Ozone (O₃) Monitoring Standard Operating Procedure

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Ozone (O₃) Monitoring Standard Operating Procedure

October 2017

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1. Introduction

1.1 Purpose and Scope

This document describes the standard operating procedure for ozone (O₃) monitoring within the Washington State Ambient Air Monitoring Network (Washington Network) supported by the Washington State Department of Ecology (Ecology).

It covers installation, quality control and maintenance for ozone analyzers, certification 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 the analyzers of model 400E and T400 manufactured by Teledyne Advanced Pollution Instrumentation (Teledyne API) 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 (NAAQS);
- 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 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, NO₂) 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 sample 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 SO₂, NOₓ, and H₂O. A microprocessor combines the reference and measurement UV signals, ambient temperature, 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

<table>
<thead>
<tr>
<th>Category</th>
<th>Equipment</th>
<th>Purchase Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools and Equipment</td>
<td>Flexible FEP tubing (¼”)</td>
<td>Yearly or as needed</td>
</tr>
<tr>
<td></td>
<td>FEP or stainless steel fittings (¼”)</td>
<td>Once; replace as needed</td>
</tr>
<tr>
<td></td>
<td>Sampling funnel</td>
<td>Once; replace as needed</td>
</tr>
<tr>
<td></td>
<td>Charcoal column</td>
<td>Once</td>
</tr>
<tr>
<td></td>
<td>NIST-traceable flow meter</td>
<td>Once</td>
</tr>
<tr>
<td></td>
<td>Various hand tools (screwdriver, volt meter, etc.)</td>
<td>Once</td>
</tr>
<tr>
<td>Consumables</td>
<td>PTFE particulate filter (47 mm diameter, pore size 5 µm)</td>
<td>Monthly or as needed</td>
</tr>
<tr>
<td></td>
<td>Extra charcoal and Purafil®</td>
<td>Yearly or as needed</td>
</tr>
</tbody>
</table>
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 neighborhood, urban, and regional. Operators may refer to 40 CFR Part 58 Appendix E: [https://www.ecfr.gov/cgi-bin/retrieveECFR?n=40v6.0.1.1.6](https://www.ecfr.gov/cgi-bin/retrieveECFR?n=40v6.0.1.1.6) for extensive siting criteria on ozone monitoring.


Table 4-1. Summary of O₃ siting criteria

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

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
should not vary by more than ± 2 °C per hour. Analyzers 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, analyze, calibrate and store ambient ozone and calibration concentration data. Ecology requires the use of an external active charcoal scrubber on the dry air port of the transfer standard to supply zero air. Both the analyzer and transfer standard are connected serially to the data logger via a 9-pin cable. To the extent possible, the system must be configured as shown in Figure 4-1.

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

At the probe tip outside the station, a tee must be used to connect the calibrator output line with the sample inlet and analyzer line. This dual-probe configuration allows the calibration gas to be fed through the full sample path in order to verify the complete sampling train, known as “through the probe” verification. The tee is sheltered under a funnel to protect the probe from precipitation.

All Washington Network ozone monitoring sites must use fluorinated ethylene propylene (FEP) Teflon® tubing throughout the sampling train (from inlet probe to the back of the analyzer). The standard probe size is ¼” outer diameter. For fittings, the only acceptable materials used in the sampling train are FEP Teflon®, borosilicate glass, or their equivalent for all state and local monitoring stations, per 40 CFR Part 58 Appendix E: https://www.ecfr.gov/cgi-
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:

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

Where:
- \(RT\) = Residence Time (s)
- \(L\) = length of sample inlet (cm)
- \(d\) = inner diameter of sample inlet (cm)
- \(flow\) = instrument flow rate (cc/min)

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

Equation 4-1. Residence time calculation
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, U.S. Environmental Protection Agency (USEPA) 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.

- **Level 1: Standard Reference Photometer (SRP)**
  The National Institute of Standards and Technology (NIST) maintains the national Level-1 SRPs in the United States. The EPA SRPs are compared against the NIST SRPs every two years. The Regional SRPs housed in California Air Resources Board (CARB) are sent back to EPA for comparison against the EPA SRPs annually.

- **Level 2: Ecology’s Primary Ozone Standard**
  Ecology’s primary standards are kept in the Quality Assurance Lab and the Calibration & Repair Lab and should only be used for recertifying the Level-3 transfer standards. The ozone standards at this level from both laboratories are sent back to CARB for comparison against the Regional SRP annually.

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**Figure 5-1. Washington Network Ozone Standard Hierarchy Chart.**
• Level 3: Transfer Standard

To ensure all ozone calibrations and performance evaluations in the Washington Network are traceable to the Level-1 SRPs, the transfer standards must be certified for traceability based on Level-2, Ecology’s primary standards. The timing for certification is before and after each ozone season (May 1 – September 30) for seasonal monitoring sites and every 6 months for year-round monitoring sites.

At Ecology, transfer standards deployed in the 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.

5.2 Transfer Standard Certification

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

Qualification consists of demonstrating that the transfer standard is sufficiently stable (repeatable) to be used as a transfer standard. All transfer standards used in the Washington Network must meet the requirements established in 40 CFR Part 50 Appendix D: https://www.ecfr.gov/cgi-bin/text-idx?SID=f53a6db453e21b6ab53d2879e7987488&mc=true&node=pt40.2.50&rgn=div5#ap40.2.50_119.d. Ecology also requires the transfer standards be designated as either Federal Reference Method (FRM) or Federal Equivalent Method (FEM). After a transfer standard has been shown to meet the qualification requirements, certification is required before it can be used.

Certification must be established through a quantitative verification for the Level-3 (field) transfer standard against the Level-2 (lab) Ecology’s primary standard. The specific requirements are:

1. At least six comparison points between the transfer standard and the Level-2 primary standard. 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. Six individual comparison set of six or more comparison points elected in step (1) must be performed on different days.
3. For each comparison set, compute the slope (m) and intercept (I) by the least squares linear regression of the transfer standard and the Level-2 primary standard.
4. When the six comparison sets are completed, calculate the average slope (m̄) and average intercept (Ī).
5. Determine the standard deviation of the six intercepts (S_i) using Equation 5-1, with one degree of freedom (N=6, N-1=5).
Where $I_i$ is the individual intercept from each comparison set.

**Equation 5-1. Standard deviation calculation**

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

\[
S_m = \frac{100}{\bar{m}} \sqrt{\frac{1}{5} \sum_{i=1}^{6} (m_i - \bar{m})^2} \%
\]

Where $m_i$ is the individual slope from each comparison set.

**Equation 5-2. Relative standard deviation calculation**

7. To maintain certification, the value of $S_I$ in step (5) must be \( \leq 1.5 \) and value of $S_m$ in step (6) must be \( \leq 3.7 \% \).

Recertification involves periodic six point comparisons between Ecology’s primary standard and the transfer standard. EPA recommends that a transfer standard be recertified quarterly to avoid loss of certification over that time period. The linear regression slope of each new comparison must be within \( \pm 5\% \) of the average slope of the current certification relationship (i.e. the average slope of the last 6 comparisons). If the transfer standard meets the specification, a new slope and intercept are computed using the 6 most recent comparisons, i.e. running averages. The new calibration relationship is computed as:

\[
\text{Standard } O_3 \text{ Concentration} = \frac{1}{\bar{m}} (\text{Indicated } O_3 \text{ concentrations} - \bar{I})
\]

**Equation 5-3. Standard ozone calculation**

Should the transfer standard fail the recertification specifications, it loses its certification and the problem must be investigated and corrected. Recertification requires repeating all the initial certification steps described above.

6. Quality Control and Maintenance

The quality control (QC) procedure includes automated and manual quality control checks at routine intervals at all seasonal and year-round ozone monitoring sites. All QC checks must be triggered through the Envidas Ultimate data logger software 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.

A number of terms for various quality control checks and challenge points exist throughout EPA literature, existing SOPs, the Envidas Ultimate framework, etc. For the purpose of clarification, this SOP adopts the uniform terminology of “Primary QC Check” and “Secondary QC Check.” These terms are paired with their corresponding EPA terms in Table 6-1 below.

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

<table>
<thead>
<tr>
<th>Ecology Term</th>
<th>EPA Term</th>
<th>Number of Target Points</th>
<th>Ecology Target Point Term</th>
<th>EPA Target Point Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary QC Check</td>
<td>One-Point QC Check</td>
<td>2 including zero</td>
<td>Primary QC Point 1</td>
<td>QC Check Concentration; Precision Point</td>
</tr>
<tr>
<td>Secondary QC Check</td>
<td>Zero/Span Check; Multi-Point Verification</td>
<td>3 including zero</td>
<td>Secondary QC Point 1</td>
<td>Span Check Value</td>
</tr>
</tbody>
</table>

In order to collect ambient ozone monitoring data representative in quantity and quality to meet the Data Quality Objectives, it is important to consider the timing for QC checks and maintenance. Depending on the hours of the day, as little as three hours of analyzer downtime can render the entire day invalid for establishing a design value. Ecology recommends the following general guideline:

- Schedule automatic QC checks during early morning hours (0100 – 0359 PST)
- Schedule and complete any maintenance work before 1000 PST to avoid missing critical sampling period, such as high ozone concentration hours
- Keep the work within 2 hours

6.1 Automated Quality Control Checks

6.1.1 Frequency
Automated QC checks must occur at the minimum frequencies shown in Table 6-2. For clarification, *automated* refers to both initiation and sequence of the QC and *automatic* refers to the sequence only. Given the relatively low expense and small amount of data lost from automatic QC checks, Ecology recommends they occur 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.

To ease inspection of the QC checks on a semi-weekly basis, Ecology recommends the primary QC checks be scheduled such that one occurs at the beginning of the week and the other occurs in latter half of the week. For example, operators can schedule the automatic primary QC check on Mondays and Thursdays.

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

<table>
<thead>
<tr>
<th>Quality Control Check Type</th>
<th>EPA Minimum Required Frequency</th>
<th>Ecology Minimum Recommended Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary QC Check</td>
<td>Once every 14 days</td>
<td>Twice a week (semi-weekly)</td>
</tr>
<tr>
<td>Secondary QC Check</td>
<td>Once every 14 days</td>
<td>Once every 14 days</td>
</tr>
</tbody>
</table>

6.1.2 Timing
Automated QC checks should be timed during the hours of lowest expected concentrations, typically during early morning hours (0100 – 0359 PST).

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. Generally, primary QC checks lasting less than 60 minutes should begin at the top of the hour to ensure that only one hour of data is lost. Secondary QC checks lasting up to 88 minutes should be timed to start at 46 minutes after the hour so that only the middle hour is lost. For example, if a QC check starts at 0146 PST and lasts until 0314 PST, only the 0200 PST hour will be lost. Both the 0100 and 0300 PST hours have enough 1-minute sample data to be considered valid.

6.1.3 Concentrations and calibration scale
All ozone monitoring sites in the Washington Network should use a primary QC point of 70 ppb and a secondary QC point of 150 ppb. If operators prefer to select additional QC points for verification, contact Quality Assurance Unit for assistance.

The upper limit for the calibration scale on the analyzer should be set to at least 200 ppb to cap the secondary QC point. If operators prefer to select a different scale for calibration, contact the Calibration & Repair Lab for assistance.
6.1.4 Flow requirements

The sample flow of the analyzer must be maintained at 800 ± 80 cc/min at sea level in order to maintain the FEM designation status (EQOA-0992-087), in accordance with 40 CFR Part 53. The output flow of the transfer standard should be at least 1 LPM above the analyzer’s requirement to ensure that ambient air will not be introduced into the probe during calibration and QC checks.

6.1.5 Acceptance criteria

The critical acceptance levels are ± 7 % of the referenced value for non-zero QC points and ± 3 ppb for zero. The zero reading from the analyzer should be compared with 0 ppb instead of the actual reading from the transfer standard. Non-zero points are compared to actual readings (2-min average) from the transfer standard. If non-zero QC points exceed ± 5% of the referenced value, operators should investigate and recalibrate the analyzer if necessary.

6.2 Manual Quality Control Checks

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

- An automatic QC check fails to run properly, or
- If operators need to initiate additional QC checks before and after recalibration

Operators must initiate the QC check from Envidas Ultimate 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).

When manually initiating a primary or secondary QC check, avoid performing them when ambient temperatures are expected to exceed 85 degrees or when a high ozone day is forecast for the region. In regions where high temperatures are unavoidable during ozone season, such as eastern Washington, strive to perform any QC checks in the morning, optimally before 1000 PST.

To begin a QC check manually, as shown in Figure 6-1 below, 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 perform. Select the Initiate option to start immediately, or the Schedule option to schedule the check to minimize data loss as described above.
Operators must make a site visit every 4 weeks to perform a thorough examination of the site conditions and instrument performance. Operators are required to fill out an electronic QC check form during the every 4-week site visit and email it to the Quality Assurance Coordinator no later than the 10th day of the following month. Figure 6-2 shows an example of a site visit and automated secondary (multi-point) QC schedule, in addition to the primary QC schedule (not shown). The QC check form can be found in Appendix A. Contact the Calibration & Repair Lab or Quality Assurance Unit to obtain an electronically fillable QC check form.
In addition to the aspects listed in the form, operators should check the following during each site visit:

- Investigate any warning messages or unusual behaviors of the analyzer and transfer standard
- Visually inspect the inlet to ensure that the cone and tee are in good condition and configured appropriately
- Inspect the sample and calibration lines to ensure that they are clean and free of moisture
- Verify that shelter conditions meet the requirements specified in Section 4.1.2
- Change the particulate filter, monthly or as needed (see Section 6.4.2)
- Ensure the most current ozone SOP and model-specific operation manuals for the analyzer and transfer standard are present in the shelter
- Ensure the latest Calibration Result Sheet of the transfer standard against Ecology’s primary standard from the Calibration & Repair Lab is present in the shelter
6.4 Maintenance

Major maintenance and repairs on the analyzers are performed by the Calibration & Repair Lab in the Ecology headquarters. However, the station operator is required to perform the routine maintenance on the instruments as shown in Table 6-3 below. Record all maintenance activities in the electronic logbook.

Table 6-3. Summary of required O₃ analyzer and transfer standard maintenance

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Minimum Required Frequency</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify diagnostic data in analyzer &amp; transfer standard</td>
<td>Every 30 days and after any maintenance</td>
<td>6.4.1</td>
</tr>
<tr>
<td>Change particulate filter</td>
<td>Every 30 days or as needed</td>
<td>6.4.2</td>
</tr>
<tr>
<td>Adjust output flow rate</td>
<td>When Output Flow &lt; 3.0 LPM</td>
<td>6.4.3</td>
</tr>
<tr>
<td>Adjust UV source lamp</td>
<td>When Photo Ref (transfer standard) or O3 Ref (analyzer) &lt; 3000 mV</td>
<td>6.4.4</td>
</tr>
<tr>
<td>Clean/replace sample and calibration lines</td>
<td>Before ozone season at seasonal sites and every 180 days at year-round sites</td>
<td>6.4.5</td>
</tr>
</tbody>
</table>

6.4.1 Verify diagnostic data

At a minimum, operators must review the diagnostic data every 30 days, preferably during their every 4th week site visit, to verify the analyzer’s operation. However, in order to identify potential problems early and prevent data loss, it is recommended that operators review the 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. Note that photo pressure and sample pressure readings may be lower than the range for sites at higher elevation. Contact the Calibration & Repair Lab for technical assistance. The fundamental diagnostic data in the ozone analyzer is summarized in Table 6-5.

Table 6-4. Acceptable operating range of transfer standard and analyzer

<table>
<thead>
<tr>
<th>Transfer Standard</th>
<th>Expected</th>
<th>Analyzer</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Function</td>
<td>Expected</td>
<td>Test Function</td>
<td>Expected</td>
</tr>
<tr>
<td>Photo Flow</td>
<td>0.72 - 0.88 LPM</td>
<td>Sample Flow</td>
<td>720 - 880 cc/min</td>
</tr>
<tr>
<td>Photo Pressure</td>
<td>27.0 - 29.9 inHg-A</td>
<td>Sample Pressure</td>
<td>27.0 - 29.9 inHg-A</td>
</tr>
<tr>
<td>Box Temp</td>
<td>20 - 40 °C</td>
<td>Box Temp</td>
<td>20 - 40 °C</td>
</tr>
<tr>
<td>Photo Ref</td>
<td>3000 - 4450 mV</td>
<td>O3 Ref</td>
<td>3000 - 4450 mV</td>
</tr>
<tr>
<td>Output Flow</td>
<td>3.0 - 4.0 LPM</td>
<td>Slope &amp; Offset</td>
<td>See Cal. Result Sheet</td>
</tr>
<tr>
<td>Slope &amp; Offset</td>
<td>See Cal. Result Sheet</td>
<td>See Cal. Result Sheet</td>
<td></td>
</tr>
</tbody>
</table>
Table 6-5. Summary of diagnostic data (adopted from Teledyne API Manual 400E)

<table>
<thead>
<tr>
<th>Test Function</th>
<th>Diagnostic Relevance and Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>STABIL</td>
<td>Indicates noise level of instrument or stability of the O₃ concentration of Sample Gas</td>
</tr>
</tbody>
</table>
| O₃ MEAS & O₃ REF | If the value is:  
|                | • Too high: UV Source has become brighter. Adjust the variable gain potentiometer (pot), see Section 6.4.4.  
|                | • Too low: < 100mV: Bad UV lamp or UV lamp power supply. < 2000mV: Lamp output has dropped, adjust UV Preamp Board or replace lamp.  
|                | • Unstable: Bad UV lamp. Defective UV lamp power supply. Failed I²C Bus.  
|                | • If the O₃ REF changes by more than 10 mV between zero and span gas: defective/leaking switching valve |
| PRES          | Sample pressure |
| SAMPLE FL     | Sample flow |
| SAMPLE TEMP   | Photometer sample temperature |
| PHOTO LAMP    | Photometer lamp temperature |
| BOX TEMP      | Box temperature |
| 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 (P1) or circuitry.  
|                | • Bad/incorrect calibration gas concentration. |
| OFFSET        | Values outside range indicate contamination of the zero air supply. |

6.4.2 Change particulate filter

A PTFE filter is used to keep dirt from entering the analyzer. The filter must be inspected during each station visit, and should be changed every 30 days or when it becomes noticeably dirty. Slow analyzer response during a calibration check may indicate a dirty filter.

The PTFE filter is located inside the analyzer and the filter holder is mounted to the left side of the front panel. 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: Operators should wear clean, laboratory-grade 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 and unscrew the black rim around the glass piece and remove the glass cover. Be careful not to contaminate the inside surface.

3. Remove the large o-ring and retaining ring with cut-outs that hold the filter in place.

4. Using a clean stainless tweezer, remove the old filter and replace with a new filter. Make sure the filter is centered in the holder.

5. As shown in Figure 6-3, 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.

---

Figure 6-3. Particulate filter assembly (Teledyne API Manual 400E)
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 PTFE cap (Do not use a metal cap).
3. After 2 minutes, when the pressures have stabilized, note the SAMP FL test function reading on the front panel (toggle the <TST TST> keys until SAMP FL appears on the screen)
4. If SAMP FL < 10 cc/m then the analyzer is free of any large leaks.

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

1. Use the transfer standard or configured sequence from Envidas Ultimate to generate a concentration of 150 ppb to confirm that the analyzer and transfer standard agree within ± 3 %.
2. If the instruments do not agree within ± 3 %, the filter must be conditioned by performing this step. 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).
3. Repeat step 1 to confirm that the filter has been properly conditioned and the analyzer and transfer standard agree within ± 3 %.

### 6.4.3 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. In the Washington Network, the transfer standard should be set to deliver an optimal flow rate of 3.5 LPM and must maintain output flows between 3.0 and 4.0 LPM. 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 6-4) and adjust the regulator until the desired flow (~3.5 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.
6.4.4 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 transfer standards) value drops below 3000 mV.

1. Make sure the analyzer/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 6-5 (applicable to all Teledyne API models).

Figure 6-4. Output pressure regulator assembly (Teledyne API Manual T703/T703U)

Figure 6-5. 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 counter-clockwise 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. (Option) 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 cover on the instruments and press EXIT key on the front panel to the main menu.

6.4.5 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 1 through September 30), 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 in order to avoid sample line contamination.

1. Disconnect the Teflon tubing from the CAL GAS OUT port on the transfer standard and the SAMPLE port on the analyzer.

2. 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 clean water.

3. Using a clean 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.

4. Condition the probe by generating a concentration of 800 ppb from 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).

5. Use the transfer standard or configured sequence from Envidas Ultimate to generate a concentration of 150 ppb to confirm that the filter has been properly conditioned and the analyzer and transfer standard agree within ± 3 %.
7. Data Collection and Storage

7.1 Envidas Channel Configuration

The correct configuration for the ozone channel and data logger validation limits are shown in Figures 7-1 and 7-2. The channel must be set up to record ozone concentrations in ppm. Although most of the configurations are set up by Ecology’s IT staff when the channel is established, operators should occasionally verify the following specifications:

- The High Range in Figure 7-1 must be 0.3
- Span Drift in Figure 7-2 must be 7% of the reference value (% of Ref)
- Zero Drift in Figure 7-2 must be 1% of the range (% of Range)

![Image of Envidas channel configuration](image_url)

Figure 7-1. O₃ channel configuration.
Figure 7-2. O₃ primary QC configuration of validation limits.
The configuration for a primary QC check set to run every Monday and Thursday is shown in Figures 7-3 through 7-5. The zero phase should last 15 minutes and the span phase should last 35 minutes. The zero reference value should be 0 ppb, and the span reference value should be a 2-minute average of the ACTCONC channel, as circled in red in Figure 7-5. Secondary QC check will have an additional span phase that also last 35 minutes (not shown).

Figure 7-3. O₃ primary QC sequence properties.
Figure 7-4. O₃ primary QC sequence configuration.
7.2 Diagnostic Data Collection

At a minimum, the data logger should be configured to collect the diagnostic parameters listed in Table 6-5 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 7-6 (analyzer) and Figure 7-7 (transfer standard) below.

Figure 7-5. O₃ primary QC configuration of phases and reference values.
Figure 7-6. Configuration of O₃ analyzer diagnostic parameter collection

<table>
<thead>
<tr>
<th>Index</th>
<th>Command</th>
<th>Description</th>
<th>Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>O3</td>
<td>O3 Concentration</td>
<td>O3 Conco.</td>
<td>PPM</td>
</tr>
<tr>
<td>2</td>
<td>STABILITY</td>
<td>Stability</td>
<td>Stability</td>
<td>PPM</td>
</tr>
<tr>
<td>3</td>
<td>RANGE</td>
<td>Instant Range</td>
<td>Instant range</td>
<td>PPM</td>
</tr>
<tr>
<td>4</td>
<td>PHOTOMEAS</td>
<td>O3 Measurement</td>
<td>O3 measure</td>
<td>MV</td>
</tr>
<tr>
<td>5</td>
<td>PHOTOREF</td>
<td>O3 Ref.</td>
<td>O3 ref</td>
<td>MV</td>
</tr>
<tr>
<td>6</td>
<td>O3GENREF</td>
<td>O3 Generator Reference</td>
<td>O3 gen ref det</td>
<td>MV</td>
</tr>
<tr>
<td>7</td>
<td>O3GENDRIVE</td>
<td>O3 Generator Drive</td>
<td>O3 temp drive V</td>
<td>MV</td>
</tr>
<tr>
<td>8</td>
<td>PHOTOSPRESS</td>
<td>Sample Press</td>
<td>Sample Press</td>
<td>INHG</td>
</tr>
<tr>
<td>9</td>
<td>PHOTOSFLOW</td>
<td>Sample Flow Rate</td>
<td>Sample flow rate</td>
<td>CM/M</td>
</tr>
<tr>
<td>10</td>
<td>PHOTOSTEMP</td>
<td>Sample Temp</td>
<td>Sample temp</td>
<td>C</td>
</tr>
<tr>
<td>11</td>
<td>ALTEMP</td>
<td>Analyzer Temp</td>
<td>Analyzer temp</td>
<td>C</td>
</tr>
<tr>
<td>12</td>
<td>PHOTILTMP</td>
<td>Photos Lamp Temp</td>
<td>Photos lamp temp</td>
<td>C</td>
</tr>
<tr>
<td>13</td>
<td>BONTMP</td>
<td>Internal Box Temp</td>
<td>Internal box temp</td>
<td>C</td>
</tr>
<tr>
<td>14</td>
<td>DPS</td>
<td>DC Power Supply</td>
<td>DC power supply</td>
<td>MV</td>
</tr>
</tbody>
</table>
Figure 7-7. Configuration of O₃ transfer standard diagnostic parameter collection

<table>
<thead>
<tr>
<th>Index</th>
<th>Command</th>
<th>Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TARGETCONC</td>
<td>O₃ to Gas</td>
<td>PPM</td>
</tr>
<tr>
<td>2</td>
<td>OUTPUTFLOW</td>
<td>Output Flow</td>
<td>LPM</td>
</tr>
<tr>
<td>3</td>
<td>REPRESS</td>
<td>Reg Press</td>
<td>PSIG</td>
</tr>
<tr>
<td>4</td>
<td>ACTCONC</td>
<td>O₃ Conc</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>TARGETCONC</td>
<td>O₃ to Gas</td>
<td>PPM</td>
</tr>
<tr>
<td>6</td>
<td>OXITEMP</td>
<td>Inter Temp</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>OXGENREF</td>
<td>O₂ Gen Ref</td>
<td>MV</td>
</tr>
<tr>
<td>8</td>
<td>OXGENFLOW</td>
<td>O₂ Gen Out</td>
<td>MV</td>
</tr>
<tr>
<td>9</td>
<td>OXGETEMP</td>
<td>O₂ Gen Temp</td>
<td>C</td>
</tr>
<tr>
<td>10</td>
<td>PHOTMEAS</td>
<td>pH Meas</td>
<td>MV</td>
</tr>
<tr>
<td>11</td>
<td>PHOTREF</td>
<td>pH Ref</td>
<td>MV</td>
</tr>
<tr>
<td>12</td>
<td>PHOTFLOW</td>
<td>pH Flow</td>
<td>LPM</td>
</tr>
<tr>
<td>13</td>
<td>PHOTELTEMP</td>
<td>pH L.Temp</td>
<td>C</td>
</tr>
<tr>
<td>14</td>
<td>PHOTSPRESS</td>
<td>pH SpPress</td>
<td>In H₂O</td>
</tr>
<tr>
<td>15</td>
<td>PHOTTEMP</td>
<td>Sample temp</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>PHOTOSLOPE</td>
<td>pH Slope</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>PHOTOFFSET</td>
<td>pH Offset</td>
<td>PPM</td>
</tr>
<tr>
<td>18</td>
<td>PHOTSTABIL</td>
<td>pH Cond Sta</td>
<td>PPM</td>
</tr>
<tr>
<td>19</td>
<td>TESTCHAN</td>
<td>Analog Out</td>
<td>MV</td>
</tr>
<tr>
<td>20</td>
<td>CLOCKTIME</td>
<td>Time</td>
<td></td>
</tr>
</tbody>
</table>

The table above shows the configuration of diagnostic parameters for O₃ transfer standard collection.
8. Data Validation and Quality Assurance

8.1 Data Validation

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 in order 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 Quality Assurance unit via email when invalid data are identified.

The Quality Assurance Unit is responsible for final level review and data validation. Data validity is evaluated using a number of criteria, including but not limited to the results and frequency of quality control checks, performance audit results, 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 unit 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 the 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.

8.2 Quality Assurance

Quality Assurance 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 Quality Assurance Unit 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.
9. References


### Appendix A: Ozone QC Check Form

<table>
<thead>
<tr>
<th>AQS No</th>
<th>Location</th>
<th>Date</th>
<th>Operator</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Analyzer Serial No</th>
<th>Calibrator Serial No</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Probe Last Cleaned</th>
<th>Ambient Pressure mmHg</th>
</tr>
</thead>
</table>

**Conditions since last QC:**

- Min Room Temp \( ^\circ F \)
- Max Room Temp \( ^\circ F \)
- Any failed QCs?
- Diagnostics normal?

**Diagnostics (during QC):**

<table>
<thead>
<tr>
<th>Photo/O3 Ref (mV)</th>
<th>Analyzer State Tag</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Pressure (inHg-A)</td>
<td></td>
<td>3000 - 4800</td>
</tr>
<tr>
<td>Output Flow (lpm)</td>
<td></td>
<td>3.0 - 4.0</td>
</tr>
</tbody>
</table>

**Multipoint QC Results:**

<table>
<thead>
<tr>
<th>Target (Calibrator)</th>
<th>Actual (Analyzer)</th>
<th>Indicated (Analyzer)</th>
<th>Difference</th>
<th>Acceptance Limits</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>± 3 ppb</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td>± 7%</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td>± 7%</td>
<td></td>
</tr>
</tbody>
</table>

**Filter Changed?**

**Post-Filter Change Results:**

<table>
<thead>
<tr>
<th>Target</th>
<th>Actual</th>
<th>Indicated</th>
<th>Difference</th>
<th>Acceptance Limits</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td>± 7%</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

---

**Target**

**Actual**

**Indicated**

**Difference**

**Acceptance Limits**

**Results**

---

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