance Plan](#).

6.5.6. Clean/replace sample lines

At a minimum, the sample and calibration lines must be cleaned or replaced every 180 days. If the site is seasonal (May–September), the sample and calibration lines must be cleaned or replaced prior to the beginning of the ozone season. More frequent cleaning/replacement may be necessary in more polluted or dirtier environments to avoid sample line contamination.

Inherently, the funnel and the probe configuration should also be inspected for cleanliness; clean or replace as needed.

1. Disconnect the Teflon tubing from the CAL GAS OUT port on the transfer standard and the SAMPLE port on the analyzer.
2. To clean, inject both lines with a soapy water solution (a syringe works well) and push the liquid through the line using a small pump, air compressor or cylinder air. Repeat this process several times and then flush the lines with distilled water.
3. If replacing lines, install brand new Teflon tubing for the sample and calibration lines, replace fittings, and connect the sample line to the analyzer and the calibration line to the transfer standard. Proceed to step 4.
4. Using a clean dry air source, blow air through the tubing for as long as necessary to remove all the water from the sample lines and then reconnect the tubing to the instruments.
5. Condition the probe by generating a concentration of 800 ppb from the transfer standard until at least 30 minutes have passed and the analyzer is stable (STABIL ≤ 0.3). Ensure the analyzer is properly vented to the outside when generating high concentrations.

7. Data Validation and Quality Assurance

Preliminary level review and validation of monitoring data are the responsibility of the operator. At a minimum, 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 ozone monitors. Operators should notify the QA team via email when invalid data are identified.

The QA team is responsible for final level review and data validation. Data validity is evaluated using several criteria, including but not limited to the results and frequency of QC checks, performance audits, and diagnostic data. During data review and validation, QA staff review electronic logbook entries to ensure documentation of site activities and that all required quality control and maintenance activities are occurring as required by this procedure and 40 CFR Part 58, Appendix A. The critical, operational and systematic criteria used by the QA team to help determine data validity are summarized in the most current version of EPA's criteria pollutant validation templates. Data not meeting EPA's critical criteria as described in the validation templates will be invalidated. Data not meeting operational and systematic criteria will be evaluated for validity using a weight-of-evidence approach.

When an analyzer fails a primary or secondary QC, data are considered invalid between the most recent preceding passing QC check and the earliest passing QC check following the failure. For more information on data review and validation, see Ecology's Air Monitoring Documentation, Data Review, and Validation Procedure.

7.1. Quality assurance

QA staff conduct performance audits at the beginning and just before the end of the ozone season (May–September) at the seasonal ozone monitoring sites, and semi-annually at the year-round ozone monitoring sites. A performance audit is an independent evaluation by the QA team that is in addition to the routine QC checks performed by the station operator. During performance audits, QA staff also visually inspect the site as well as the sampling and calibration lines.

8. References

EPA. Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, published Jan. 2017.

EPA. Measurement Quality Objectives and Validation Templates from QA Handbook Volume II, Appendix D, published Mar. 2017.

EPA. Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone, Technical Assistance Document, published January 2023.

"Network Design Criteria for Ambient Air Quality Monitoring." Code of Federal Regulations Title 40, Pt. 58, Appendix D, 2024 ed.

"Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring." Code of Federal Regulations Title 40, Pt. 58, Appendix E, 2024 ed.

"Reference Measurement Principle and Calibration Procedure for the Measurement of Ozone in the Atmosphere". Code of Federal Regulations Title 40, Pt. 50, Appendix D, 2015 ed.

Teledyne API (2016). Operation Manual: Models T703 and T703U Photometric O3 Calibrator. San Diego, 2016.

Teledyne API (2011). Operation Manual: Model 400E Photometric O3 Analyzer. San Diego, 2011.

Teledyne API (2009). Operation Manual: Model 703E Photometric O3 Calibrator. San Diego, 2009.

Washington State Department of Ecology. Washington Ambient Air Monitoring Network Quality Assurance Plan, published Jan. 2021.

Washington State Department of Ecology. Air Monitoring Site Selection and Installation Procedure, published Feb. 2024.

Washington State Department of Ecology. Air Monitoring Documentation, Data Review, and Validation Procedure, publication May 2024.

Appendix A: Quality Control Check Form

Revised 03292022

AQS No ____________ Date ____________

Location ____________ Operator ____________

Analyzer Serial No ____________ Calibrator Serial No ____________

Analyzer State Tag ____________ Calibrator State Tag ____________

Probe Last Cleaned ____________ QC Start Time ____________ PST

Ambient Pressure ____________ mmHg QC Stop Time ____________ PST

Pressure Standard S/N ____________

Standard Calibration Date ____________

Analyzer Calibration Factor:

Slope		Offset	

Conditions since last QC:

Min Room Temp ____________ °F

Max Room Temp ____________ °F

Shelter Temp Probe Last Verified ____________

Any failed QCs? ____________

Diagnostics normal*? ____________

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

Diagnostics during QC:

	Calibrator	Analyzer	Range
Photo/O3 Ref (mV)			[3000 - 4800]
Sample Pressure (inHg-A)			Enter Ambient Pressure
Output Flow (lpm)		--	[3.0 - 4.0]
Photo/Sample Flow (ccm)			800 ± 10% **

Multipoint QC Point Results:

Report Time: ____________ PST

Target	Actual (Calibrator)	Indicated (Analyzer)	Difference	Acceptance Limits	Results
0				± 3 ppb	
70				± 7%	
150				± 7%	

Post-Filter Change Results:

Filter Changed? ____________

Target	Actual	Indicated	Difference	Acceptance Limits	Results
150				± 7%	

Notes:

** Sample flow rate should be measured volumetrically at local T & P conditions (EQOA-0992-087).

Figure A-1: O_3 QC Check Form

WA Department Of Ecology Ozone Analyzer Calibration Verification

Control #
Form 061919

Pre_Calibration Values	
Analyzer SLOPE	
Analyzer OFFSET	

Perform M-P calibration of analyzer with zero and 300 ppb span concentration prior to verification

Post_Calibration Values	
Analyzer SLOPE	
Analyzer OFFSET	

Multi-point Verification Worksheet

Analyzer S#			TxferStd OUTPUT FLOW =	
Date			TxferStd REG PRESSURE =	
Technician			TxferStd BOX TEMP =	
TxferStd Serial #			TxferStd PHOTO REFERENCE =	
TxferStd Id #			TxferStd PHOTO FLOW =	
Analyzer PT1			TxferStd PHOTO SPRESS =	
Analyzer PT2			TxferStd PHOTO SLOPE =	
Analyzer PT3			TxferStd PHOTO OFFSET =	
Analyzer PT4			Analyzer PRES =	
Analyzer PT5			Analyzer SAMP FL =	
			Analyzer BOX TEMP =	
TxferStd PT1	240		Analyzer SLOPE =	
TxferStd PT2	180		Analyzer OFFSET =	
TxferStd PT3	120		Room Temp =	
TxferStd PT4	60		Room Pressure =	
TxferStd PT5	0		Analyzer O3 REF =	

		Standards Used		
		Model #	Serial #	Calibration Exp. Date
Room Temp				
Room Pressure				

Figure A- 2: O_3 Analyzer Calibration Verification Form

O3 Transfer Standard Verification Data Form

Institute Conducting Verification:	WA State Dept of Ecology
Operator:	
Cycle 3 Date:	
Naming Convention	

Transfer Standard of Higher Authority

Transfer Standard Role:	Level 2 Bench
Make:	Teledyne
Model:	
Serial Number:	
Verification Date:	

Calibration Factors

Span Setting:	
Zero Setting:	

Candidate Transfer Standard Information

Candidate Transfer Standard Role:	
Make:	
Model:	
Serial Number:	
Preventive Maintenance Date:	
Acceptance Testing Date:	

Calibration Factors *(describe calibration factor changes in comments)*

	Span Setting	Zero Setting
As Found:		
As Left:		

Comments: Adjusted slope to align with CCQM.03.2019 ozone absorption cross-section value

Acceptance Criteria Checklist

Verification Results:	fail	
Transfer Standard Role check:	error	
Preventive Maintenance Completed:	fail	
Acceptance Testing Completed:	fail	
Per Point Difference:	error	
Regression Slope Check:	error	
Regression Intercept Check:	error	
Std Deviation Slope:	error	#DIV/0!
Std Deviation Intercept:	error	#DIV/0!

Submit Verification Data Form

Cycle 1 Verification Data

Cycle 1 Date:	
Regression Slope:	#DIV/0!
Regression Intercept:	#DIV/0!

	Higher Level Standard Teledyne SN	Candidate Transfer Standard SN	Percent Difference	Absolute Difference	Per Point Difference #DIV/0!
Zero:			NA	0.0	NA
Point 1:			#DIV/0!	0.0	#DIV/0!
Point 2:			#DIV/0!	0.0	#DIV/0!
Point 3:			#DIV/0!	0.0	#DIV/0!
Point 4:			#DIV/0!	0.0	#DIV/0!
Point 5:			#DIV/0!	0.0	#DIV/0!
Point 6:			#DIV/0!	0.0	#DIV/0!
Point 7:			#DIV/0!	0.0	#DIV/0!
Point 8:			#DIV/0!	0.0	#DIV/0!
Point 9:			#DIV/0!	0.0	#DIV/0!
Point 10:			#DIV/0!	0.0	#DIV/0!
Zero:			NA	0.0	NA

Cycle 2 Verification Data

Cycle 2 Date:	
Regression Slope:	#DIV/0!
Regression Intercept:	#DIV/0!

	Higher Level Standard Teledyne SN	Candidate Transfer Standard SN	Percent Difference	Absolute Difference	Per Point Difference #DIV/0!
Zero:			NA	0.0	NA
Point 1:			#DIV/0!	0.0	#DIV/0!
Point 2:			#DIV/0!	0.0	#DIV/0!
Point 3:			#DIV/0!	0.0	#DIV/0!
Point 4:			#DIV/0!	0.0	#DIV/0!
Point 5:			#DIV/0!	0.0	#DIV/0!
Point 6:			#DIV/0!	0.0	#DIV/0!
Point 7:			#DIV/0!	0.0	#DIV/0!
Point 8:			#DIV/0!	0.0	#DIV/0!
Point 9:			#DIV/0!	0.0	#DIV/0!
Point 10:			#DIV/0!	0.0	#DIV/0!
Zero:			NA	0.0	NA

Cycle 3 Verification Data

Cycle 3 Date:	
Regression Slope:	#DIV/0!
Regression Intercept:	#DIV/0!

	Higher Level Standard Teledyne SN	Candidate Transfer Standard SN	Percent Difference	Absolute Difference	Per Point Difference #DIV/0!
Zero:			NA	0.0	NA
Point 1:			#DIV/0!	0.0	#DIV/0!
Point 2:			#DIV/0!	0.0	#DIV/0!
Point 3:			#DIV/0!	0.0	#DIV/0!
Point 4:			#DIV/0!	0.0	#DIV/0!
Point 5:			#DIV/0!	0.0	#DIV/0!
Point 6:			#DIV/0!	0.0	#DIV/0!
Point 7:			#DIV/0!	0.0	#DIV/0!
Point 8:			#DIV/0!	0.0	#DIV/0!
Point 9:			#DIV/0!	0.0	#DIV/0!
Point 10:			#DIV/0!	0.0	#DIV/0!
Zero:			NA	0.0	NA

Figure A- 3: O_3 Transfer Standard Verification Report (page 1)

Department Of Ecology Calibration Report

Date	**06/17/19**
Location	Lacey
Calibration Personnel	J Wolbert
Instrument	710
Operational Range	0 to 500 ppb
ID Number	E143426
ID Type	State
Calibration Room Temp. (Deg. C)	24.3
Barometric Pressure (mm Hg)	762

Instrument Operational Indicators:

Output Flow (LPM)	3.6
Box Temp. (Deg.C)	29.2
Photo Ref.	4146.9
Photo Flow	0.7910
Slope	0.996
Offset	-0.1
Photo Press	29.0

Calibration Equipment	API 67
ID Number	E133673
Calibrating Method	Reference Comparison
Room Temperature Standard	181119786
Temp Calibration Date Due	3/16/2020
Ambient Pressure Standard	OE1425
Pressure Calibration Date Due	11/4/2019

RESULTS:

SLOPE=	0.989627
INTERCEPT=	0.708578
CORRELATION COEFFICIENT=	0.999997
Previous Avg. Slope=	N/A
Deviation From Last Avg. Slope=	#VALUE!
New Avg. Slope=	**0.9962**
New Avg. Intercept=	**0.2893**
New Avg. Cor. Coefficient=	**1.0000**
New Correction Factor=	**1.0039**

SET POINT ppb	PRIMARY STANDARD INDEPENDENT		TRANSFER STANDARD DEPENDENT	Point to Point Comparison
270	272		270	-0.74%
215	216		215	-0.74%
160	161		160	-0.50%
105	106		105	-0.66%
50	50		50	0.00%
0	0		1	

Meeting The Criteria

Relative Standard Deviation for Slope	Intercept Standard Deviation	The New Slope Within 5% of Previous Average Slope
PASSED	**PASSED**	**N/A**

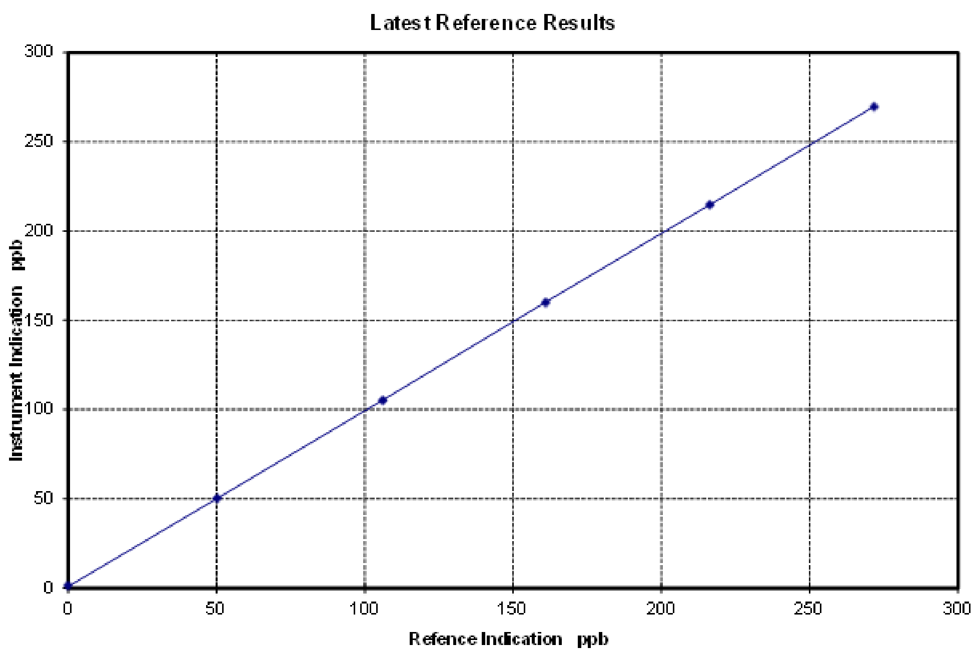

Figure A- 4: O_3 Transfer Standard Verification Report (page 2)

Department Of Ecology Calibration Report

Date	**03/18/19**
Location	Lacey
Calibration Personnel	J Wolbert
Analyzer	**4500**
ID Number	E141521
ID Type	Washington State
Operational Range	0-500 ppb
Analyzer Pressure (in-Hg-H)	27.6
Analyzer Flow (ccpm)	853
Analyzer Box Temp (deg. C)	27.4
Analyzer Slope	1.012
Analyzer Offset (ppb)	-3.5
Analyzer O3 REF (mv)	4381.9
Calibration Room Temp. (deg. C)	22
Barometric Pressure (mm/hg)	761
Ambient Pressure Standard	OE1425
Pressure Calibration Date Due	11/4/2019

Transfer Standard Equipment	**464**
ID Number	E140464
TRS Output Flow (LPM)	3.7
TRS Regular Pressure (in-Hg-H)	9.4
TRS Box Temperature (deg. C)	29.9
TRS Photo Reference (mV)	4540.9
TRS Flow (LPM)	0.813
TRS Photo Spress (in-Hg-H)	29.1
TRS Slope (m)	1.014
TRS offset (ppb)	-0.7

RESULTS:

SLOPE=	**0.9930**
INTERCEPT (ppb)=	**0.3000**
CORRELATION COEFFICIENT=	**1.0000**

Room Temperature Standard	181119786
Temp Calibration Date Due	3/16/2020

Meeting The Criteria

PASSED / FAILED (0.9<=m<=1.1)	PASSED / FAILED (-3<=I<=3 ppb)		PASSED / FAILED (Correlation >0.995)	PASSED/FAILED (Δm<= 15%)
PASSED	**PASSED**		**PASSED**	**PASSED**

SETPOINT ppb	TRANSFER STANDARDS INDEPENDENT		ANALYZER VALUE DEPENDENT	Point to Point Comparison
240	240		238.4	-0.67%
180	180		179.2	-0.44%
120	120		119.5	-0.42%
60	60		60.2	0.33%
0	0		0.0	

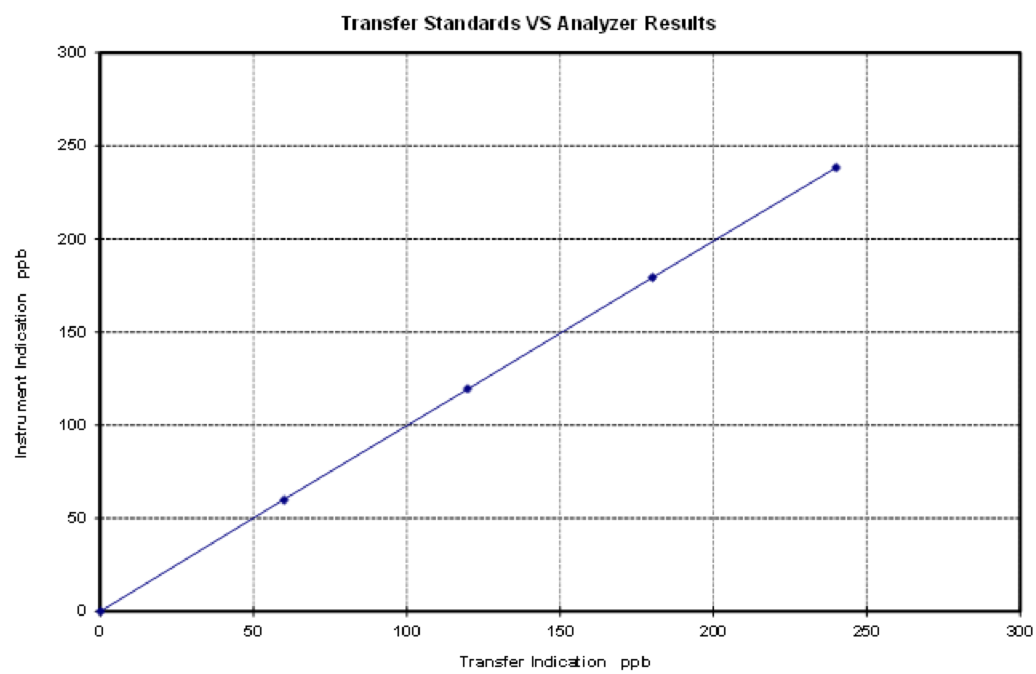

Figure A- 5: O_3 Analyzer Calibration Report

API T400 Annual Maintenance Worksheet

Control# 6182019

Tech: J Wolbert	Date		
	Serial #		

Adjustments / Observations

		pre cal	post cal
Dark Calibration	mV =		
		@ zero	@ Span
M/R Valve Check	O3 REF		
		pre cal	post cal
Photometer Flow Calibration	SAMP FL		
		pre cal	post cal
Photo Pressure	Photo Pressure		
		No Flow	1.5 Flow
Dry Air Pump Vacuum	in Hg =		
Dry Air Pump Rebuild?	Yes? Post Vacuum		
		pre cal	post cal
Photometer UV lamp	PHOTO_DET		
Photometer UV lamp replaced?	Yes? Post PHOTO_DET		

Repairs

	Yes	No
New Sample Filter?		
Clean Absorption Tube?		

Leak Check	SAMP_FL=		<10 ccm
	PRESS=		<10 in Hg
Regression		as found	as left
	SLOPE =		
	OFFSET =		

Problems seen:

Repairs done:

Figure A- 6: O_3 Analyzer Maintenance Worksheet

API T703 Annual Maintenance Worksheet

Control# 6182019

Tech: J Wolbert	Date		
	Serial #		
Adjustments / Observations			
		pre cal	post cal
Dark Calibration	mV		
		@ zero	@ Span
M/R Valve Check	O3 REF		
		pre cal	post cal
Photo Pressure	PHOTO SPRESS=		
		pre cal	post cal
Regulator Pressure	PSI=		
	Volumetric flow	pre cal	post cal
Photometer Flow Calibration	PHOTO FLOW		
	STP 0^{c} Flow	pre cal	post cal
Output Flow Calibration	OUTPUT FLOW =		
		pre cal	post cal
Photometer UV Lamp Adjust	PHOTO DET		
		No Flow	1.5 LPM Flow
Dry Air Pump Vacuum	in Hg =		
Repairs			
		Yes	No
Dry Air Pump Rebuild?			
Clean Absorption tube?			
Photometer UV lamp replaced?			
Ozone generator lamp replaced?			
O3 Generator Calibration?			
Leak Check	SAMP_FL=		<10 ccm
	PHOTO SPRESS=		<10 inHg
Regression		as found	as left
	SLOPE =		
	OFFSET =		

Problems Observed:

Repairs Performed:

Figure A- 7: O_3 Transfer Standard Maintenance Worksheet