Quality Assurance Project Plan

Prepared by

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Prepared for

Tesoro Refining & Marketing Company LLC
Tesoro Los Angeles Refinery
Carson Operations, Wilmington Operations,
and Sulfur Recovery Plant
Carson, CA

August 27, 2024
Version 4

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A. Project Management

A.1 Title Page

Quality Assurance Project Plan
Fenceline Monitoring for the Tesoro Los Angeles Refinery (Carson Operations, Wilmington Operations, and Sulfur Recovery Plant)

Signature	Date
Name Tesoro Los Angeles Refinery	Title
Signature	Date
Name South Coast Air Quality Management District	Title
Signature	Date
Name Sonoma Technology, Inc.	Title

This Quality Assurance Project Plan (QAPP) is hereby recommended for approval and commits the Tesoro Los Angeles Refinery (LAR) to follow the elements described within. This document applies to the Carson Operations (Facility ID 174655), Wilmington Operations (Facility ID 800436) and Sulfur Recovery Plant (Facility ID 151798).

A.2 Table of Contents

Figures

Tables

Review and Revision History

Version	Date	Responsible Party	Description of Change
1	November 15, 2019	Tesoro LAR	Initial Submission to South Coast AQMD
2	October 13, 2020	Tesoro LAR	Revised Submission to South Coast AQMD
3	May 25, 2021	Tesoro LAR	Revised Submission to South Coast AQMD
4	August 27, 2024	Tesoro LAR	Updated in response to the January 5, 2024, adoption of amended Rule 1180

This QAPP is intended to be a living document, meaning it will undergo regular review to ensure that data quality assurance practices are robust and current. The QAPP will be reviewed at least on an annual basis and any proposed updates will be submitted for approval to South Coast Air Quality Management District (South Coast AQMD). The official version of this QAPP is maintained by Tesoro LAR in Carson, CA. This QAPP contains all critical documents for this program, including Standard Operating Procedures (SOPs) and blank data entry forms.

A.3 Distribution List

Name	Organization	Role
Parvez Abbas	Tesoro LAR	Program Manager
Robert T. Nguyen	Tesoro LAR	Environmental Manager
Andrea Polidori, PhD	South Coast AQMD	Assistant Deputy Executive Officer, Monitoring and Analysis Division
Olga Pikelnaya, PhD	South Coast AQMD	Rule 1180 Program Manager
Yifan Yu, PhD	South Coast AQMD	Program Supervisor
Clinton MacDonald	Sonoma Technology	Senior Advisor
All Project Personnel	Sonoma Technology	Various

Personnel included in the above list will be provided with revisions of all critical documentation.

A.4 Project Organization

This QAPP details the specifications for operating the monitoring network. It outlines the operation and maintenance of all instrumentation, equipment, data management, quality control (QC) procedures, and public reporting via automated notifications and a publicly accessible website.

Refinery staff work with Sonoma Technology to operate and maintain the fenceline monitoring network in accordance with Rule 1180. An organization chart (**Figure 1**) and various project roles are detailed below. Project contact information is provided in **Table 1**.

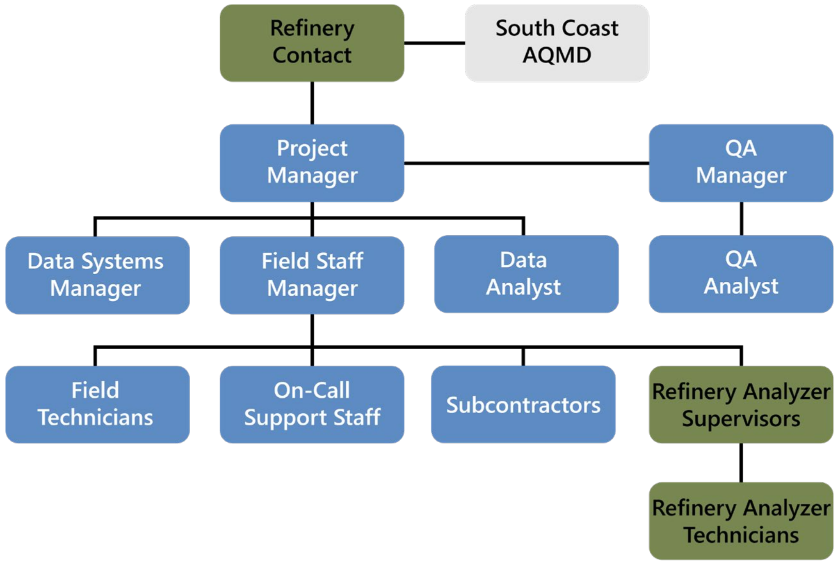

Figure 1. Organization chart for the refinery's fenceline monitoring project.

Refinery Contact. The Refinery Contact is responsible for project and program oversight and serves as the primary point of contact for the refinery. They facilitate communication between the refinery and South Coast AQMD.

Project Manager. The Sonoma Technology Project Manager is responsible for the successful execution of the fenceline monitoring project and serves as the primary point of contact for the contractor. The Project Manager oversees day-to-day monitoring operations, coordinates with all project personnel, and reports to the Refinery Contact. They also work closely with the Quality Assurance Manager (QA Manager) to ensure the QAPP and SOPs are followed and oversee corrective action plans (CAPs) when needed.

Quality Assurance Manager. The Sonoma Technology QA Manager provides overall guidance for the evaluation of data. The QA Manager is responsible for evaluating data for adherence to project specifications and ensuring that QA activities remain independent from data collection. If deviations are discovered, the QA Manager coordinates with the Project Manager to determine and implement necessary corrective actions.

Field Staff Manager. The Sonoma Technology Field Staff Manager oversees the team responsible for operating and maintaining all instrumentation and equipment at the refinery fenceline monitoring sites. They work closely with Field Technicians and Subcontractors, coordinate staff coverage and additional science support as needed, and regularly provide updates to the Project Manager.

Field Technicians. Sonoma Technology Field Technicians share the responsibility of successful instrumentation and equipment operation and provide routine maintenance according to SOPs. They are qualified to work on refinery property and with all scientific instrumentation. They also perform required quality checks according to this QAPP and document their work in site logs.

On-Call Support Staff. Sonoma Technology On-Call Support Staff are responsible for responding to automated system alerts outside of normal business hours, including remotely troubleshooting data flow outages and validating potential detection events. They are trained on the theory of operation for all field instrumentation and equipment and conduct abbreviated data checks to identify operational issues requiring field support.

Subcontractors. Subcontractors may be used to provide additional technical support for instrumentation and equipment. They are overseen by the Sonoma Technology Field Staff Manager and adhere to all project requirements.

Refinery Analyzer Supervisors. The Refinery Analyzer Supervisors oversee the Refinery Analyzer Technicians. They work closely with the Sonoma Technology Field Staff Manager, Field Technicians, and Subcontractors, and coordinate additional field support as needed.

Refinery Analyzer Technicians. Refinery Analyzer Technicians share the responsibility of the successful instrumentation and equipment operation and provide routine maintenance according to SOPs. They are qualified to work on refinery property and with all scientific instrumentation. They also perform required quality checks according to this QAPP and document their work in site logs.

Data Analysts. Data Analysts conduct routine daily data checks to ensure accuracy of real-time reporting on the public website, and relay issues to the Field Staff Manager as needed. They also conduct an extended analysis every calendar quarter to generate data products for regulatory reporting efforts, including the assembly of final data sets.

Quality Assurance Analyst. The Quality Assurance Analyst (QA Analyst) conducts independent reviews of data products to confirm data analysis activities have been conducted according to the QAPP. The QA Analyst works closely with the QA Manager and Data Analysts.

Data System Manager. The Data System Manager is responsible for continuous real-time data flow, routine operation of the automated alerting system, and proper data display on the public website. They work closely with Field Technicians, Data Analysts, and the Project Manager to ensure the system is operational and real-time data are reported to the public.

Table 1. Project contact information.

Name	Organization	Role	Contact Information
Parvez Abbas	Tesoro LAR	Program Manager	pabbas@marathonpetroleum.com 310-847-5266
Clinton MacDonald	Sonoma Technology	Senior Advisor	clint@sonomatech.com 707-665-9900

A.5 Problem Definition and Background

Tesoro LAR conducts air quality monitoring at the Carson Operations, Wilmington Operations, and Sulphur Recovery Plant (SRP), pursuant to South Coast AQMD Rule 1180.[1] Measurements are collected according to a Fenceline Air Monitoring Plan (FAMP) consistent with Fenceline Air Monitoring Plan Guidelines,[2] and data are reported in real time on a publicly accessible website.

The required compounds to be measured under amended Rule 1180 include criteria air pollutants (sulfur dioxide [SO_2], oxides of nitrogen [NO_x], and particulate matter less than 10 and 2.5 microns in diameter [PM_{10} and $PM_{2.5}$]), volatile organic compounds (total VOCs, formaldehyde, acetaldehyde, acrolein, 1,3-butadiene, naphthalene, polycyclic aromatic hydrocarbons [PAHs], styrene, benzene, toluene, ethylbenzene, and xylenes [BTEX]), metals (cadmium, manganese, and nickel), and other compounds (hydrogen sulfide [H_2S], carbonyl sulfide, ammonia, black carbon [BC], hydrogen cyanide, and hydrogen fluoride). Facility-specific exemptions and justifications for monitoring are detailed in the FAMP.

The California Environmental Protection Agency (EPA) Office of Environmental Health Hazard Assessment's (OEHHA) acute 1-hr reference exposure limit (REL) values are used as a reference under Rule 1180 for fenceline monitoring because they represent the concentration thresholds above which compounds are considered hazardous to human health. For criteria air pollutants, the National Ambient Air Quality Standard (NAAQS) values are used where they are lower than OEHHA RELs.

Rule 1180 requires public notifications when hourly concentrations measured by the fenceline monitoring system exceed defined thresholds. Table 2 lists the notification thresholds for the compounds included in this fenceline monitoring program, for which sampling methods capable of measuring below these values were selected. All thresholds are defined on an hourly basis and units are ppb, unless otherwise indicated. Detailed information regarding monitoring methods is provided in the FAMP (Revision 2) and Section B of this document.

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[1] https://www.aqmd.gov/docs/default-source/rule-book/reg-xi/r1180.pdf

[2] https://www.aqmd.gov/docs/default-source/rule-book/support-documents/1180/rule-1180-guidelines.pdf

Table 2. Rule 1180 notification thresholds.

Compound	Health Standard-Based Notification Threshold	Information-Based Notification Threshold
Criteria Air Pollutants		
SO_2	75 ppb	--
NO_x	100 ppb	--
$PM_{2.5}$	35 µg/m^3 (24-hr)	--
PM_{10}	50 µg/m^3 (24-hr)	--
Volatile Organic Compounds		
Total VOCs	N/A	730 ppb
Formaldehyde	44 ppb	--
Acetaldehyde	260 ppb	--
Acrolein	1.1 ppb [a]	--
1,3–Butadiene	297 ppb	--
Naphthalene	N/A	--
Styrene	5,000 ppb	--
Benzene	8 ppb	--
Toluene	1,300 ppb	--
Ethylbenzene	N/A	--
Xylenes	5,000 ppb	--
Metals		
Cadmium	N/A	--
Manganese	0.17 µg/m^3 (8-hr)	--
Nickel	0.2 µg/m^3	--
Other Compounds		
Hydrogen Sulfide	30 ppb	--
Carbonyl Sulfide	270 ppb	--
Ammonia	4,507 ppb	--
Black Carbon	N/A	--
Hydrogen Cyanide	309 ppb	--

[a] The minimum detection limit (MDL) of acrolein as measured by FTIR is greater than the notification threshold, so notifications are not sent, as described in the FAMP.

A.6 Project Description

Tesoro LAR currently conducts fenceline monitoring for criteria air pollutants (SO_2, NO_2), volatile organic compounds (total VOCs, formaldehyde, acetaldehyde, acrolein, 1,3-butadiene, styrene, BTEX), and other compounds (H_2S, carbonyl sulfide, ammonia, BC, hydrogen cyanide).

Additional monitoring for naphthalene, $PM_{2.5}$, PM_{10}, and metals (cadmium, nickel, and manganese; Carson Operations only), and implementation of a new monitoring system at the SRP, will be conducted following (1) the January 5, 2024, amendment of Rule 1180 as described in the FAMP and (2) South Coast AQMD approval of the FAMP.

PAHs will potentially be monitored after the South Coast AQMD Executive Officer provides written notice that real-time monitoring of PAHs is feasible, in accordance with Rule 1180. All Tesoro LAR facilities are exempt from monitoring hydrogen fluoride.

Sampling sites were selected in consideration of nearby local receptors (e.g., schools, daycare facilities, recreational areas, hospitals, and residences) and dominant winds in the area. Preliminary data from fenceline monitors are quality controlled and reported in real time to a publicly accessible website. Final quarterly reports are (1) posted on the public website where they can be viewed and downloaded and (2) routinely submitted to South Coast AQMD Monitoring and Analysis Division. Additional details are provided in the FAMP and Section B of this document.

A.7 Quality Objectives and Criteria

Data Quality Objectives

Data quality objectives (DQOs) outline the major question(s) to be answered by a monitoring project and ensure collected data are of sufficient quality to support project goals. The U.S. EPA provides a seven-step process to establish DQOs[3]:

1. **Problem Statement**: The goal of this monitoring program is to meet the requirements of South Coast Rule 1180, which was established to provide the public with information regarding concentrations of target compounds at the fencelines of refining facilities.
2. **Decision**: Refineries provide information to the public regarding concentrations of target compounds consistent with South Coast Rule 1180 and their FAMP.
3. **Information Inputs**: Concentration data from open-path analyzers and point monitors are provided as 5-min and 1-hr rolling average concentrations. Data are reviewed with respect to representativeness and comparability, using measurements from other available sources in similar geographic locations as a basis of comparison.

[3] https://www.epa.gov/quality/guidance-systematic-planning-using-data-quality-objectives-process-epa-qag-4

4. **Study Boundaries**: Concentration measurements are collected along refinery fencelines in accordance with South Coast AQMD Rule 1180 and each facility's FAMP.
5. **Decision Rule**: Measurements are collected and reported in real time, in accordance with South Coast AQMD Rule 1180 and the facility's FAMP.
6. **Acceptance Criteria**: Data will be considered acceptable for reporting provided they meet the defined performance criteria for the project.
7. **Data Collection**: Unless otherwise noted in the FAMP, data are collected every 5 minutes, 24 hours a day and 7 days a week. Automated screening is performed in real time before data are posted to a publicly accessible website.

Data Quality Indicators

Data quality indicators (DQIs) are the quantitative statistics and qualitative descriptors used to interpret data's degree of acceptability or utility in consideration of the project's DQOs. The DQIs for this South Coast AQMD Rule 1180 fenceline monitoring project are defined below. Accuracy and precision are quantitative metrics, representativeness and comparability are qualitative metrics, and completeness is a combined quantitative and qualitative metric.

Accuracy is the metric of agreement between an observed value and an accepted reference value, and is calculated using some derivation of error or recovery from a bump test data set. Additional details are provided in Section B.7 of this document.

Precision is the metric of mutual agreement among individual measurements of the same parameter, otherwise known as the random component of error. Precision is calculated using some derivation of the standard deviation of a bump test data set. Additional details are provided in Section B.7 of this document.

Representativeness refers to the degree to which data collected by the monitoring project broadly represent ambient conditions, variations between sampling sites, and potential detection events. Representativeness is primarily controlled by the sampling locations, which are detailed in the FAMP.

Concentrations of target compounds will be reported in parts per billion (ppb) and micrograms per cubic meter (μg/m^3), consistent with the requirements of Rule 1180. Routine bump tests with National Institute of Standards and Technology (NIST)-traceable reference gases ensure that concentrations reported by open-path analyzers and point monitors are comparable to other available measurements.

Completeness is a measure of the amount of usable data obtained by the monitoring project compared to the potential amount expected to be obtained under normal operating conditions. The goal of the monitoring project is to maximize system uptime through robust analyzer maintenance, routine data review, and short response times for addressing system issues.

Measurement Quality Objectives

Measurement quality objectives (MQOs) are individual performance or acceptance goals that directly translate each DQI into discrete analytical performance criteria. The MQOs for this fenceline monitoring project are detailed below.

Accuracy and Precision

Accuracy and precision are assessed for open-path analyzers and point monitors through routine bump and span tests with NIST-traceable reference gases where possible. The acceptance criteria shown in **Table 3** are used for periodic testing (i.e., monthly, quarterly, annually), as well as for continuous, automated QC (AutoQC) of real-time data.

An appropriate manufacturer-specific reference kit is used to assess accuracy of the meteorological sensors (wind speed and direction, temperature and relative humidity, and visibility) by comparing observations to reference measurements.

Additional details regarding instrument calibration and frequency are provided in Section B.7.

Table 3. Acceptance criteria for instrumentation and equipment.

QA/QC Checks	Frequency	Acceptance Criteria
UV-DOAS		
Bump Test (Accuracy and Precision)	Quarterly (and after major service)	±25%
Spectral Match (r^2)	Continuous	0.8–1.0
Signal Intensity	Continuous	≥70%
Integration Time	Continuous	≤250 msec
FTIR		
Bump Test (Accuracy and Precision)	Quarterly (and after major service)	±25%
Spectral Match (r^2)	Continuous	0.7–1.0
Signal Intensity	Continuous	≥2%
H_2S Point Monitor		
Zero Test	Monthly (and after major service)	±2 ppb
Multipoint Calibration	Quarterly (and after major service)	±2 ppb (zero) ±20% (each nonzero test conc.)
Aethalometer		
Flow Check	Monthly	±10%
Leak Check	Monthly	±10%
Clean Air Test	Semiannual	<550 ng/m^3
Stability Test	Semiannual	<450 ng/m^3
Neutral Density Check	Annually	±10%
PM Analyzer		
Flow Check	Monthly	±5%
Span Dust Check	Quarterly	±0.5 channel tolerance
Meteorological Sensors		
Wind Speed (Accuracy)	Annual	±0.25 m/s (below 5 m/s) ±5% (above 5 m/s)
Wind Direction (Accuracy)	Annual	±5 degrees
Visibility Sensor		
Extinction Coefficient (Accuracy)	Annually	±10%

Completeness

Data completeness is assessed by reviewing the data quality control and operational (QC/OP) codes assigned for each sample path/site and compound. Completeness statistics are defined as follows:

Possible: The maximum number of data points that could theoretically be logged in the Data Management System (DMS) during each quarter.

Captured: The number of data points that were logged in the DMS during each quarter.

Missing: The number of data points not logged in the DMS during each quarter.

- Missing = Possible – Captured

% Missing: The percentage of Missing data points relative to Possible during each quarter.

- % Missing = (Missing / Possible) * 100

Invalid-Weather: The number of data points that are invalid due to weather during each quarter.

- These data are designated as QC = 9, OP = 73 – "Low Visibility Conditions"

Planned Maintenance: The number of data points that are invalid due to planned instrument maintenance during each quarter.

- These data are designated as QC = 9, OP = 28 – "Planned Instrument Maintenance"

Unplanned Maintenance: The number of data points that are invalid due to unplanned instrument maintenance during each quarter.

- These data are designated as QC = 9, OP = 29 – "Unplanned Instrument Maintenance"

Expected: The number of Possible data points corrected for periods of low visibility conditions and planned instrument maintenance during each quarter.

- Expected = Possible – Invalid-Weather – Planned Maintenance

Invalid: The number of data points with an invalid QC code (QC = 9) during each quarter.

% Invalid: The percentage of Invalid data points relative to Possible during each quarter.

- % Invalid = (Invalid / Possible) * 100

Suspect/Questionable: The number of data points with a suspect QC code (QC = 5) during each quarter.

% Suspect/Questionable: The percentage of suspect/questionable data points relative to Possible during each quarter.

- % Suspect = (Suspect / Possible) * 100

Valid: The number of data points with a valid QC code (QC = 0) during each quarter.

% Valid: The percentage of Valid data points relative to Possible during each quarter.

- % Valid = (Valid / Possible) * 100

Public Recorded: The number of data points with a valid or suspect QC code (QC = 0 or 5) reported on the public website for each quarter.

% Complete: The percentage of Public Recorded data points relative to Expected during each quarter.

- % Complete = (Public Recorded / Expected) * 100

A.8 Special Training and Certifications

All project personnel are provided with necessary training and oversight, including:

1. Safety courses administered through the Occupational Safety Councils of America (OSCA)
2. Instrument-specific training from vendors
3. Data validation training from experienced Data Analysts
4. Routine operations and maintenance training from experienced Field Technicians

Training is conducted by (1) senior staff with at least one year of experience operating refinery fenceline monitoring systems and (2) analyzer manufacturers. Project personnel are provided copies of the FAMP, QAPP, and SOPs, and receive updated versions when they become available. Initial training is provided prior to performing work on the system, and refresher trainings are conducted on an annual basis. The QA Manager will identify specific training requirements for all project personnel and determine when trainees are qualified to work independently. Training records will be maintained by the Field Staff Manager. Additional details regarding training and certification are provided in the SOPs attached to this QAPP (Attachments 1–8).

A.9 Documents and Records

Quality system documentation, including the FAMP, QAPP, and SOPs, are routinely revised to reflect current best practices, improvements to available technology and data control practices, and fenceline monitoring program changes. Revisions are undertaken at the direction of the QA Manager. In addition to quality system documentation, quarterly reports are produced to provide a summary of system performance over each calendar quarter, which may include data summaries, statistical analyses, and results of QC tests. These reports are generated by relevant project staff, overseen by the QA Manager, and delivered to South Coast AQMD. They will also be made available for download on the public website.

The fenceline contractor (Sonoma Technology) achieves work product quality through a series of internal review-and-correction cycles and an external review by the client. Documents undergo at least two internal reviews—the first by a senior technical staff member who is knowledgeable about the subject matter but is not the primary author of the work, and the second by a technical editor who is skilled in English mechanics and writing style. Before any document (draft or final) is delivered to the refinery, the lead author or Project Manager conducts a final quality review and approves it for delivery. Final approved versions in PDF format are distributed to refinery staff and/or appropriate project personnel via email.

Sonoma Technology employs a robust, systematic approach to version tracking and file maintenance. Each document is stored by project number on a shared fileserver. Only the most recent version is stored in the top-level folder, and each draft version is tracked by a timestamp as well as all reviewers' initials in a subfolder. A unique Master File Number is assigned to each document and all versions of that document retain that number.

Sonoma Technology's proprietary Deliverables Organizer and Tracking System (DOTS) is used to track progress and facilitate management of all documentation and work products. The web-based system retains information on document versions, including the dates and names of employees who edited, reviewed, and revised each document. DOTS also contains standard reports for tracking deliverables through the QA/QC and delivery process and ensures that document information can be easily retrieved. A lead author or the Project Manager creates a DOTS entry for each upcoming deliverable, and then a Technical Editor maintains the DOTS record as each deliverable progresses through the update, review, delivery, and archiving process. Microsoft Word and PDF versions of all final approved documents are preserved on Sonoma Technology's fileserver in a secured Master File Library.

All staff involved in fenceline monitoring have been provided with electronic copies of SOPs. Revised versions of SOPs will be distributed to both refinery and contractor staff via email and will be stored on a shared drive. Additionally, hard copies of the SOPs and analyzer user manuals are kept in the analyzer shelters and replaced when revisions are completed. Updating digital and hard copies of the QAPP and SOPs ensures that staff only use the most recent version to meet measurement and data quality objectives.

The analyzer shelters also contain logbooks where all onsite activities related to the fenceline monitoring system are recorded. This includes planned maintenance activities and emergency site visits. The field logbooks are scanned each month to generate electronic copies.

Any corrections made to hard-copy documents will be indicated by (1) a cross out of the previous entry, (2) the addition of a new entry, (3) the date of correction, and (4) the initials or name of the individual making the correction. Electronic documents (reports and data) are stored on a password-protected server at Sonoma Technology, with current and previous versions stored by project and document.

All project documentation will be retained for at least 5 years following the end of the project.

B. Data Generation and Acquisition

B.1 Sampling Process Design

The fenceline monitoring system is designed to meet the following key sampling objectives:

- Provide measurements of air pollutant concentrations in real-time with short enough time resolutions to adequately address significant emissions changes from facility operations;
- Gather accurate meteorological data to identify factors that may impact air pollutant levels near facility operations; and
- Track long-term air pollutant levels, variations, and trends over time at or near refinery property boundaries.

A combination of open-path analyzers and point monitors were selected after consideration of all Rule 1180 requirements, including (1) spatial coverage necessary to monitor hundreds of meters of refinery fenceline; (2) 5-min resolution for real-time data; and (3) required detection limits, accuracy, and precision of target compounds. Heavy fog, rain, or smoke may block the signal from an open-path instrument and prevent data collection, but even light fog can partially absorb the signal and interfere with measurements. Visibility sensors confirm when low-visibility conditions result in invalid data from open-path instruments.

Sampling locations are shown in **Figure 2** and are further described in the FAMP. Additional details about open-path analyzers and point monitors are provided in Section B.2.

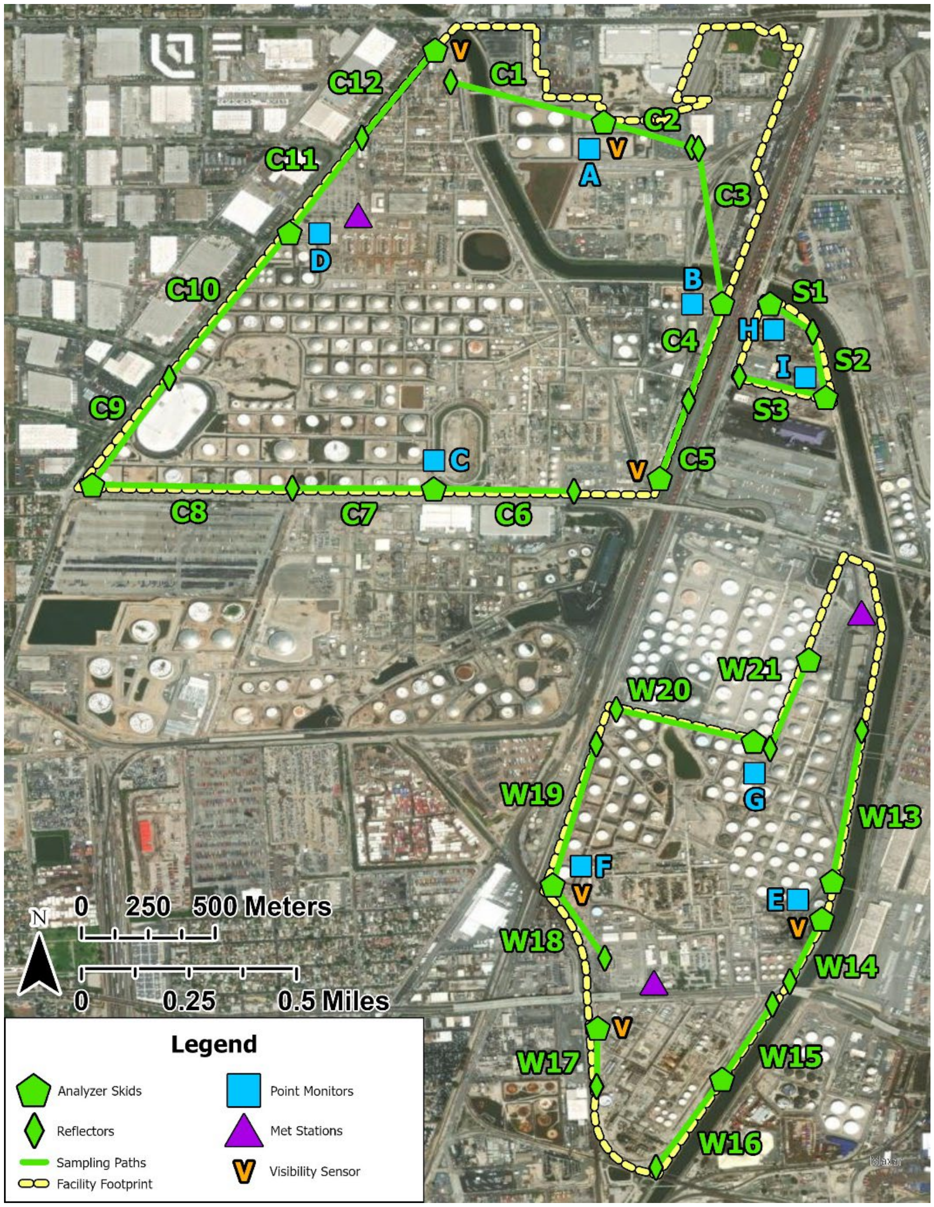

Figure 2. Fenceline monitoring sampling locations for Tesoro LAR, including the Carson Operations, Wilmington Operations, and SRP.

B.2 Sampling Methods

BTEX, SO_2, NO_2, and naphthalene are measured by monostatic UV-DOAS (source/detector on one end of the sampling path with a retroreflector on the other) with a xenon light source. The xenon light source is required to achieve sufficient detection limits for target compounds. Each of these compounds has a unique absorbance spectrum, meaning they absorb different amounts of light at discrete wavelengths. These are measured by the analyzer, which then compares regions of a sample absorbance spectra to the same regions of a reference absorbance spectra.

Total VOCs, formaldehyde, acetaldehyde, acrolein, 1,3-butadiene, styrene, carbonyl sulfide, ammonia, and hydrogen cyanide, are measured by monostatic FTIR, which operates similarly to the UV-DOAS. A combination of industry standard and proprietary methods is used to mitigate interference from water vapor and interference gases.

South Coast AQMD Rule 102 defines VOC as any volatile compound of carbon, excluding methane, carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, ammonium carbonate, and exempt compounds. South Coast AQMD Methods 25.1 and 25.3 analysis and compliance reporting indicates non-methane non-ethane organic compounds to be reported as VOC for compliance permit limits. A subset of VOCs are ambient air ozone precursors and/or associated with human inhalation health risk and are considered under Rule 1180. The Total VOC reported by the fenceline monitoring system may contain regional off-site VOCs. As with other compounds measured by the open-path FTIR analyzer, individual constituent gases (propane, butane, and pentane) are measured against reference spectra.

For both UV-DOAS and FTIR, a classic least squares regression analysis provides a spectral match parameter (r^2), which is used to identify potential interferences present in the sample path. The primary means of avoiding absorbance due to interfering gases is to select regions of the absorbance spectrum specific to the target compounds and free of absorbance from other gases. Spectral subtraction is used in cases with overlapping absorbance features, and the subtraction technique is proprietary to the instrument manufacturer. Spectral matching is used to identify target compounds, and Beer's Law is used to report the concentration. This approach is comparable to U.S. EPA's TO-16 Methodology.[4]

H_2S concentrations are measured through cavity ring-down spectroscopy (CRDS), which is a direct absorbance technique. BC is measured with aethalometers, which draw air through permeable tape and measure the absorbance at a defined wavelength of the deposited samples. This system detects particles in the air commonly associated with vehicle emissions (diesel exhaust) and wood burning (soot). PM_{10} and $PM_{2.5}$ will be measured with optical scattering. Metals (cadmium, manganese, and nickel) will be measured by Energy Dispersive X-Ray Fluorescence (EDXRF), which exposes a sample deposited on filter tape to high-energy X-rays and uses the resulting fluorescence to directly measure concentration.

MDLs for each analyzer are provided in the FAMP. Instrument operations and maintenance, emergency site visits, and corrective actions are detailed in Section B.6 of this document.

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[4] U.S. Environmental Protection Agency (1999) Compendium of methods for the determination of toxic organic compounds in ambient air: compendium method TO-16. Second edition, prepared by the U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH, EPA/625/R-96/010b, January. Available at https://www3.epa.gov/ttnamti1/files/ambient/airtox/tocomp99.pdf.

B.3 Sample Handling and Custody

Analyzers are located in secure sites to prohibit tampering or handling by anyone other than authorized personnel. Technicians keep sampling shelters clean and routinely check analyzers for debris or residue during site visits. Real-time data are transmitted to the DMS by cellular modem and can only be accessed by authorized personnel. All changes to data within the DMS are tracked through chain-of-custody logs.

No laboratory analyses are required for this monitoring project, so no discussion of sample preparation, storage, or transport is required.

B.4 Analytical Methods

Refer to Section B.2 of this document for information regarding real-time sampling methods. No laboratory analyses are required for this monitoring project.

B.5 Quality Control Requirements

Real-time data from open-path analyzers undergo several rounds of QC, including AutoQC logic which flags data before they are posted on the public website. Analysis and QC of real-time data is described in Section D.2 of this document and the SOP for Data Verification and Validation (**Attachment 8**).

B.6 Instrument/Equipment Testing, Inspection, and Maintenance

Routine Maintenance

Tables 4 and 5 summarize the routine maintenance activities as recommended by the UV-DOAS and FTIR instrument manufacturer, and additional details are provided in the instrument SOPs (**Attachments 1 and 2**). Preventive maintenance frequency depends on the operating environment and may need to be adjusted depending on field conditions. Any necessary changes will be reflected as an update to this QAPP, which will be submitted to South Coast AQMD for approval.

Table 4. Schedule of routine maintenance activities for Cerex UV-DOAS open-path analyzers.

Activity	Monthly	Quarterly	Annually
Visually inspect the system	✓		
Inspect detector optics; clean if necessary	✓		
Inspect all electrical cables for wear; replace as needed	✓		
Confirm the alignment of the light source and detector	✓		
Ensure that there are no obstructions between the light source and detector (e.g., refinery equipment, vegetation, or vehicles)	✓		
Perform bump test		✓	
Replace light source		✓	
Replace system filters		✓	
Archive historical data and remove from analyzer computer			✓
Clean detector optics			✓
Verify system settings			✓

Table 5. Schedule of routine maintenance activities for Cerex FTIR open-path analyzers.

Activity	Monthly	Quarterly	Annually	Biannually	Every 5 Years
Visually inspect the system	✓				
Inspect detector and retroreflector optics; clean if necessary	✓				
Confirm the alignment of the light source/detector and retroreflector	✓				
Ensure there are no obstructions between the light source/detector and retroreflector (e.g., refinery equipment, vegetation, or vehicles)	✓				
Clean retroreflectors	✓				
Perform bump test		✓			
Archive historical data and remove from analyzer computer			✓		
Test and document signal levels to establish a baseline for light source and retroreflector replacement frequency			✓		
Replace cryocooler				✓	
Replace the light source					✓

Maintenance activities for the H_2S point monitors are summarized in Table 6 and additional details are provided in the SOP (Attachment 3).

Table 6. Schedule of routine maintenance activities for H_2S point monitors.

Activity	Monthly	Quarterly	Annually
Inspect sample lines	✓		
Inspect and clean insect/moisture trap	✓		
Perform zero check/baseline correction	✓		
Perform gas verification test		✓	
Archive historical data and remove from analyzer computer			✓
Replace particulate filters			✓

Maintenance activities for the aethalometers are summarized in Table 7 and additional details are provided in the SOP (Attachment 4).

Table 7. Schedule of maintenance activities for the Magee AE33 Aethalometer.

Activity	Monthly	Semiannual	Annual
Visually inspect the system	✓		
Clean size selective inlet	✓		
Perform flow check; calibrate when needed	✓		
Leak check	✓		
Inspect tape roll and replace as needed		✓	
Inspect optical chamber and clean as necessary		✓	
Clean air test		✓	
Stability test		✓	
Neutral density filter test			✓
Grease optical chamber sliders			✓
Inspect bypass cartridge filter and change as needed			✓

Maintenance activities for the PM point monitors are summarized in Table 8 and additional details are provided in the SOP (Attachment 5).

Table 8. Schedule of maintenance activities for the Teledyne T640X.

Activity	Monthly	Semi Annual	Annual
Clean inlet	✓		
Check/adjust PMT with SpanDust™	✓		
Check pump performance	✓		
Flow rate verification (sample, bypass and total flow)	✓		
Perform leak check	✓		
Inspect inner and outer sample tubes	✓		
Inspect and clean optical chamber and RH/T sensor		✓	
Change disposable filter for 5-LPM flow and bypass flow			✓

Maintenance activities for the metals monitor are summarized in Table 9 and additional details are provided in the SOP (Attachment 6).

Table 9. Schedule of maintenance activities for the Cooper Xact metals monitor.

Activity	Monthly	Quarterly	Annual
Check the upscale (reference) measurements	✓		
Inspect tape roll and replace as needed	✓		
Perform leak check		✓	
Perform flow check		✓	
Perform XRF calibration		✓	
Perform flow calibration			✓
Examine tubing, enclosure, and components for particle accumulation, rust, or damage; clean as needed			✓
Perform Xact recalibration			✓

Annual maintenance activities for the meteorological sensors are summarized in Table 10.

Table 10. Maintenance activities for meteorological sensors.

Item	Action
Tower	Check that the tower is securely anchored to the shelter
	Check the tower for signs of damage or excessive wear
	Inspect all bolts at the tower base for any signs of corrosion (rust)
	Check the tower's vertical alignment
Anemometer	Note if any component (tail, propeller) is missing or has suffered obvious damage
	Check that the whole sensor moves freely with a changing wind direction and the propeller rotates freely when windy
Temperature/ RH Sensor and Shield	Inspect the hardware holding the temperature/RH sensor shield assembly to the tower and tighten the bolts if necessary
	Check that the cable connections are secure
Visibility Sensors	Inspect the sensor for dirt, spiderwebs, birds' nests, or other obstructions and clean the glass windows
	Check that the cable connections are secure
	Inspect the hardware holding the sensors to the tower and tighten bolts if necessary
Data Logger Enclosure	Verify that the enclosure is secured inside the shelter and is operational
	Check that the cabling to the enclosure is secure and undamaged
	Check the integrity of the cables connecting the data logger box to the sensors
Guy Wires	Where guy wires are used, check if they are taut and the attachment points are tight; verify cables are not frayed and the integrity has not been compromised in any way
Solar Power	Where solar power is used, check that the solar panel is clean and free of debris; confirm all connections to the battery are secure and free from corrosion.

Maintenance activities for the visibility sensor are summarized in Table 11 and additional details are provided in the SOP (Attachment 7).

Table 11. Schedule of routine maintenance activities for visibility sensor.

Activity	Monthly	Annually
Visually inspect the system, including all cables	✓	
Inspect detector optics; clean if necessary	✓	
Perform calibration (extinction coefficient)		✓

Emergency Maintenance and Corrective Actions

Emergency maintenance occurs when problems are identified with the fenceline monitoring network. Two teams of after-hours (on-call) support personnel remotely monitor the status of instrumentation and the data pipeline (acquisition, DMS, public website) Automated alerts are sent if potential issues are identified, such as:

1. Missing data
2. Reported concentrations outside of an expected range
3. Instrument diagnostics indicate a potential malfunction

The Sonoma Technology field operations team (Field Ops) is led by the Field Staff Manager, and the information systems team (IS Ops) is led by the Data Systems Manager. The nature of potential issues determines which team receives automated alerts. On-call personnel are required to acknowledge alerts within 30 minutes of receipt and attempt to resolve potential issues remotely. This approach ensures that issues are identified and addressed in a timely manner, which maximizes fenceline monitoring network uptime.

The Field Ops team addresses most issues pertaining to instrumentation and equipment. In the case of missing data, refinery personnel are notified if the alert cannot be resolved remotely, South Coast AQMD is notified of monitoring downtime as required by Rule 1180, and a maintenance message may be posted on the public website depending on the event. Backup monitoring may be conducted as described by the FAMP if an extended outage is anticipated. In the case of elevated concentrations, data are reviewed and the refinery is notified whether the detection is legitimate or due to a potential instrument malfunction. Data flags are updated on the public website during daily data checks to ensure accuracy, including for potential after-hours events. Any required field site visits occur on the next business day, and all corrective actions performed are documented in on-site logbooks.

The IS Ops team addresses most issues pertaining to data flow and the public website. **Table 12** outlines examples of automated screening, which the IS Ops team may review to troubleshoot potential issues.

Table 12. Examples of automated screening pertaining to the data pipeline and public website.

Target	Test	Frequency	Threshold
Website Availability	HTTP test of the public and internal websites	300 sec	Pass/Fail
DMS	CPU utilization	300 sec	>60%
	Memory use		>75%
	Disk space used		>75%
Data Flow	Time since last datum received	30 min	Pass/Fail
Data Processing Errors	Process scheduler	300 sec	Pass/Fail

Initial Factory Acceptance Tests

Tesoro LAR follows the internal project procedure to complete a factory acceptance test (FAT) and a site acceptance test (SAT) for each new instrument installed and operated at the site. Generally the FAT and SAT scope of work is formalized by the instrument manufacturer in discussion with the site preferred vendor for the installation and operation of the instrument. The FAT generally follows the qualification stage of the design quantification and includes a series of testing done on instrument, carried out at the manufacturer's site or at the facility to ensure all components work according to its functionality and operates within the design specifications.

These FAT and SAT validates the instrument operation and performance to meet accuracy, representativeness, completeness, sensitivity, and accuracy requirements.

B.7 Instrument Calibration and Frequency

As discussed in Section A.7, DQIs for open-path analyzers are assessed through completion of bump tests and calibrations. These are part of the routine operations and maintenance of the system, which are further detailed in Section B.6 and the instrument SOPs (Attachments 1–8).

Bump testing verifies open-path analyzer detection capability, accuracy, and precision. Concentrations are selected such that they are well above the level of quantitation, but near or below levels of concern for target compounds. Accordingly, path-average concentrations for p-xylene and isobutylene are typically on the order of 1–25 ppb. Bump tests are performed when the atmospheric influence on sample variability is assumed to be minimal, meaning tests are not conducted in rain, fog, or when ambient concentrations of target compounds or interfering gases (e.g., ozone) are changing rapidly. Retroreflector housings include a heater system designed to mitigate the effects of condensation and particulates on the retroreflector surface.

Bump tests are performed by introducing NIST-traceable reference gases (where possible) into the open sampling path using a test cell. During the test, light passes through the test cell and entire atmospheric path length to the detector. Because the light travels through the ambient atmosphere, which includes other gases and particles as it would during a normal measurement, this test is a representative assessment of the instrument's capabilities under the influence of environmental conditions. During bump tests, a number (N) of replicated measurements (x_i) of a standard reference material of known magnitude (x_{std}) will be measured. An acceptable number of trials is defined as 7≤N≤15, and a subset of test data which meet the acceptance criteria (Section A.7) will be used for subsequent calculations. The average value of these measurements is calculated as:

$$\bar{x} = \frac{\sum_i x_i}{N}$$

The standard deviation (σ) is defined as:

$$\sigma = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{N-1}}.$$

From these definitions, accuracy (as % Error) is defined as:

$$\%\,Error = \left|\frac{\bar{x} - x_{std}}{x_{std}}\right| \times 100\%$$

Precision (as the % coefficient of variation, CV) is defined as:

$$Precision \equiv \%CV = \frac{\sigma}{\bar{x}} \times 100\%$$

The frequency of bump testing may be decreased over time if measurements prove adequate stability or metadata provide assurance that instruments are working properly. Any potential changes will be reflected as an update to this QAPP, which will be sent to South Coast AQMD for approval.

B.8 Inspection/Acceptance of Supplies and Consumables

The Field Staff Manager is responsible for inspection and acceptance of all supplies and consumables for the monitoring project. A certification of reference gases used for routine bump and span tests will be requested from the gas supplier (where possible), and standards will not be used past their expiration dates.

B.9 Non-Direct Measurements

Part of the data validation methods detailed in Section D.2 includes comparison of fenceline monitoring data to remote background and average urban concentrations with the goal of determining overall data reasonableness. This comparison includes a combination of qualitative and quantitative assessments of general spatial or temporal trends in target compound concentrations, such that measurements from this monitoring program may be compared against external data sources. Though no direct quantitative data product is generated from this comparison effort, comparisons to external data sources generally increase the confidence in data products and, by extension, the overall value of the monitoring project.

External sources of data used for comparison may include the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), South Coast AQMD (e.g., MATES-V), and the U.S. EPA. Common target compounds may include PM, BC, or criteria air pollutants, depending on available data sets. Data used for comparison will include quality controlled final data where available, though preliminary data may be considered for qualitative assessments.

Importantly, because these data sets are external and were not collected, verified, or validated by this project's personnel, they will not serve as an independent benchmark for data validation or invalidation. They will only be used as secondary references to gauge overall reasonableness of data once all QC steps have been completed. Additional information regarding data verification and validation methods is provided in Section D.2 and the SOP for Data Verification and Validation (Attachment 8).

B.10 Data Management

Raw data collected at each monitoring site are stored on the analyzer computer and only reviewed if data validation efforts identify potential issues that require additional investigation. A Data Acquisition System (DAS), or data logger, performs basic QC, averages to 5-min resolution, and aggregates data into a desired file format. Data are then transmitted from each sampling site to a cloud-based file storage service via cellular modems, where they are stored and available for retrieval as needed. Data from the cloud are ingested into Sonoma Technology's Insight© DMS, where a robust AutoQC logic assigns data flags in real time based on instrument diagnostics and local meteorological measurements. From this point forward, data are persisted within the DMS and any changes to data are recorded via chain-of-custody logs.

These preliminary data are displayed on the public website within 10–15 minutes of collection. Data are reviewed daily by air quality Data Analysts to assess system operations, confirm automated data flagging is correct, and ensure any corrections to data flagging are propagated to the public website immediately. Extended analyses are performed every calendar quarter and reviewed by the project QA Manager. Figure 3 illustrates the general data flow and QC schematic. Additional details regarding data verification and validation are provided in Section D.2 and the SOP for Data Verification and Validation (Attachment 8).

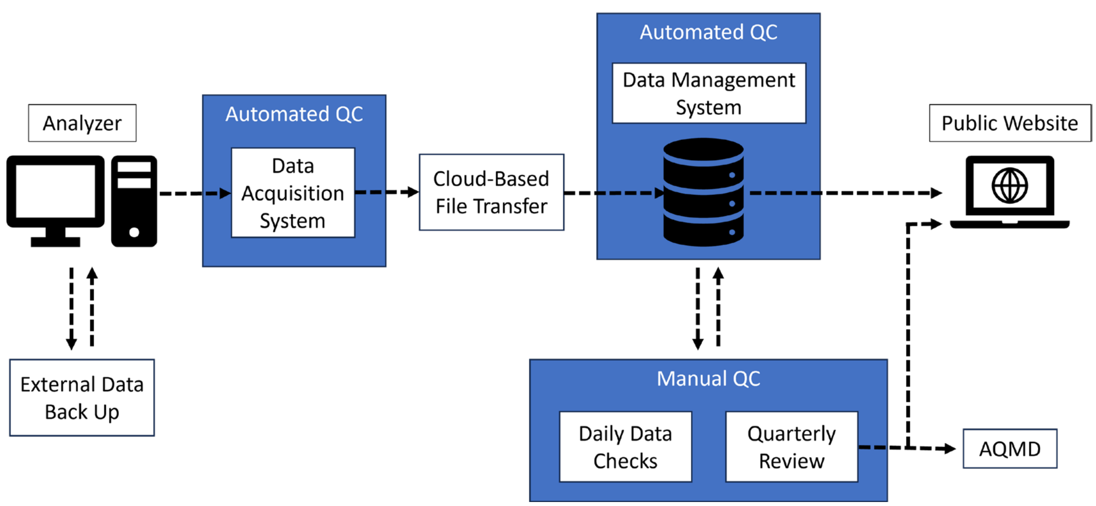


Figure 3. Data flow and QC schematic.

As described in Section B.6, data archival and management on the analyzer computers is part of routine operations and maintenance. Data are copied to external hard drives either manually or via an automated copy script and deleted from analyzer computers after confirmation that copy efforts were successful. Old files are deleted from the analyzer computer to allow continued data collection.

All ingested data are retained in the DMS. During quarterly analysis, data are downloaded from the database, analyzed, validated, and then backfilled into the DMS as final data sets. Redundancy of DMS data is maintained on a cloud-based system and data will be stored for at least 5 years after sampling.

Absorbance spectra for open-path measurements are validated with analytic software packages provided by manufacturers. Reference libraries and runtime settings are copied from analyzers in the field onto the auxiliary system where analysis is performed. Doing so ensures accuracy of spectral information and allows Data Analysts to view individual absorbance spectra and associated fits. The ability to retain spectral files and independently validate spectral matches and reported concentrations is a key part of the data validation process for open-path analyzers.

C. Assessment and Oversight

C.1 Assessments and Response Actions

On an annual basis, the refinery will work with the fenceline monitoring contractor to assess network performance through:

1. Review of data completeness by monitoring path, instrument, and compound
2. Comparison of bump test results via control charting
3. Analysis of reported concentrations in the context of refinery operations
4. Analysis of reported concentrations with respect to meteorological conditions

Using analyses similar to those used to support the network design, the contractor will further evaluate the overall performance of the network to ensure it is meeting project objectives. The contractor will also prepare an internal technical memorandum summarizing findings for the refinery. Following the monitoring network assessment, any necessary changes will be reflected as an update to this QAPP, which will be submitted to South Coast AQMD for approval.

C.2 Reports to Management

Public Website

Posting data to a public website constitutes the most immediate and frequent reporting effort. Preliminary data collected by the fenceline monitoring network are displayed on a public website within 10–15 minutes of acquisition with time series plots and map marker visualizations of 5-min and rolling hourly concentration values. Data are quality controlled in real time with AutoQC logic, and the resulting data flags (QC/OP codes) assigned to each data point determine how they appear on the website. Additional information regarding data display on the public website is provided in Section D.2 and in the SOP for Data Verification and Validation (Attachment 8).

The website is operated and maintained by the refinery's fenceline monitoring contractor, and the general public is the intended user of the preliminary data. Accordingly, the public website contains supplemental information written at a public-friendly level about the monitoring network, target compounds, how to interpret data visualizations, and frequently asked questions (FAQs).

Data Accessibility

The most recent 5 calendar years of electronic historical data collected by the fenceline monitoring system will be made available on the public website within 60 calendar days after the conclusion of each quarter.

Upon request, the most recent 5 calendar years of electronic historical data collected by the fenceline monitoring system will be available for submission to the South Coast AQMD Executive Officer.

D. Data Validation and Usability

D.1 Data Review, Verification, and Validation

Data verification is a process of comparing how data were gathered to the procedures established by the project QAPP and SOPs. It is a data review technique that evaluates the conformance of data collection practices to established methods, procedures, or specifications. Data verification usually consists of checking that SOPs were followed and QC activities were performed.[5]

Data validation is a process of confirming that reported values meet the quality objectives of the project. It is a data review technique that examines whether the particular requirements for an intended use are fulfilled. Data validation examines whether acceptance criteria outlined in the QAPP were achieved.[7]

To produce defensible, high quality environmental information, project data and personnel shall:

- Meet regulatory requirements
  - Monitor in accordance with the FAMP
  - Achieve the acceptance criteria outlined in the QAPP
  - Follow the procedures outlined in the SOPs
- Maintain scientific robustness
  - Use validated methods and accepted practices for scientific quality
  - Include standard materials traceable to an authoritative source (NIST or equivalent)
  - Systematically review data usability against program objectives
- Ensure defensibility
  - Document all data collection steps and retain associated raw data
  - Maintain data integrity and reliability through chain-of-custody logging
  - Ensure ethical practices in achieving all project objectives

Additional details are provided in the SOP for Data Verification and Validation (Attachment 8).

D.2 Verification and Validation Methods

Data collected at each monitoring site receives five rounds of QC between the point of collection and final data set submission to South Coast AQMD. A detailed process flow diagram of the data pipeline is provided in Section B.10.

[5] EPA Quality Assurance Handbook Vol II.

Tiered Data Quality Control

Data proceed through a tiered order at each point of the data flow and QC schematic as follows.

Level 0. Raw data collected on analyzer computers are referred to as Level 0 data. They do not receive any QC but are retained for future review as needed.

Level 0.5. These data have been logged by the DAS and received only the most basic AutoQC. This stage of QC includes checking basic instrument diagnostic thresholds and whether a sufficient number of raw analyzer data points were collected to generate a 5-min average. Maintenance and calibration periods are commonly flagged at this stage, which do not receive additional QC because they are not representative of ambient monitoring data.

Level 1. Upon ingest to the DMS, a robust AutoQC logic further assesses data quality and assigns a QC and OP code to each individual data point in real time. The QC codes categorize data as valid, suspect/questionable, or invalid, and the OP codes provide additional context relevant to the assigned QC data flag. Unique AutoQC logic trees are developed for each piece of instrumentation and equipment by air quality scientists with input from instrument manufacturers where needed. Level 1 preliminary data are displayed on the public website within 10–15 minutes of collection.

Level 2. Daily review by Data Analysts allows system operation assessment and ensures automated data flagging is correct. Data Analysts may adjust the QC/OP codes to reflect recent operational issues and have the ability to adjust data values if an independent validation of the raw data requires this action. Any and all changes to QC/OP codes or data values are recorded by the DMS via the chain-of-custody logs and are made according to processes outlined in the SOPs and this document.

Level 3. Extended analyses are performed by Data Analysts every calendar quarter to validate data over longer time periods and with respect to other benchmarks, such as known background concentrations. As with Level 2 data, any and all changes to QC codes, OP codes, or data values are recorded by the DMS via the chain-of-custody logs and are made according to processes outlined in the SOPs and this document.

Level 4. The final stage of QC is an independent review of data by the QA Analyst to confirm that analysis activities have been conducted according to the QAPP. Final data sets are prepared for submission to the regulatory agency and in support of quarterly reporting activities.

Data Flagging

Data flags within the Sonoma Technology DMS are composed of QC and OP codes. QC codes are defined as follows:

- **Invalid (QC=9).** Data that do not meet defined thresholds for acceptance are flagged with this QC code in the DMS. Causes of invalid data include low visibility conditions, maintenance and calibration, open-path analyzer misalignment, and instrument malfunction. Data are only invalidated if acceptance criteria are not met or if a clear cause is identified that warrants invalidation. If data are anomalous but no clear cause is identified, data are flagged as suspect/questionable.

- **Missing (QC=8).** If insufficient data to generate a 5-min average are received by the DAS, data are considered missing and flagged with this QC code in final data deliveries.
- **Insufficient Data (QC=7).** If insufficient data to generate an hourly average are received by the DMS, rolling hourly data is flagged with this QC code.
- **Suspect/Questionable (QC=5).** Data which meet defined thresholds for acceptance but indicate marginal operating conditions based on secondary review criteria are flagged with this QC code. For example, elevated integration time reported by the UV-DOAS analyzer that coincides with elevated signal strength may indicate that data require additional review but are likely accurate. Other causes of suspect/questionable data include concentrations out of the expected range, concentrations exceeding a defined rate-of-change, or stuck data values.
- **Valid (QC=0).** Data that meet all defined thresholds for acceptance are considered valid and flagged with this QC code.

Because data validity is assessed based on instrument diagnostics like signal strength and integration time, valid data (QC=0) do not necessarily indicate that the raw concentrations reported by the open-path analyzers are accurate. Depending on the instrument, additional parameters are reviewed by the AutoQC logic to further evaluate concentration data, such as the correlation between measured and reference library spectra (spectral match) and evaluation of the reported concentrations to the defined instrument MDL. Additional information regarding how data are displayed on the website is included below (see Public Website Display).

QC and OP codes together provide information regarding data quality and additional relevant context, as shown in **Table 13**.

Table 13. QC and OP codes assigned in the Sonoma Technology Insight DMS.

QC and OP Codes	
QC Codes	
0	Valid
5	Suspect/Questionable
7	Insufficient Data
8	Missing
9	Invalid
OP Codes	
0	Valid
5	Suspect
7	Insufficient Data
9	Invalid
17	Below MDL
28	Planned Instrument Maintenance
29	Unplanned Instrument Maintenance
70	Instrument Malfunction
72	Marginal Operating Conditions (Good Spectral Match)
73	Low-Visibility Conditions
74	Poor Spectral Match
76	Marginal Operating Conditions (Poor Spectral Match)
100	Manual Data Review
101	Range Check
102	Rate-of-Change Check
103	Sticking Check

Automated Data Screening

For open-path analyzers, the DAS determines if each raw data point should be included in the 5-min average based on whether real-time instrument diagnostics are above the defined thresholds shown in Table 2 (Section A.5), which include signal return and spectral fit metrics. For analyzers with raw data resolutions on the order of 2 – 4 minutes (e.g., FTIR), the DAS requires one measurement with diagnostic parameters above the defined thresholds for the 5-min average data point to be generated. For open-path analyzers with raw data resolutions on the order of 30 seconds (e.g., UV-DOAS), the DAS requires six measurements with diagnostic parameters above the defined thresholds for the 5-min average data point to be generated. The number of data points used to calculate the

5-min average data point are reported in the final quarterly data sets. Following data screening by the DAS, data are considered Level 0.5.

In addition to the AutoQC logic conducted upon ingest to the DMS, Table 14 summarizes data screening checks, which help focus data review efforts on potentially anomalous data. These checks are based on expected instrument performance and expected concentrations of target compounds relative to ambient background. The DMS auto-screening checks include:

- Range: This check flags data outside of an expected or reasonable range when 5-min concentration values are greater than the defined threshold.
- Rate-of-Change: Rapid changes between individual 5-min values without a clear cause are flagged for additional review as they may be anomalous.
- Sticking: Stuck values are flagged for additional review as they generally do not represent ambient data. Sticking checks are not applied to data that are below the instrument detection limit (i.e., concentration values of 0).

QC flags assigned through AutoQC logic and screening checks are reviewed during daily data checks and quarterly analysis. Following all automated screening checks, data are considered Level 1.

Table 14. Automated screening checks for 5-min data within the DMS (units are in ppb).

Compound	Range (ppb)	Rate-of-Change (ppb)	Sticking
Benzene	24	8	Four or more stuck values
Toluene	29,400	9,800	
Ethylbenzene	1,380	460	
Xylenes	15,000	5,000	
SO_2	225	75	
Naphthalene	225	75	
Total VOCs	2,190	730	
Formaldehyde	135	45	
Acetaldehyde	780	260	
Acrolein	90	30	
1,3-Butadiene	900	300	
Styrene	14,700	4,900	
Carbonyl Sulfide	810	270	
Ammonia	1,380	460	
Hydrogen Cyanide	927	309	
NO_2	300	100	
H_2S	90	30	
BC	30	10	
PM	150	50	

Daily Data Checks

In addition to AutoQC checks, Data Analysts review data from the fenceline monitoring network on an at least a daily basis to identify operational issues and maximize system uptime, typically with a one- to two-day running time series plot of select parameters on an internal field operations website. Data Analysts assesses the current operational status of the monitoring network and whether concentration patterns are reasonable with respect to the time of day, season, current meteorological conditions, facility operations, and concentration levels measured at other sites. Data are also reviewed on the public website to confirm that data flow and visualizations are current, and to additionally identify any anomalous behavior. Findings are documented after each check and made available to the Project Management, Field Staff, Data Analysts performing quarterly analysis, and the QA Manager.

Examples of observations requiring additional review include low signal strength or high integration time; spikes or dips in diagnostic parameters or reported concentrations; stuck or missing data; negative concentrations; and concentrations that are outside of an expected range based on nearby measurements or known atmospheric chemistry. Data are only invalidated if they do not meet defined acceptance criteria (Section A.7) or a clear and verifiable cause has been identified and documented. Examples of reasons for invalidation include instrument malfunction, power failure, and bump test data that were incorrectly flagged.

Data flagged as suspect or invalid by automated screening may also be validated during daily data checks if appropriate, meaning that temporary data flags are typically resolved within one to two business days. Following the daily data check, data are considered Level 2.

Anomalous Observations

If anomalies are observed during daily data checks, Data Analysts investigate whether an instrument malfunction occurred or if the anomalous data are explainable and therefore correct. Any need for corrective action is communicated to the Project Manager and Field Staff Manager for further coordination. Technical staff may remotely access analyzers in the field to perform basic troubleshooting and site visits are conducted as required.

When elevated concentrations (i.e., concentrations greater than routine background observations) are reported by open-path analyzers, a visual review of individual absorption spectra is performed using data processing software provided by the instrument manufacturer. Additional information regarding spectral validation of open-path data is provided in the SOPs attached to this document. If this additional review proves data to be invalid, they are flagged accordingly and may be removed from the public display. The rationale for data invalidation is maintained in the chain-of-custody logs, and corrective action is overseen by the Field Staff Manager, usually within one to two business days. If extended instrument downtime is necessary to address a data quality issue, South Coast AQMD personnel will be notified in accordance with Rule 1180 and backup monitoring will proceed according to the FAMP.

On-Call Response

Similar review processes are completed outside of business hours by after-hours support staff in the event of missing data alerts or an exceedance of defined concentration thresholds. This helps to maximize system uptime and ensure the accuracy of data reported to the public website in real time.

Quarterly Review and Reporting

Data undergo an extended analysis every 90 days through quarterly reporting, after which they are considered Level 3. Where possible, quarterly analysis is conducted by the same analysts that have been completing daily data checks to ensure consistency and familiarity with the monitoring network. Any and all changes to QC/OP codes or data values are recorded by the DMS via chain-of-custody logs and are made according to processes outlined in the SOPs and this document.

Analysts verify that SOPs were followed and QC activities were performed according to the QAPP. Examples of quarterly data verification may include:

- Review of daily data check documentation and routine instrument maintenance records to ensure consistency
- Confirmation that routine maintenance, calibrations, bump tests, and span tests were conducted according to schedule
- Review of instrument logbooks to assess whether data flagged as invalid or suspect/questionable are explainable based on recorded observations
- Review of site operator logbooks to assess whether observations by Field Technicians require additional examination of data
- Review of changes to data QC/OP codes or data values, and confirmation that they were appropriately recorded

Data Validation

Analysts validate data by exporting quarterly data sets from the DMS and analyzing them with a robust QC analysis code. Analysis code is maintained through an internal code repository, reviewed regularly, updated as requirements evolve, and shared with all analysts. The primary goal of quarterly data validation is to ensure reported values meet the DQOs of the project and acceptance criteria outlined in the QAPP were achieved. Quarterly data validation typically includes:

- Generation of monthly and quarterly summaries of data statistics (including concentration minimums, maximums, averages, and standard deviations)
- Identification and review of statistical anomalies and outliers. Negative outliers are defined as concentration values below –3 * MDL, and positive outliers are usually identified with automated screening (range) checks

- Inspection of measurements before and after anomalous data, missing data, instrument bump tests, and maintenance activities
- Review of data flagged as suspect/questionable, and flag adjustment to valid or invalid status, as appropriate
- Confirmation that bump and span test results are within acceptance criteria detailed in the QAPP
- Comparison of data to remote background concentrations and average urban concentrations, including assessment of data consistency over longer time periods, to determine data reasonableness; other data sources for comparison are detailed in Section B.9
- Verification that data are realistically achievable and not beyond the limits of what can be measured by the instrument
- Review of data completeness as detailed in Section A.7

Independent Review

An independent review of post-QC quarterly data sets ensures that data are reasonable and analysis activities were conducted according to this QAPP. This independent review is conducted on a representative sub-set of data using similar methods to those described for quarterly analysis by the QA Manager or a Data Analyst who does not routinely work on the project. Daily data check documentation and routine instrument maintenance records are also reviewed to ensure that the appropriate QC checks were applied. After this review, data are considered Level 4 (final).

Final data sets are prepared as a part of quarterly data reporting and will be made available for electronic transmission to the South Coast AQMD Executive Officer and for public download as required by Rule 1180. Additional details are provided in Section C.2.

Public Website Display

Invalid Data (QC=9) are not representative of ambient conditions and are therefore omitted from the public website display. On the time series plot and associated “tooltip” detail pane, no concentration value is shown and data are labeled “Invalid.” The map marker behavior is similar, but provides an extended message with additional information, such as the identification of maintenance periods, instrument malfunctions, or low-visibility conditions. Concentration values and diagnostic information for invalid data are retained within the DMS and included in final data sets.

Missing Data (QC=8) are not displayed on the website. Tooltip detail panes on the time series and map markers indicate where data are missing for each 5-min record. Null record indicators are created for these periods as a part of quarterly analysis and are included in final data sets.

Insufficient Data (QC=7) only applies to the rolling hourly average concentrations, and the public website display behavior is the same as described for missing data.

Suspect/Questionable Data (QC=5) and **Valid Data (QC=0)** are displayed on the time series and map marker visualizations. Because suspect/questionable data do not coincide with failed acceptance criteria and merely indicate marginal operating conditions or the need for further manual review, concentration values are included in completeness calculations and statistical analyses. As such, they are also displayed on the public website.

Open-path data with a poor spectral match are considered **non-detections** because the concentration of the target compound is so low that the analyzer does not determine it was present. In this scenario, the numerical output of the analyzer usually represents instrument noise but can occasionally range in magnitude depending on the result of the analytical fitting routine to the reference spectra. To reflect the status as a non-detection, data with poor spectral matches are adjusted to "0 ppb" and subsequently shown on the public website. Tooltip detail panes on the time series and map markers show "<MDL" or "BD" (below detection) for non-detections. Unadjusted concentration values for these non-detections are retained by the DMS.

Open-path data with a spectral match greater than the acceptance criteria (Table 2 in Section A.5) are considered **detections**, and the concentrations are displayed on the public website time series plots as recorded. If the recorded concentration is less than the defined instrument MDL, the tooltip detail panes on the time series and map markers show "<MDL" or "BD." If the recorded concentrations are greater than the defined instrument MDL, the tooltip detail panes on the time series and map markers show the recorded concentration.

A summary of public website display behavior according to QC/OP codes is shown in Table 15. Additional details regarding QC/OP codes are provided in Table 13.

Table 15. Summary of public website display behavior according to QC and OP codes.

QC Code	OP Code	Concentration	Flag
9	70	None	Invalid
9	73	None	Invalid
9	28	None	Invalid
9	29	None	Invalid
5	76	0	Below Detection (BD or <MDL)
5	17	As Recorded	Below Detection (BD or <MDL)
5	72	As Recorded	Suspect (Questionable)
0	74	0	Below Detection (BD or <MDL)
0	17	As Recorded	Below Detection (BD or <MDL)
0	0	As Recorded	Valid Data

D.3 Reconciliation with User Requirements

As discussed in Section C.2, the public website constitutes the primary, real-time reporting effort of preliminary data to the public. Changes to data concentrations or data flags affect how data are displayed and are immediately propagated to the public website. In this manner, the refinery routinely provides the public with information regarding concentrations of target compounds at the fenceline of refining facilities, consistent with Rule 1180 requirements.

Key components of the public website intended to meet and exceed user requirements of South Coast AQMD Rule 1180 include visual display of data in real time, context for the public to better understand the concentrations displayed, and a mechanism for feedback. The website also includes functionality to notify the public with custom messaging about instrument maintenance activities, potential issues with the monitoring network, or any other relevant information affecting the use of data. Members of the public can also opt in or out of public email and/or SMS notifications through the public website.

E. Standard Operating Procedures

Instrument-specific SOPs for the systems listed below are provided as attachments to this document.

- **Attachment 1**: Standard Operating Procedure for the CEREX UV Sentry UV-DOAS
- **Attachment 2**: Standard Operating Procedure for the CEREX AirSentry FTIR
- **Attachment 3**: Standard Operating Procedure for the Picarro G2204 H_2S Analyzer
- **Attachment 4**: Standard Operating Procedure for the Magee Scientific Aethalometer Model AE33
- **Attachment 5**: Standard Operating Procedure for the Teledyne Model 640x Real-Time Continuous PM Monitor
- **Attachment 6**: Standard Operating Procedure for the SaliBri Cooper Inc. Xact 625i
- **Attachment 7**: Standard Operating Procedure for Campbell Visibility Sensor (CS 120A)
- **Attachment 8**: Standard Operating Procedure for Data Verification and Validation

Standard Operating Procedures for the CEREX UV Sentry UV-DOAS

July 24, 2024

STI-7024

Contents

1. Scope and Application

This SOP covers the use of the CEREX UV Sentry UV-DOAS analyzer in a fenceline monitoring application. This document addresses routine maintenance activities including visual inspections, instrument checks, data management, QA audit testing, and data validation. The maintenance forms are provided in Section 9.

2. Introduction and Overview

The CEREX UV Sentry ultraviolet differential absorption spectrometer (UV-DOAS, shown in **Figure 1**) is an instrument that is used to detect BTEX, SO_2, NO_2, and a number of other gases in the ultraviolet (UV) region of the electromagnetic spectrum. The instrument consists of a Xenon light source, several optical elements, including a spectrometer. UV-DOAS instruments may be configured so that the spectrometer and source are in one location (monostatic) or at opposite ends of the path (bistatic). For a monostatic configuration, the light from the light source is collimated with the primary mirror and directed along a path length of about 500 m. At the other end of the path is an array of corner-cube reflectors called retroreflectors that direct the light directly back into the analyzer where the light is dispersed and measured using a spectrometer. The working range of the spectrometer is from about 200 to 400 nm. This document addresses the routine operations and maintenance procedures for the Cerex Monitoring Solutions UV Sentry units. The procedure is intended to guide the field technician in ensuring and verifying that the equipment is performing to expectations. As required, hard copies of this procedure and the associated test forms will be kept on site and a copy of the test form showing the results will be sent to the Refinery Project Manager upon completion of the test procedure.

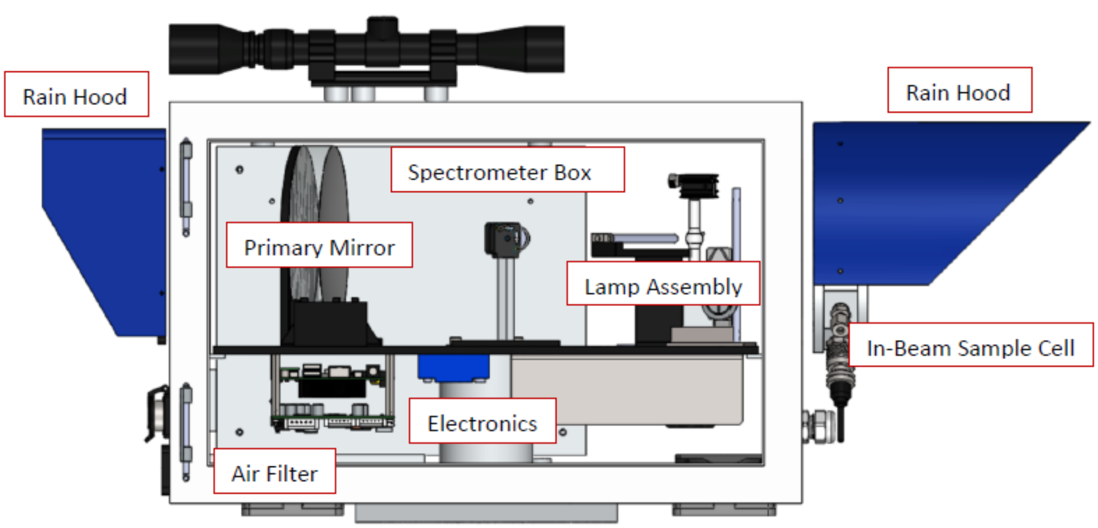


Figure 1. Schematic of the monostatic UV Sentry UV-DOAS analyzer.

The purpose of field maintenance is to ensure that the instrument is operated within specification and for field verification of the factory calibration of the UV Sentry. The QA Test process challenges the instrument using known concentrations of select BTEX reference gases and/or Sulfur Dioxide to verify proper detection and quantification under field conditions.

3. Definitions

Table 1. Definitions of terms and acronyms used in this document.

Term/Acronym	Definition
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes (Xylenes are composed of ortho, meta and para isomers)
Bump Test	Also known as QA Audit; test where gas of a known concentration is introduced to the analyzer to check for response accuracy and precision
CMS	Continuous Monitoring Software
Coefficient of Determination (R^2)	The square of the correlation coefficient. R^2 ranges from 0 (not correlated) to 1 (perfect correlation).
Correlation Coefficient (r)	A coefficient that measures the linear correlation between two sets of data. In the case of the UV-DOAS, it measures the correlation between the modeled and measured spectral data. It ranges from -1 (perfect anticorrelation) to 1 (perfect correlation).
Integration Time	The amount of time the spectrometer detector collects light for (typically 20 to 300 ms)
Intensity	A measure of how much light was collected
Percent Match	The coefficient of determination multiplied by 100. (R^2 x 100).
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
QAPP	Quality Assurance Project Plan
SOP	Standard Operating Procedure
UV-DOAS	Ultraviolet Differential Absorption Spectroscopy

4. Safe Work, Hazard Identification, and Precautions

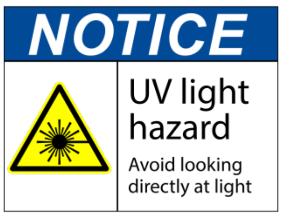
The following information is intended to provide guidance in ensuring a safe work environment.

Operator Qualifications

Installing, operating, and servicing Cerex UV Sentry analyzers should only be performed by personnel trained in the operation of the system components, familiar with the potential hazards associated with the deployment site, and familiar with the handling of gas delivery and testing equipment.

Work should conform to the manufacturer guidance and site health and safety practices.

The Cerex Monitoring Solutions UV Sentry Series Analyzers are not rated for safe operation in hazardous or explosive environments (not intrinsically safe). Any use in an area that may contain flammable mixtures or highly corrosive vapors requires special preparation to ensure operator safety and safe operation of the equipment.



WARNING – Eye hazard. Risk of eye injury. CEREX UV-DOAS Analyzers contain an ultra-violet light source that may cause eye injury after prolonged exposure. Always wear UVA/B/C eye protection when working on or near the operating equipment.

Procedure Warnings

The procedure contained within this document requires the handling of toxic substances including but not limited to benzene, aromatic hydrocarbons, and sulfur dioxide gas, and it requires the operation of equipment designed for toxic gas containment and dispensation. Improper handling of materials or hardware may result in serious injury, destruction of property, or damage to the UV Sentry. Only qualified individuals should attempt or perform analyzer operation or testing activities.

Safe Operating Precautions

Ensure that a clear escape path is identified.

Standard site personal protective equipment (PPE) is appropriate. If gloves are required for work on optics, nitrile or latex should be used.

NOTICE

Please check off the following steps before conducting maintenance. Doing so reduces the chances of false notifications to the public and clients.

- ❐ Notify the client and project manager of maintenance tasks.
- ❐ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.

- ❒ Confirm that the data is invalidated on the public website before proceeding with maintenance.
- ❒ When maintenance is complete check the public site <u>for at least 15 min</u> to ensure proper reporting (no missing data, no high values, etc.).
- ❒ Take out of maintenance mode
- ❒ Notify the project manager and client when maintenance is complete.

5. Routine Operations

To set the UV-DOAS instrument to acquire data for normal operations, the instrument CMS must be operating and the instrument must be aligned. These actions are detailed in the steps below.

1. Start the CMS software (if not already initiated). You should see a window similar to the one shown below in Figure 2.

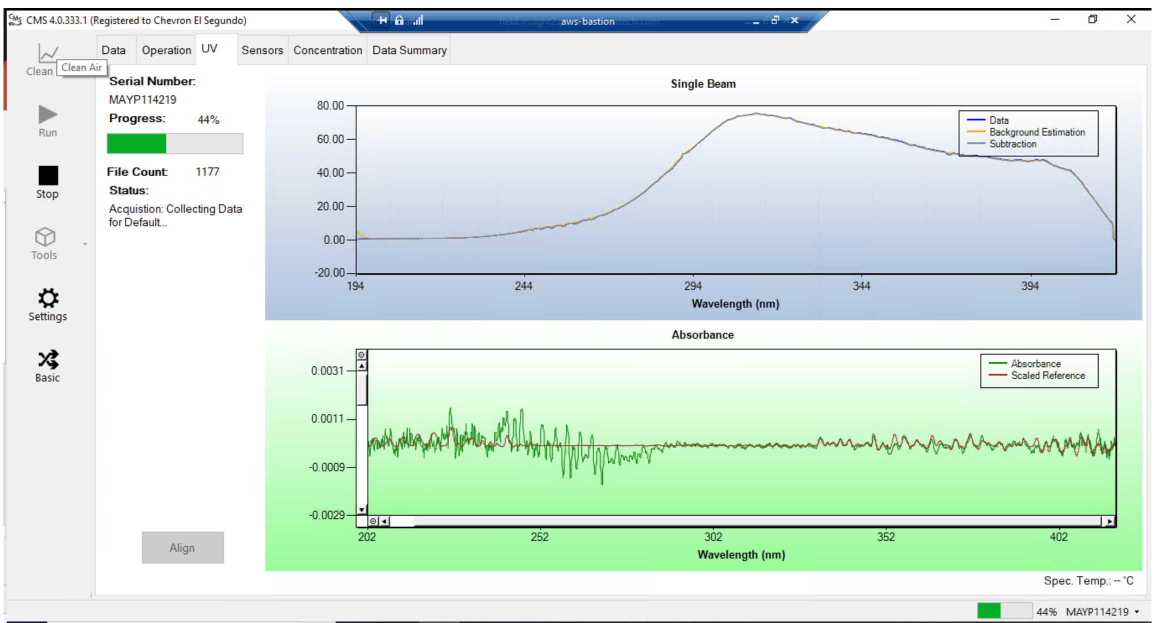


Figure 2. Screenshot showing the **UV** tab of the CMS software. Note that the **Align** button is grayed out because the instrument is in run mode (the **Run** button is also grayed out because the instrument is in run mode).

2. Under the **UV** tab, left-click on the **Align** button. This action brings up a new screen showing the instantaneous single beam plot (intensity vs wavelength). If the **Align** button is not active, you may need to press **Stop**. The **Align** mode is shown in Figure 3.

Figure 3. Screenshot for **Align** mode. The integration time can be entered in the upper right of the screen. In this particular screenshot, the integration time is 38 ms.

3. Enter an integration time of 25 ms and optimize the signal intensity by adjusting the pan-tilt head of the UV-DOAS unit to adjust the position of the UV beam on the retroreflector.

NOTE: Make sure not to saturate the peak of the spectrum when at 25 ms integration time. An example of a saturated spectrum is shown in Figure 4; note that the spectrum is flattened out starting at about 290 nm. Also, ensure there is sufficient intensity at 250 nm compared to the stray light intensity. If there is more than 10% stray light, advanced optical adjustment or bulb change may be necessary. To measure stray light, block the beam from exiting the analyzer with an opaque object (such as a black cloth) and measure the intensity at the wavelength of interest.

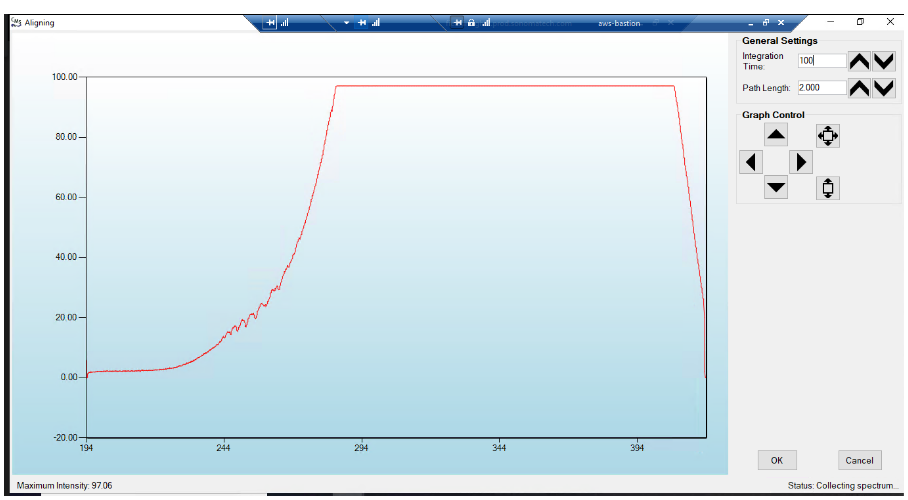


Figure 4. An example of a saturated spectrum when in **Align** mode. Note the "flat top" profile of the spectrum. The spectrum flattens out because the detector has saturated at those wavelengths and cannot quantitatively measure additional light.

4. Once sufficient alignment is obtained, exit the align mode by pressing **Cancel**.
5. Verify settings by left-clicking **Settings**.

Note: If you need to change any setting back to the original configuration, you must go to **File** and **Save** and **Save As Default.** If you change settings, record why they were changed and what they were changed to in the instrument logbook. If settings are changed, they are automatically saved under the directory: C:\Users\CMS-USER\Documents\Cerex\CMS.

- <u>RunTime</u>
  - General
    - Operator Name: **Default** (these will change based on the path and site you are working on)
    - Sitename: **Cerex** (these will change based on the path and site you are working on)
    - Auto Run: **ON**
    - Auto Run Delay (s): **15**
  - File
    - File Type: **.CSV**
    - Primary Data Logging File: **ON**
      - C:\Users\CMS-USER\Documents\Cerex\Data
    - Secondary Data File Logging: **ON**
      - \\OPT1-PC1\VLOData\OPT1_Path1\UVSentry_POC1
        - Note this path will change based on the different computer and path you are working on. This is just a basic file writing path to show you what it should look like.
    - Single Data Folder: **OFF**
    - Primary Summary File Logging: **ON**
      - C:\Users\CMS-USER\Documents\Cerex\Data
    - Secondary Summary File Logging: **ON**
      - \\OPT1-PC1\VLOData\OPT1_Path1\UVSentry_POC1
        - Note this path will change based on the different computer and path you are working on. This is just a basic file writing path to show you what it should look like
    - Single Summary File: **OFF**
  - Library
    - Library File: C:\Users\CMS-USER\Documents\Cerex\Library\
  - UI
    - Sort Column: Compound Name
    - Data Summary Chart: **OFF**
    - Concentration Chart: **OFF**
    - Password Protection Settings: **ON**

        - Pump Control: **OFF**
        - Status Control: **OFF**
        - Testing Control: **OFF**
- Analysis
    - General
        - Moving Average Interval: **12**
        - Display Units: **PPM**
    - Concentration
        - Zero Readings on Non-Detect: **OFF**
        - Zero Readings on Negative concentrations: **OFF**
        - Display BDL: **OFF**
        - Quick Analysis MDL Wave length Range: **276-280 (The range doesn't matter)**
        - Temperature/ Pressure Concentration: **OFF**
    - Filters
        - Absorbance Savitzhy-Golay: **ON**
        - Baseline Correction Savitzky-Golay: **OFF**

- Instruments
    - UV
        - Operation
            - UV: **ON**
            - Acquisition Time (s): **30 (this is the "averaging time" of the instrument)**
            - Integration Time (ms): **Always will change if Auto integration is turned on**. This is the amount of time that the instrument will collect light.
            - Path Length (m): **2 (2 for monostatic, 1 for bistatic)**
            - Trigger Mode: **Normal**
        - Auto Routine
            - Auto Integration: **ON** **(the software will determine the integration time)**
            - Intervals (s): **300**
            - Wavenumber Range: **300-310 (This is the range where the intensity will be measured for autointegration determination. This is different on all instruments due to Spectral Background and Intensity Range)**
            - Intensity Range **75-85 (This is the target intensity range for the autointegration routine)**
            - Maximum Integration: **300**
            - Auto Background: **ON**
            - Interval (Acquisitions): **5**
            - Wavenumber Range: **266-270**

        - Verification
            - Verification: **OFF** **(This inactivates all inputs)**
- Controller
    - General
        - Serial Port: **n/a**
        - Sensor Refresh Interval (s): **15**
    - Sensors
        - **Don't Touch Anything**
    - Alarms
        - **Don't Touch Anything**
- Email
    - General
        - Data Recipient: **Blank**
        - Email Sender: **Blank**
        - Email Periods (s): **60 (doesn't matter the time, we don't use this setting)**
        - Send Data: **OFF**
    - SMTP
        - Server: **smtp.gmail.com**
        - Port: **587**
        - Username: **Blank**
        - Password: **Blank**
        - Timeout (s): **100**
        - SSL Authentication: **ON**
- Auxiliary Coms
    - Modbus
        - Modbus: **ON**
        - System Type: **Ethernet**
        - TCP Port: **502**
        - Unit ID: **2**
        - 16-bit unsigned int to: **OFF**

6. After settings are verified and the instrument is aligned, you can place the instrument in run mode.

6. Equipment and Supplies

1. Field notebook
2. Tool kit, especially including: 7/64 hex driver, complete set of combination wrenches, adjustable wrenches, screwdrivers, etc.
3. Cleaning supplies designated to be safe for use on a Cerex UV-DOAS – especially lens paper

4. All relevant PPE, hardware, and procedural guidance per SOP, Safety Plan, and Safe Work Permit
5. Local or remote network link device (as required).
6. External laptop computer with network interface device to the Sentry unit (as required)
7. Cerex UV Sentry Unit equipped with CMS software
8. Cerex UV-DOAS 8" x 8" x 1" pleated filter
9. Isopropyl alcohol (≥80%)
10. Distilled water
11. Pressurized sprayers
12. Cerex UV-DOAS UV source bulb
13. Nitrile gloves
14. Cell bump test apparatus (including panels, regulators, valves, meters, etc.)
15. Tubing as required: 1/4" PTFE tubing for gas supply from the bottle to the QA cell
16. Tubing as required: 3/8" PTFE tubing with inline flow indicator from the QA cell to the scrubber
17. Flow regulation system capable of delivering gas 0.1 to 5 L/min at a total system pressure of 3 psig or less
18. Gas scrubber appropriate for gas used. Activated carbon may be used for benzene.
19. Reference standard traceable zero compressed air purge gas
20. Reference standard traceable gas blend in nitrogen for detection at about 5X instrument theoretical detection limit or higher
21. Cerex UV Sentry Unit equipped with CMS software
22. Spare reflector for alignment

7. Maintenance Activities

The following sections outline the routine performance indicator checks and maintenance activities to be carried out for each analyzer and sensor, followed by maintenance forms (see Section 9) used to indicate when the checks are completed and document any corrective actions taken. These activities are also expected, based upon the project plan, to be logged in a site logbook either in hard copy or electronic form and can reference this SOP and associated forms.

The following UV-DOAS maintenance activities and performance checks are recommended by the manufacturer:

- Visually inspect the system.
- Inspect optics on detector and retroreflector; clean if necessary.
- Inspect system filters on the optics and retroreflectors.
- Confirm the alignment to verify there has not been significant physical movement. Note: this is automatically monitored as well.
- Download data from detector hard drive and delete old files to free space, if needed. Ensure data are backed up on external drive.
- Ensure there are no obstructions between the detector and the retroreflector (such as equipment, vegetation, vehicles).
- Change out the UV source.
- Replace ventilation exit and intake filters.
- Clean optics on detector and retroreflector.
- Realign system after service.
- Perform bump test (simulates system-observed gas content at the required path average concentration) to verify the system can detect at or below a lower alarm limit.
- Review and test light and signal levels.
- Verify system software settings.
- Deliver previous years data to client and remove from brick and analyzer.

7.1 Visual Inspections

1. Ensure that the instrument is running and the data look reasonable.
2. Clean and correct any obvious problems with the system (cobwebs, rodent nests, broken optics, etc.).
3. Inspect all electrical cables for wear; replace as needed.
4. Indicate that these visual checks are complete on the form included at the end of this document.
5. Document any changes to the system in the course of these checks in the site logbook.

7.2 Filter Inspection and Replacement

Filters are present on both the instrument and the retroreflector fans. Some DOAS units may have two filters on the analyzer to mitigate salt intrusion and subsequent corrosion. Ensure all system filters are visually inspected and replaced if dirty.

Remove and inspect instrument filters following the procedure described here. Replace if necessary. Ensure fans are running (they should make an audible sound) when the system is turned back on.

NOTICE

The UV Sentry should be powered down prior to changing the filter. When powering down, adhere to the recommended shut-down procedure, which includes properly shutting down all applications, and then shut down the instrument PC.

When the PC has been successfully shut down, remove the power cord from the unit.

The UV Sentry contains a filter that must be changed on a periodic basis. Good airflow through the filter is directly related to the ability of the instrument to properly regulate internal temperature. If the filter is allowed to become clogged (through lack of maintenance), the system can overheat, and go into thermal shutdown. In extreme cases, damage may occur to the internal electronics.

The main filter is a custom size 8″ x 8″ x 1″ pleated filter, which is stocked at the Cerex factory. If a large number of replacement filters are ordered, the lead time could be several weeks.

7.2.1 Filter Installation Procedure

1. Power down the instrument—you cannot replace the filter with the instrument running. First, close the software and shut down the onboard PC. Next, disconnect the power.
2. The filter is accessible by removing the black plate located beneath the instrument touchscreen. The plate has the words “Filter Access” imprinted on it (**Figure 5**).
3. Use a 7/64 hex driver to remove the six socket-head cap screws that retain the Filter Access Panel.

Figure 5. Location of filter access plate.

4. Once the access plate is removed, the filter can be accessed for removal and replacement. Old filters should be discarded and not re-used. Insert the new filter with the "Airflow" arrow pointing in the "UP" direction (**Figures 6 and 7**).
5. When inserting the new filter, do not force the filter into the slot. If you encounter any unusual resistance, open the side door, and ensure no wires have fallen into the filter slot.
6. When fully inserted, the filter should be flush with the instrument case.

Figure 6. Filter access plate removed and filter partially removed.

Figure 7. Filter completely removed.

7. Re-attach the black filter access panel using the same driver and six screws.
8. Power up the instrument, make sure CMS software has started, and realign the instrument.

7.3 Light Level Check

For good visibility conditions, signal strength is normally >90% and integration time is normally <50 ms. If it is determined that these values are out of range, re-alignment may be needed.

Check and record signal strength at 250 nm. With an integration time of less than 125 ms, minimum signal intensity at 250 nm should be greater than 5%.

7.3.1 Check for Stray Light

Ensure there is sufficient intensity at 250 nm compared to the stray light intensity. If there is more than 10-20% stray light, advanced optical cleaning, replacement, alignment, or bulb change may be necessary. To measure stray light, block the beam from exiting the analyzer with an opaque object (such as a black cloth) and measure the intensity at the wavelength of interest. Calculate stray light by dividing the intensity of the beam while blocked by the intensity of the unblocked beam and multiplying by 100:

$$\%stray\ light = \frac{Intensity\ of\ blocked\ beam\ (\%)}{Intensity\ of\ unblocked\ beam(\%)} \times 100\%$$

Note the result of this stray light calculation in the form at the end of this document.

7.4 System Settings

Check the system settings and compare them to those documented in Section 5 (Routine Operations); if any settings do not match those listed in Section 5, provide any explanation for the changes. If you change any settings, document how the settings were changed in the instrument logbook present at the site. Note that all instrument settings are saved by the analyzer on a daily basis.

7.5 Data Management

7.5.1 Archiving and Deleting Older Data

> **Note:** Data older than twelve months should be deleted from the instrument each month to prevent the instrument from filling its 125 GB internal hard drive.

Raw instrument data are stored on the analyzer computer, the site PC, and the hard drive attached to the site PC. Data consists of spectral data containing two columns: one for wavelength, and the other for intensity. There are also two types of "summary" files that contain data resulting from the classical least squares analysis of the spectral data as a function of time. These file formats are described in the CMS Software User Manual.[1] Spectral data and summary files are automatically written to the site PC and moved to the external hard drive after a regular interval. Deliver the external hard drive to the client with the frequency indicated in the QAPP.

As noted above, data on the instrument must be deleted at monthly intervals. Details on the proper procedure for deleting data files from the instrument are as follows.

1. Confirm that the data files have been successfully written to site PC and the external hard drive attached to the site PC.
2. Make a note of the amount of available space on the instrument's internal drive on the maintenance form.
3. Locate files older than 12 months on the instrument file directory here: C:\Users\CMS-USER\Documents\Cerex\Data\.

Note: This procedure excludes the Bump Test folder, which should always remain on the instrument computer.

4. Log into the brick PC located in the instrument shelter and locate the data files written from the instrument onto the external hard drive.
5. Confirm all Complete Data Summary files and Simple Data Summary files for the desired

[1] CMS Software User Manual Rev 4. CMS Version 4.0.298.1, CEREX Monitoring Solutions, December 5, 2017.

month have been transferred over completely to the external hard drive attached to the brick PC.

6. Once you have confirmed that those files have transferred over to the external hard drive, delete those exact Complete Data Summary and Simple Data Summary files from the instrument data folders.
7. For each individual day of single beam folders, ensure that the amount of single beam files are the same on both the external hard drive located on the brick pc and the internal hard of the instrument.
8. If both folder locations match and you have ensured proper file download, you may permanently delete the Single Beam folders from the instrument computer.
9. After all data older than 12 months have been deleted, note how much free space is now available on the instrument's internal drive. If removal of the files does not result in enough free disk space, the disk drive may need to be reindexed (see Section 7.4.2).

7.5.2 Rebuilding the Instruments Indexing Preferences

If deleting data from the instrument does not seem to increase free instrument disk space, you may need to re-index the files. To rebuild the index preferences, follow these steps.

1. Under the **Control Panel Menu**, use the search function in the lower left-hand corner of the task bar to search for "Indexing Options."
2. Click on the **Advanced** tab with the shield logo.
3. Click **Rebuild**.

   Note: Once "Rebuild" has been selected, a message saying that it might slow user activity will appear. This will not affect the instruments' ability to perform data collection. On the original indexing option screen, the magnifying glass in the upper right-hand corner will move and the number of items indexed will slowly increase. Take note of the available space on the instrument's internal drive once the indexing has been completed.

7.6 Clean Optics on Detector and Retroreflector

Cleaning the retroreflector is an important part of the maintenance plan. Over time, the retroreflector will collect debris that can alter the performance of the instrument. Caution should be taken as there are electrical fan heaters that are used to keep moisture and particulates from collecting on the retroreflectors.

Optic Cleaning

If light levels are low or visual inspection reveals soiled optics, cleaning optical surfaces with lens paper and solvent can improve light throughput. This applies to the primary mirror, secondary mirror, and quartz windows. In general, if the optic is not dirty, don't clean it, as excessive cleaning of optics can result in scratches and wear over time. If the optic is obviously soiled and is affecting performance, take the following steps. Mirrors with metallic coatings should be treated with extra care because these surfaces are easily damaged on contact.

1. Wear powder-free gloves to avoid transferring skin oils onto the optics.
2. Use compressed air/canned air to remove particles from the surface of the optic. If the optic is sufficiently clean after this step, stop here.
3. Use a solvent (isopropyl alcohol or methanol/acetone in a 60/40 ratio) and lens tissue to wipe the optic clean. If using acetone, make sure to use acetone-impenetrable gloves. Wipe slowly from the edges first with a solvent-soaked lens tissue. One technique is to drop solvent on the unfolded lens tissue and drag from one end to the other.

7.6.1 Retroreflector Cleaning

1. Power down any equipment to prevent electrical shock or damage to the system.
2. Use a gentle stream of distilled water, usually from a weed sprayer or other type of gentle delivery method, to remove any salt or dust built up on the retroreflector.
3. Use a gentle stream of 80% isopropyl alcohol, usually from a weed sprayer or other type of gentle delivery method, to remove any remaining salt or dust built up on the retroreflector.
4. Once the retroreflector has been cleaned and is dry, repower any electrical equipment you powered down and clean any spills you created while cleaning.

7.7 Inspect and Change Out UV Source If Intensity Spectrum Has Dropped Below Acceptable Range

NOTICE

Never power the UV Sentry without a properly installed Xenon UV Source obtained from Cerex.

Powering the system without a UV source may cause an electrical short, which will permanently damage the instrument.

Always remove the Xenon UV Source and secure the analyzer heat sink anode prior to transporting or shipping the UV Sentry.

Failure to remove the Xenon Source and secure the Heat Sink anode prior to transporting or shipping the UV Sentry may cause destruction of the source as well as the anode.

Always check the polarity of the Xenon UV Source for proper installation prior to powering the analyzer.

Installing the UV source with reverse polarity will permanently damage the UV Source and cause immediate failure. The Xenon UV Source is shipped from Cerex with Heat Shrink and labeling over the Anode (+) end of the Source. The UV Source must be installed so the Anode (+) end of the bulb mounts to the Anode Heat Sink. The UV Source will be oriented with the (+) end at the top.

7.7.1 Xenon UV Source Handling

The UV Sentry Xenon Source is shipped from Cerex in a protective plastic enclosure (see **Figure 8**). The (+) Anode end of the UV Source is labeled "UP." The UV Source must be installed with the (+) side UP. Always wear clean powder-free nitrile gloves when handling the UV Source. Oils from hands deposited on the UV Source glass bulb will cause damage in operation. Remove the "UP +" label from the UV Source prior to installation. If the glass bulb is touched with bare hands, clean the glass bulb with isopropyl alcohol or acetone prior to installation.

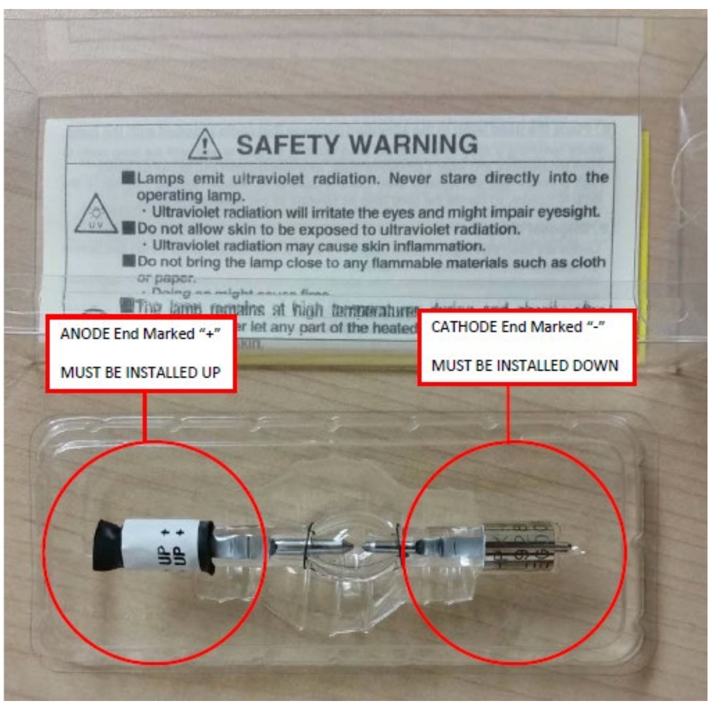


Figure 8. The ANODE end of the UV Source is marked (+). The CATHODE end of the UV Source is marked (-).

7.7.2 UV Sentry Xenon Source Removal

Prior to shipping or transporting the UV Sentry, remove the Xenon UV Source and secure the anode heat sink assembly.

1. Power off the analyzer and disconnect from power. Allow the analyzer to cool completely.
2. Use the provided key to remove the Source Access Panel (see Figure 9).

Figure 9. Opening the source access panel.

3. Wearing clean nitrile gloves, loosen the retaining thumbscrew on the Anode Heatsink at the top of the UV Source (see Figure 10).

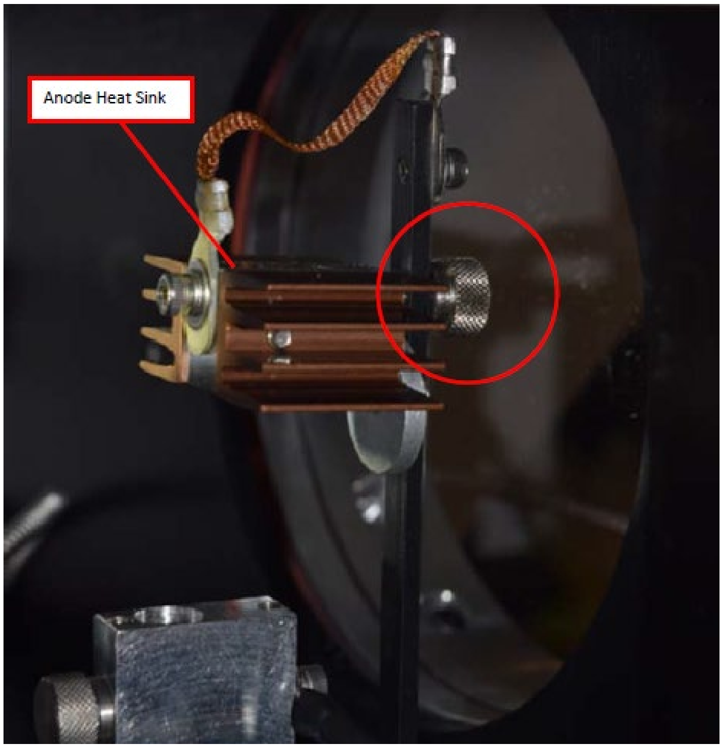


Figure 10. Anode heatsink at the top of the UV source.

4. Lift the Anode Heat Sink off the top of the UV Source. It is connected to the post by a cable. Gently let the heat sink dangle.
5. Loosen the retaining thumbscrew on the Cathode block at the bottom of the source (Figure 11).

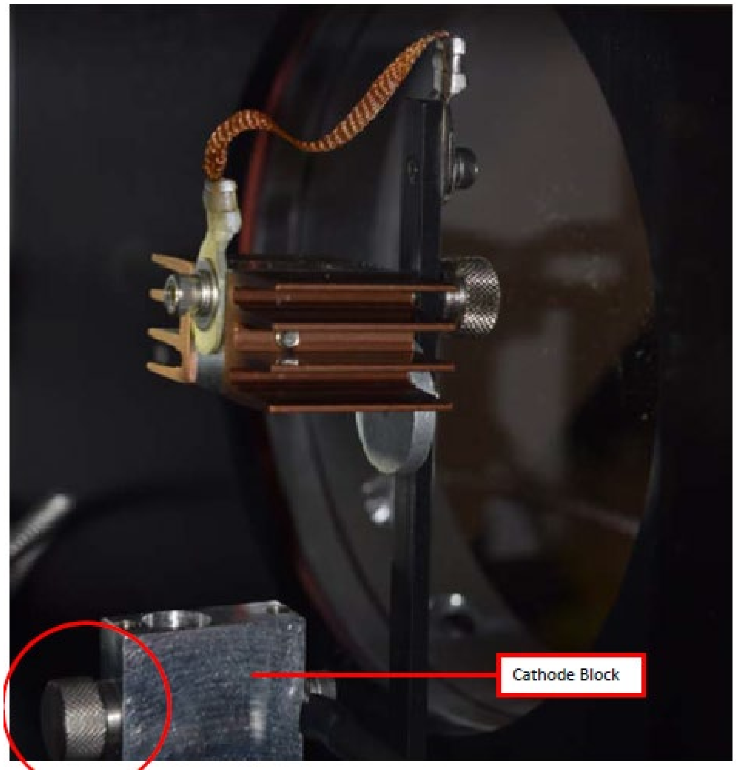


Figure 11. Loosen the thumbscrew on the Cathode block at the bottom of the UV source.

6. Lift the source lamp straight up and out of the mount.

7.7.3 UV Sentry Xenon UV Source Installation

1. Insert the Cathode (-) end of the Xenon UV Source into the Cathode Block (see **Figure 12**). The Cathode end of the UV Source is marked with (-).

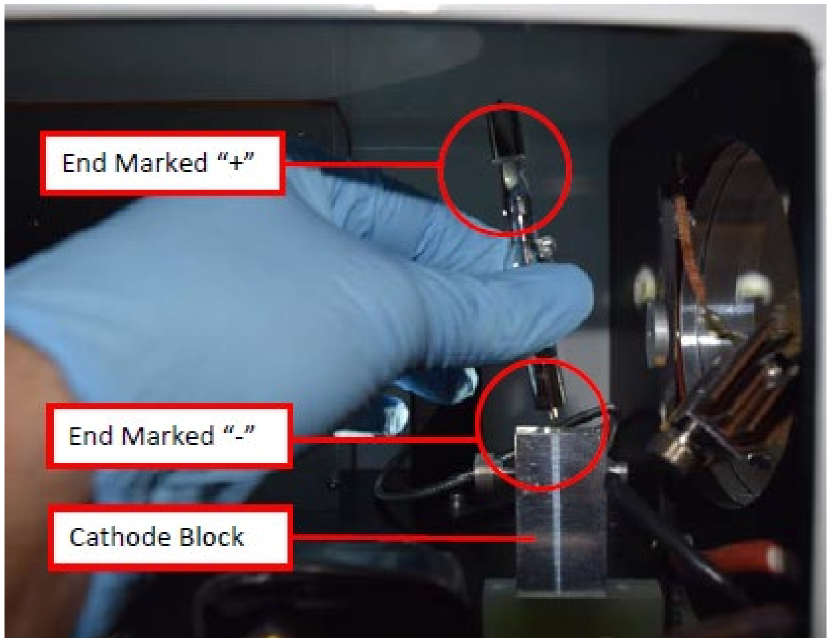


Figure 12. Inserting the Xenon UV Source into the Cathode block.

2. Rotate the UV Source so the nipple on the glass envelope faces the aluminum disc on the mounting post.
3. Tighten the Cathode block thumbscrew gently. Gently pull up on the Xenon UV Source to verify the thumbscrew has made contact with the nipple on the UV Source cathode.
4. Slide the Anode Heat Sink (+) over the top of the UV Source Anode. The Anode end of the UV Source is marked (+). Gently tighten the Anode Heat Sink thumbscrew to secure. Gently pull up on the heat sink to ensure the thumbscrew has made contact with the nipple on the UV Source anode.
5. Reinstall the Source Access Panel prior to powering on the analyzer.
6. Confirm signal strength through remote desktop connection before leaving path.

7.7.4 Secondary Optic Alignment

If there is lower intensity than what was previously observed after the UV Source been replaced, an internal alignment of the secondary optic might be required. This should only be performed by a technician who has been properly trained to perform internal alignments.

Note: Proper PPE must be worn (glasses, sunblock) while performing a secondary alignment to prevent over-exposure to high intensity UV light from the UV Source within the instrument. Also, use an opaque object (such as cardboard or paper) to block as much of the light from the bulb as possible while still maintaining a view of the secondary mirror and fiber (if required).

1. Stop CMS and navigate to the **Alignment** menu.
2. Properly align the instrument at 20 to 25 ms integration time, as shown in **Figure 3**. Make a note of the intensity at 254 nm and the overall shape of the UV signal return.
3. Open the side of the instrument to gain access to the secondary optic.
4. Ensure alignment achieves maximum signal return and is fully aligned to the retroreflector. This is achieved by maximizing signal intensity in align mode at an 8 ms integration time. If signal cannot be confirmed in align mode, this can be done visually by maximizing the visual return brightness on the retroreflector either by looking through the telescope or by placing your head next to the instrument and observing the returned reflection from the retroreflector.
5. If the entire spectrum is visible in the alignment menu, take note of the deep UV intensity at 254 nm. If the instrument is over saturation, as seen in **Figure 4**, take note of the wavelength at which the oversaturation starts.
6. Once the instrument is aligned, take care not to bump the instrument.
7. Adjust the first secondary mirror mount thumb screw to maximize the overall intensity.
8. Move on to the second mirror mount thumb screw and repeat the same process of adjustment to maximize the signal return.
9. In an iterative process, continue to adjust the optical mount screws to maximize intensity, one at a time, until no further gain in signal intensity is achieved.

Note: Only adjust the two thumb screws of the secondary optic.

10. Set the integration time back to 20-25 ms and make sure the instrument is able to achieve a proper UV spectrum, as shown in Figure 3. If you are not able to achieve the proper UV spectrum, repeat steps 6-8.
11. Take note of the overall shape of the UV intensity and adjust secondary mirror to maximize intensity at 254 nm.
12. Close the access door of the instrument enclosure. Observe if having the access door closed changed the internal alignment.
13. Return the instrument to its normal operation and observe the first few scans to ensure the UV spectra are acquired.

7.8 Perform Bump Test

7.8.1 Apparatus Setup

Audits of open-path analyzers require high concentration (~100 ppm) calibration gases. Standard refinery personal protective equipment (PPE) should be worn at all times, including safety glasses.

This procedure requires the use of pressurized gas cylinders; training on proper handling of pressurized systems is required. The operator-supplied Standard Operating Procedure (SOP), approved by the End User and in compliance with End User's Health and Safety Plan, is also required.

Set up the apparatus to enable, at a minimum, (a) gas flow to the calibration cell of the instrument and (b) flushing of the cell with zero/clean air. An example system is shown in Figure 13. The advantages of this system are (1) the exhaust from the calibration cell is scrubbed, (2) there are check valves in place to prevent cell overpressure, and (3) the regulator attached to the compressed gas cylinder can be flushed with clean air.

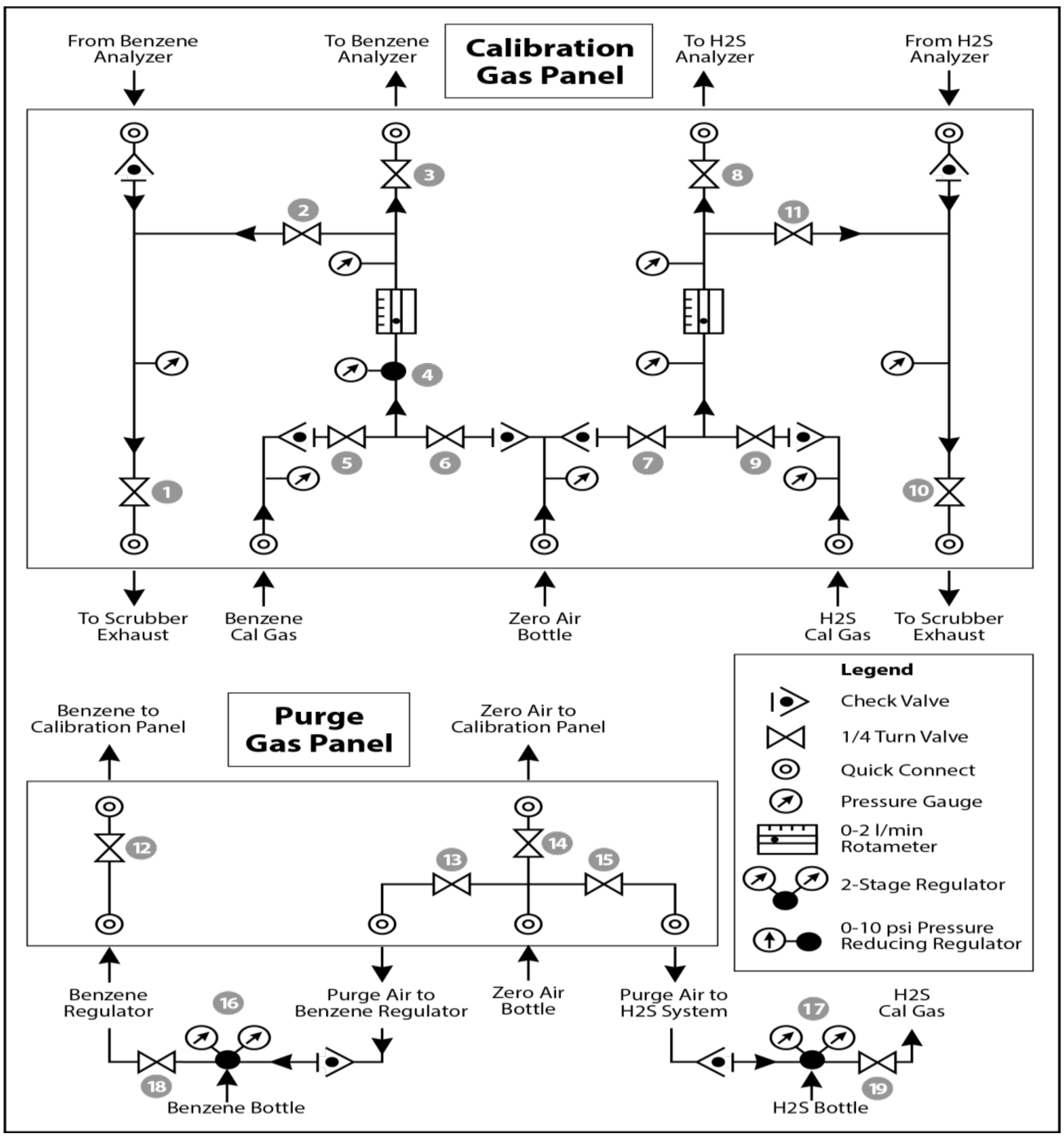


Figure 13. Diagram of the calibration gas panel (top) and purge gas panel (bottom) used for gas delivery.

7.8.2 Prepare CMS for Gas Testing

Note: There is a summary of system settings in Section 5 that can help you when you are changing any setting in the Cerex UV-DOAS instrument.

7.8.3 Configure CMS for Test (This may be concurrent with Gas Purge System setup)

1. The analyzer should be powered and running for **at least 30 minutes**.
2. Stop CMS data collection by pressing the **STOP** button.

7.8.4 Configure Test Files

1. Click **Advanced** on the left side of the CMS software window; password is *advanced*.
2. Under **Advanced** -> **Settings** -> **Runtime -> File**, note the current file path so that it can be restored at the end of the test.
3. Under **Advanced** -> **Settings** -> **Runtime -> File**, turn off **Secondary Logging**.
4. Change the primary file logging paths (both of them) to: C:\Users\CMS-USER\Documents\Cerex\Data\bumptest. Then select **File** and select **Save**.

7.8.5 Leak Check (Optional, for use with the calibration panel)

1. Ensure all the tubing from the purging panel is connected to the calibration panel. Ensure gas cylinders are connected to the purge panel as depicted in Figure 13. Then attach the calibration panel to the analyzer connection in the analyzer shelter.
2. Connect the PTFE tubing containing the activated carbon scrubber to the analyzer exhaust.
3. Close all valves on the calibration and purging panel.
4. Verify that the regulators on the zero air and benzene cylinders are completely closed (all the way to the LEFT!!) to prevent any pressure buildup at the regulator.
5. Open high-pressure valves on both the benzene and zero air bottles.
6. Open valve (14) and slowly open the regulator on the zero air cylinder to a pressure of 5-10 psi, observed on the calibration panel zero gas pressure gauge. Do this by making small adjustments at the cylinder regulator and watching the pressure on the calibration panel.
7. Open valve (12) and slowly open the regulator on the benzene cylinder to a pressure of 5-10 psi on the pressure gauge on the benzene calibration gas channel of the panel. Do this by making small adjustments at the cylinder regulator and watching the pressure on the calibration panel.
8. Open the bypass valve (2).
9. Open zero air valve (6) and slowly open the regulator to a final pressure of about 2 psi (as read on cell and exhaust pressure gauges). **DO NOT pressurize above 3 psi**.

10. Now pressurize cell: slowly open the valve going to the cell (valve 3) and close the bypass valve (2) while carefully watching the cell pressure gauge after the regulator (4). If you note any sudden pressure increase, just open the bypass valve (2) to relieve the pressure on the cell. Wait until the same pressure is reached on the pressure gauge of the exhaust side of the calibration panel.
11. Close the zero air valve (6) going to the benzene regulator on the panel so the system is now fully closed off to external pressure.
12. Watch the system for a minimum of 5 minutes to ensure there is no pressure drop and the system is leak free.
13. Open the leak check valve (1) to release the pressure from the system, and then close all the valves on both panels.
14. Record leak check.
15. Click the **ALIGN** button at the bottom left of the plot display.
16. Adjust the alignment until the signal intensity is optimized.
    a. **Target intensity is 70 – 90%.**
    b. **Target integration time is between 20 ms and 25 ms.**
17. **Record** the intensity and integration time.

7.8.6 Bump Test with Calibration Panel

This procedure was written assuming that the benzene and zero (purge) air side of the calibration panel has been pressurized according to the procedure above. At this point it is prudent to set up the instrument to start taking test measurements according to the UV-DOAS test procedure.

Background Measurement Using Zero (Purge) Gas

1. Close the secondary pressure regulator (4) on the panel by turning all the way to the left.
2. Open the leak check (1) and bypass valve (2).
3. Open Zero Air Valve (6).
4. Adjust the flow of purge air going through the bypass until the desired flow rate (1 lpm) and pressure are achieved by slowly increasing the pressure on the secondary pressure regulator (4). The backpressure on the scrubber (measured between valves [1] and [2]) is typically less than 1 psi.
5. Open the valve going to the cell (3) and close the valve on the bypass (2) while carefully watching the cell pressure gauge after the regulator (4). If you note any sudden pressure increase, just open the bypass valve (2) to relieve the pressure on the cell. Wait until the desired flow rate has stayed the same and the pressure on the entire system has not

increased.

6. Press **RUN** to start background acquisitions.
7. Flow compressed zero air purge gas at total flow of 1 L/min for 10 30-second acquisitions.
8. Monitor until a stable zero reading is reached and then allow the analyzer to run until an acceptable background is reached.
9. Close the zero gas valve (6).
10. Close all valves.
11. Close the secondary pressure regulator (4) on the panel.

Span Test

1. Open the leak check (1) and bypass valve (2).
2. Open the benzene valve (5).
3. Adjust the flow of benzene going through the bypass and scrubber until the desired flow rate (1 lpm) and pressure are achieved by slowly increasing the pressure on the secondary pressure regulator (4). The backpressure on the scrubber (measured between valves (1) and (2)) is typically less than 1 psi.
4. Open the valve going to the cell (3) and close the valve on the bypass (2) while carefully watching the cell pressure gauge after the regulator (4). If you note any sudden pressure increase, just open the bypass valve (2) to relieve the pressure on the cell. Ensure the desired flow rate has stayed the same and adjust as needed.
5. Wait 5 minutes to fill and condition lines and cell.
6. After 5 minutes of Check Gas flow, press **Start** in CMS.
7. Collect Check Gas data.
    a. Observe the concentration reported on the **DATA** tab.
    b. After the concentration becomes stable, allow the analyzer **to run until 7-15 stable measurements are made.**
    c. **Verify that the values meet the QA criteria. If the test fails QA criteria, follow the corrective actions listed at the end of this section (see: Data Evaluation, Reporting, and Corrective Action).**

Completion of Test and Purge of Benzene Regulator (Calibration panel only)

1. Close the benzene cylinder. You will see benzene pressure increase and/or fluctuate as the pressure on the bottle regulator drops. This is normal - be patient and wait for the benzene pressure to zero out.

2. When pressure on cylinder and panel read zero, open the benzene purge valve (13)
3. **Verify that the target gas(es) concentration has returned to 0 ppm** with non-detect percent match.

NOTE If not, ambient background target gas concentration has changed during the procedure; testing may need to be repeated to verify results.

4. Once zero reading is indicated on the UV-DOAS, close all valves.
5. Close the zero air cylinder and allow for all the pressure to be released from the system.
6. Close all valves and ensure there is zero pressure on the system.
7. Disconnect tubing to the analyzer and activated carbon scrubber.

7.8.7 Bump Test Without Calibration Panel

Background Measurement

1. Attach 1/4" PTFE tubing from the ambient air and Benzene gas tank valve to the UV-DOAS test cell.
2. Attach 3/8" PTFE tubing with scrubber to the exhaust port on the UV-DOAS test cell.
3. Flip the ambient air/gas tank valve to allow for flow from the ambient air pump and power on the pump. Adjust the flow from the ambient air pump until the desired flow rate (1 lpm) is achieved by slowly increasing the flow on the rotameter attached to the valve.
4. Press **RUN** to start background acquisitions.
5. Flow ambient air from the pump at a total flow of 1 L/min for 10 30-second acquisitions.
6. Monitor until a stable zero reading is reached and then allow the analyzer to run until an acceptable background is reached.
7. Press **STOP** to stop background acquisitions.

Span Test

1. Open the benzene gas tank valve and flip the ambient air/gas tank valve to allow for flow from the benzene gas tank. Adjust the flow from the gas tank until the desired flow rate (1 lpm) is achieved by slowly increasing the flow on the gas tank regulator.
2. Wait 5 minutes to fill and condition lines and cell.
3. After 5 minutes of Check Gas flow, press **START** in CMS.

4. Collect Check Gas data.

    a. Observe the concentration reported on the **DATA** tab.

    b. After the concentration becomes stable, allow the analyzer **to run until 7-15 stable measurements are made.**

    c. **Verify that the values meet the QA criteria. If the test fails QA criteria, follow the corrective actions listed at the end of this section (see: Data Evaluation, Reporting, and Corrective Action)**

Completion of the Test

1. Flip the ambient air/gas tank valve to allow for flow from the ambient air pump. Maintain a flow of approximately 1 L/min.

2. Close the benzene gas cylinder.

3. **Verify that the target gas(es) concentration has returned to 0 ppm** with non-detect percent match.

NOTE If not, ambient background target gas concentration has changed during the procedure; testing may need to be repeated to verify results.

4. Once zero reading is indicated on the UV-DOAS, turn off the ambient air pump.
5. Disconnect tubing to the analyzer and activated carbon scrubber.
6. Re-align the analyzer if needed after disconnecting tubing from the analyzer test cell.
7. Label the bump test data file, and go to the "Restore Normal Operation" section of this procedure.

7.8.8 Restore Normal Operation

1. **Restore** Normal Operation.

    Note: When restoring normal operation, you will change the file writing path in the settings menu back to the normal file writing path (this is slightly different for each unit, so make a note when first setting up the instrument for the QA test). Once you restart CMS, you will see the file number located on the UV main menu of CMS. If the file count restarts and starts at file 1, you have the incorrect file writing path because it is starting a new folder for the entire day. Also, once you restart CMS, look at the single beam graph also located on the CMS UV main menu to ensure a good alignment and intensity in the lower UV wavelengths.

2. **STOP** CMS.

3. Click **Advanced** on the left side of the CMS software window; password is *advanced*.
4. Under **Advanced** -> **Settings** -> **Runtime -> File**, turn On **Secondary Logging**. Change both of the primary file logging paths to: C:\Users\CMS-USER\Documents\Cerex\Data. Then select **File** and click **Save**.
5. Check the system alignment as previously described.
6. Press **RUN** to begin monitoring.

7.8.9 Test Suspension

In the event of a leak or plant alarm requiring suspension of work, the process should be safely suspended.

1. If a plant or site alarm sounds during the validation, stop the test immediately as follows.
2. Close the reference gas bottle valve completely.
3. Allow the system to flow purge gas to the scrubber/vent.

7.8.10 Data Evaluation, Reporting and Corrective Action

During these tests, a number (N) of replicated measurements (x_i) of a standard reference material of known magnitude (x_{std}) will be measured. Here, an acceptable number of trials will be defined as 7≤N≤15. The average value of these measurements is calculated as

$$\bar{x} = \frac{\sum_i x_i}{N} \quad (1)$$

and the sample standard deviation (σ) as:

$$\sigma = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{N-1}}. \quad (2)$$

From these definitions, % error is defined as:

$$\%\ error = \left|\frac{\bar{x} - x_{std}}{x_{std}}\right| \times 100\% \quad (3)$$

and precision as the coefficient of variation expressed as a percentage (% CV):

$$Precision \equiv \%\ CV = \frac{\sigma}{\bar{x}} \times 100\% \quad (4)$$

1. Concentration
   a. Average the concentration of 15 consecutive stable measurements.
   b. Report the % error between the average and the certified value. The acceptable % error is listed in the QAPP.

      Note: To calculate the certified value that will be seen on the Cerex UV-DOAS from the actual certified instrument calibration gas concentration, you multiply the certified gas concentration by the calibration cell length (0.047 meters) and divide that answer by the path length set in the instrument software. For most Cerex instruments in operation by Sonoma Technology, the path length is set to 2 meters for monostatic instruments and 1 meter for bistatic instruments.

2. Calculate the Limits of Detection and Quantitation.
    a. Calculate the mean (average), sample standard deviation, and % error (sometimes also referred to as % difference) of the selected results.
    b. Report the Detection Limit as three times the standard deviation.
    c. Report the Quantitation Limit as five times the standard deviation.
3. Compile all configuration files, spectra files, and log files into a single folder.
    a. The folder should be named "CUS LOC QATest UV# YearMonDy" where CUS is a three-letter designator for the customer and LOC is a three-letter designator for the facility location.

The QAPP contains the acceptance criteria and warning levels to be used for the test.

Note:

- **If the test produces an error or precision greater than the warning level**: corrective action should be taken so that the precision and error are below the warning levels.
- **If the test produces an error or precision greater than the acceptance criteria**: corrective action should be taken so that the precision and error are below the warning levels. Equipment will not be placed into service (taken out of "maintenance mode") until it meets all measurement criteria.

If the measurements do not meet the data quality objectives listed in the QAPP, repeat the procedure without adjustment. If the instrument still fails to meet the QA criteria, retest the following day with no adjustment. If these repeated tests continue to fail, initiate corrective actions such as:

- Realign the system and perform the test again.
- Reviewing data for potential interferants, including a detailed check of absorbance spectra in the analysis regions configured for the analyte, noting any excessive noise or unexpected absorbance features.
- Consulting with the project technical lead to identify abnormal changes to the background
- Check wavelength calibration
- Checking for large changes in stray light since the last test and adjusting calibration factors as necessary
- Reviewing gas testing apparatus for leaks or other similar problems

- Review and confirm specifications of standard calibration equipment and gases (expiration dates, concentrations, etc.)

In the event of a failed test after following all steps outlined above, inform the Sonoma Technology Project Manager and Quality Assurance Manager who will review the instrument performance parameters in the list above.

If all parameters indicate that the instrument was performing properly since the last test, data since the last test will be flagged as suspect. If an issue with the instrument is identified, data since the date and time of the instrument issue will be flagged as invalid. All data flagging will be performed by Data Analysts in consultation with the Quality Assurance Manager.

8. Data Validation and Quality Control

Data for the fenceline monitoring network appears on both public and internal sites. The internal website allows for detailed quality control and flagging of the data. Data are checked daily and finalized quarterly as outlined in the QAPP. This section outlines how to perform daily and quarterly data validation.

8.1 Daily Checks

Both the public website and the admin website need to be checked twice daily (for example, before 10 AM and 10 PM).

1. Ensure that the site is operating properly by pointing your browser to the public website.
2. View the data display on the public website. Take note of any outages by selecting **All Compounds**” from the pollutant dropdown menu.
3. View the time series graphs for each compound by selecting each compound in the pollutant dropdown menu. Verify that pollutant concentrations are reasonable by using the guidance in **Table 2**. Notify the field operations team if anything seems erroneous.

Table 2. Parameters measured with the UV-DOAS and typical observations.

Parameter	Observational Notes
Visibility	~30 miles is the maximum measured by the sensor. Values are typically less than 30 miles due to smog and fog.
Integration Time	Should generally be <250 ms. Report values stuck at 300 ms to PM and fieldopsalerts. Should be anticorrelated with visibility for fog events.
Winds	Typically there is a sea breeze during the day, land breeze at night. Winds are stronger near the coast at met west.
Benzene	Typically below MDL (~1 ppb) – note any high values above REL or immediately visible on the public website (this is a toxic compound
Toluene	Typically below MDL (~1 ppb) – note any high values above REL.
Ethylbenzene	Typically below MDL (~1 ppb) – note any high values above REL.
o-xylene	Typically below MDL (~1 ppb)– note any high values above REL.
m-xylene	Typically below MDL (~1 ppb) – note any high values above REL.
p-xylene	Typically below MDL (~1 ppb) – note any high values above REL.
SO_2	0 to 100 ppb, usually zero. Refineries are a local source – note any high values above REL.
NO_2	Typically 0 to 200 ppb. Values typically peak at night; sunlight destroys it, traffic and combustion produce it. Some instruments may not detect NO_2 if they are saturated.

8.2 Quarterly Validation

Quarterly validation activities involve looking at the data over a longer time period (3 months) than the daily checks (typically a time range of a few days).

1. Plot time series and look for statistical anomalies. If problems are found they may be flagged using the DMS.
2. Review any instrument bump test results.
3. Verify that daily instrument checks were acceptable.
4. Review manual changes to operations/data, and verify that the changes were logged and appropriately flagged; ensure that logged information is complete and understandable.
5. Ensure that instrument checks have the appropriate (Quality Control) QC codes applied.
6. Assign invalid data a Null Code, providing a reason for data being invalid.
7. If a record is not created for a particular site/date/time/parameter combination, create a null record for data completeness.
8. Inspect data consistency.
9. Review collected data ranges for consistency – ranges should remain within expected values over months of monitoring.
10. Check bump test values for completeness; ensure they meet acceptance criteria.
11. Review quarterly data completeness.

9. Maintenance Forms

Path:______________________________

Technician:________________________

Date:______________________________

Instructions: complete checks described below and enter data or initial next to each one once complete. Make note of any corrective action.

- ❒ Notify the client and project manager of maintenance tasks.
- ❒ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.
- ❒ Confirm that the data is invalidated on the public website before proceeding with maintenance.
- ❒ When maintenance is complete check the public site for at least 15 min to ensure proper reporting (no missing data, no high values, etc.).
- ❒ Take out of maintenance mode
- ❒ Notify the project manager and client when maintenance is complete.

Upon completion sign and date:________________________________

Table 3. Maintenance activities and performance indicator checks for the UV-DOAS.

Activity / Check	Completed (Y/N)
Visually inspect the system.	
Inspect optics on detector and retroreflector; clean if necessary.	
Inspect system filters on the optics and retroreflectors.	
Confirm the alignment to verify there has not been significant physical movement. Note: this is automatically monitored as well.	
Download data from detector hard drive and delete old files to free space, if needed. Ensure data are backed up on external drive.	
Ensure there are no obstructions between the detector and the retroreflector (such as equipment, vegetation, vehicles).	
Change out the UV source.[a]	
Replace ventilation exit and intake filters.	
Clean optics on detector and retroreflector.	
Realign system after service.	
Perform bump test (simulates system-observed gas content at the required path average concentration) to verify the system can detect at or below a lower alarm limit.	
Review and test light and signal levels. Check average light intensity to establish baseline for bulb change frequency.	
Verify system software settings.	
Deliver previous years data to client and remove from brick and analyzer	

[a] UV bulbs will be changed depending on deep UV performance.

Corrective Actions for UV-DOAS:

UV Sentry Fenceline Detection System

DATE: ________________ Location: ______________________________

Test Technician 1:___________________________ 2:___________________________

Physical one-way path length_____________ m Instrument Configuration (mono/bistatic)_____________

Sentry Alignment and Light Levels

Integration time ________________________ Target 20-24 ms
300 nm Intensity ________________________ Target 80-120%
254 nm Intensity ________________________ Target >5%
Blocked Beam Intensity at 254 nm ________________
% Stray Light ________________________

Gas Purge System

Flow purge gas Start Time ____________________

Prepare CMS

Path length in the CMS Configuration (typically 1 m for monostatic and 2 m for bistatic)____________________ m

Configure Test Files

Site File (i.e., QA Audit UV# YearMoDy) ____
Baseline Check ____________________ init

Reference Gas

Concentration ____________________ ppm
Source ____
Date ____________________
Cylinder Pressure ____________________

NOTES:

QA Audit Record - UV Sentry Detection System - Page 2

Purge Flow Conditions

Start Time ______________________

Purge Gas flow ______________________ L/min

NOTES: Around 1 LPM

Check Gas Test

Initial Gas flow ______________________ L/min

Around 1 LPM

Start Time ______________________

Collect Check Gas Data Start Time ______________________

Data Record:

TIME	PPM	R2
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________

Verify Client ______________________ Init

Stop Time ______________________ Init

Open the **PURGE** gas Time ______________________

Reference Concentration _________ ppm

Average Concentration _________ ppm

% error _________ %

Std Deviation _________ ppm

% CV _________ ppm

Restore Normal Operation

Restore running data file ________________________ Init

Press **RUN** to begin monitoring. ________________________ Init

Sonoma Technology

Standard Operating Procedures for the CEREX AirSentry FTIR

July 24, 2024

STI-7036

Contents

1. Scope and Application

This SOP covers the use of the CEREX AirSentry FTIR analyzer in a fenceline monitoring application. This document addresses routine maintenance activities including visual inspections, instrument checks, data management, QA audit testing, and data validation.

2. Introduction and Overview

The Cerex AirSentry FTIR monitoring system uses Infrared (IR) light for gas detection. The system works by first generating IR radiation from an extremely hot Globar source. The light from the source is directed down the open path using a Cassegrain long-path telescope. When the light reaches the opposite end of the path it is reflected using a retroreflector array back to the telescope which then receives the light and sends it to the detector. The Infrared detection system is based on a Michelson Interferometer with a cooled Mercury Cadmium Telluride (MCT) or Deuterated TriGlycine Sulfate (DTGS) detector. A schematic of the Cerex AirSentry FTIR monitoring system is shown in **Figure 1.**

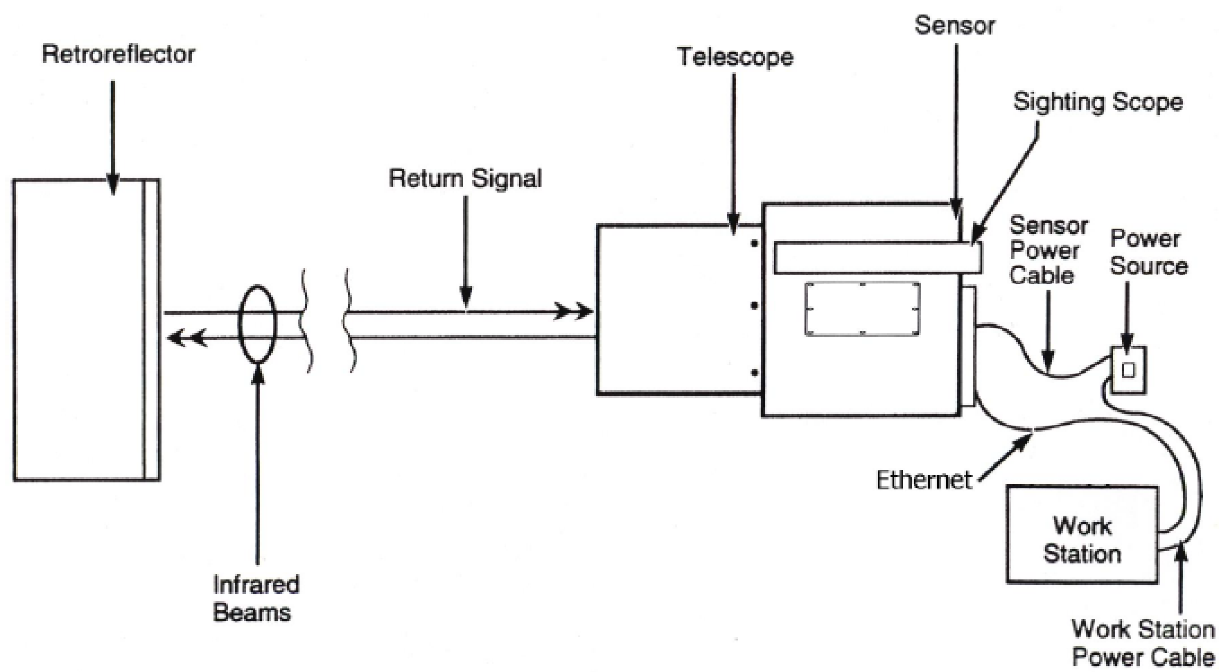


Figure 1. Schematic of the instrument.

The Michelson Interferometer includes the IR source and an optical assembly that includes both stationary and moving mirrors. While the light path defined by the stationary mirror is of fixed length, the light path defined by the moving mirror varies. The Interferometer creates an interference pattern by combining the light from the stationary and moving mirror, thus cancelling different wavelengths of the IR spectrum at different times during each scan of the moving mirror. Once the IR beam returns from the sample volume defined by the path of the IR beam in the air, it is focused onto a cooled MCT or DTGS detector, which converts the incident IR wavelengths into electrical currents at high speed. The MCT detector synchronized with the interferometer continuously scans the full range of the IR spectrum. The IR spectrum, or single beam, is produced by measuring the electrical currents at each given scan and applying a Fourier Transform to produce a graph of signal intensity versus wavelength.

The raw data goes through several transformations in the software. The final step occurs when the software compares the peaks produced in the field data, against quantitative library references of the target gases being analyzed. This allows identification and quantification of each specific gas. Since the calibration is inherent in the library references stored on the PC, there is no requirement for the AirSentry FTIR to undergo "calibration." There is no need to perform a recalibration on a periodic basis. However, as calibration verification is often a requirement in many applications, Cerex provides the (optional) provision to conduct a verification of the system.

3. Definitions

Table 1. List of definitions.

Term/Acronym	Definition
Beer's Law	A mathematical relationship that relates the attenuation of light to the concentration of a substance/material.
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes (Xylenes are composed of ortho, meta, and para isomers)
Bump Test	Also known as QA Audit, this is a test where gas of a known concentration is introduced to the analyzer to check for response accuracy (as %error) and precision.
CMS	Continuous Monitoring Software
Coefficent of Determination (R^2)	The square of the correlation coefficient. R^2 ranges from 0 (not correlated) to 1 (perfect correlation).
Correlation Coefficient (r)	A coefficient that measures the linear correlation between two sets of data. In the case of the UV-DOAS, it measures the correlation between the modeled and measured spectral data. It ranges from -1 (perfect anticorrelation) to 1 (perfect correlation).
Cryocooler	A device used to achieve cryogenic (very low) temperatures. A Stirling engine is commonly used to cool the FTIR detector.
FTIR	Fourier Transform Infrared Spectrometer/Spectroscopy
Infrared (IR)	Light that has wavelengths of 700 nm to 1 mm, or 14,000 to 10 cm^{-1}.

Term/Acronym	Definition
Interferometer	Device that uses the interference of light to measure the light "spectrum".
Intensity	A measure of how much light was collected.
MCT detector	A semiconductor detector made of mercury, cadmium, and telluride.
PC	Personal Computer
Percent Match	The coefficient of determination multiplied by 100. (R^2 x 100).
PPE	Personal Protective Equipment
QA	Quality Assurance
Retroreflector	A special array of "corner cube" mirrors that reflect light directly back to the source location. For FTIR, these are made using gold thin-film coatings.
Spectral Resolution	The ability of a measurement to resolve features in a spectrum. It is the smallest difference in wavelengths (or wavenumbers) that can be distinguished.
Spectroscopy	A technique that uses the absorption of light to detect and quantify the amount and properties of atoms and molecules.
Wavenumber	A common unit = 1/wavelength. It is the "spatial frequency" of the wave. This unit is commonly used in IR spectroscopy.
MDA	Missing Data Alerts

4. Safe Work and Hazard Identification

The following information should be noted when preparing work plans and permits for safe work practices.

Safe Operating Precautions

1. Ensure that a clear escape path is identified.
2. Standard site PPE is appropriate. If gloves are required, nitrile or latex should be used.

Operator Qualifications

Installing, operating, and servicing Cerex AirSentry FTIR analyzers should only be performed by personnel trained in the operation of the system components and familiar with the handling of gas delivery and testing equipment. This includes troubleshooting, cleaning, replacement of parts, IR light source installation, etc. Operator should be fully trained and experienced in the use of compressed gas cylinders, 1 and 2 stage regulators used in conjunction with the cylinders, flow controllers, and tubing connections. Operator should be experienced with the parameters of flow and pressure, and how these relate to compressed gas and its use with calibrating gas analysis equipment.

Safe Work and Hazardous Environment Operation

Work should conform with manufacturer guidance and site health and safety practices.

The Cerex Monitoring Solutions AirSentry Series Analyzers are not rated for safe operation in hazardous or explosive environments. Any use in an area that may contain flammable mixtures or highly corrosive vapors requires special preparation to ensure operator safety and safe operation of the equipment.


CAUTION – Laser Radiation. Risk of eye injury with prolonged direct exposure. CEREX FTIR Analyzers contain a Class 3B invisible laser radiation when the interferometer cover is removed. Do not remove the interferometer cover. Eye protection is recommended when working near the IR source.

Procedure Warnings

This QA Test procedure requires the handling of a pressurized isobutylene. Improper handling of materials or hardware may result in serious injury, destruction of property, or damage to the AirSentry FTIR. Only qualified individuals should attempt or perform analyzer quality assurance test activities. Cerex assumes no liability for the use or misuse of this guidance document, or for operator-performed QA Tests, Calibration, or Gas Handling activities. No claims are made by Cerex as to the compliance of this procedure with any regulations or engineering best practices. The operator is solely responsible for the safety of personnel and property.

NOTICE

Please check off the following steps before conducting maintenance. Doing so reduces the chance of false notifications to the public and clients.

❒ Notify the client and project manager of maintenance tasks.
❒ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.

- ❒ Confirm that the data is invalidated on the public website before proceeding with maintenance.
- ❒ When maintenance is complete check the public site for at least 15 min to ensure proper reporting (no missing data, no high values, etc.).
- ❒ Take out of maintenance mode.
- ❒ Notify the project manager and client when maintenance is complete.

5. Routine Operations

To set the FTIR instrument to acquire data for normal operations, the instrument CMS must be operating and the instrument must be aligned. These actions are detailed in the steps below.

1. Start the CMS software (if not already initiated). You should see a window similar to the one shown in Figure 2.

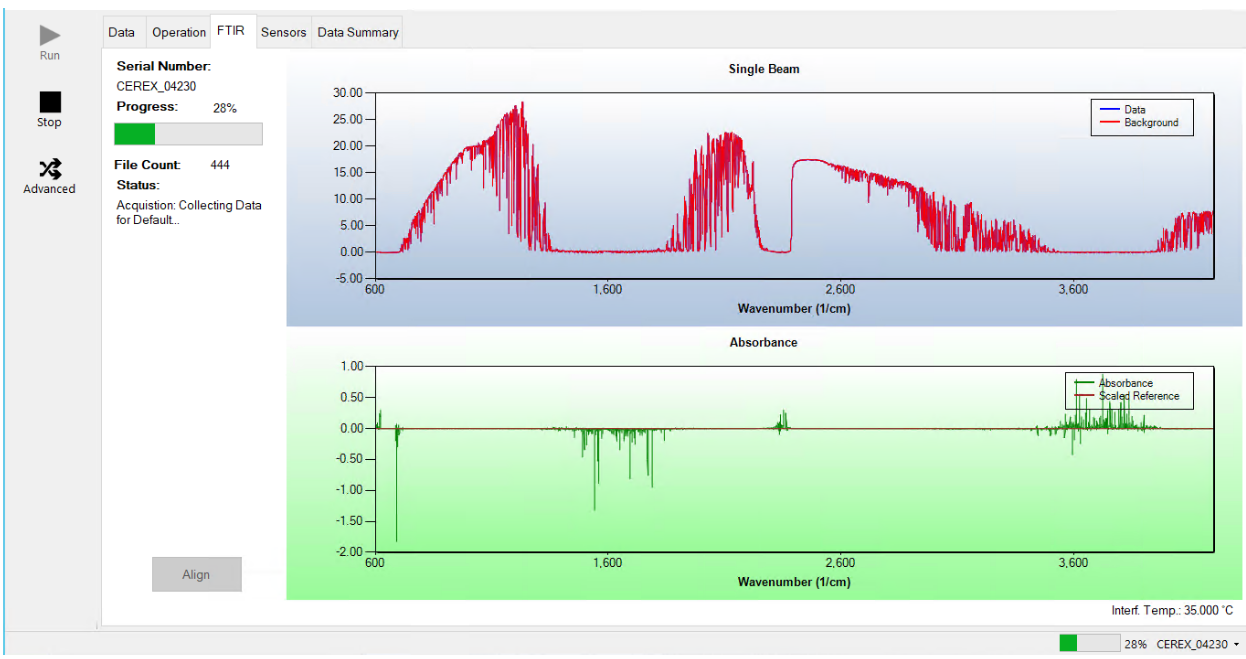


Figure 2. Screenshot showing the FTIR tab of the CMS software. Note that the Align and Run buttons are grayed out because the instrument is in run mode.

2. Under the **FTIR** tab, left-click on the **Align** button. This action brings up a new screen showing the instantaneous single beam plot (intensity versus wavelength). If the **Align** button is not active, you may need to press **Stop**. The **Align** mode is shown in Figure 3.

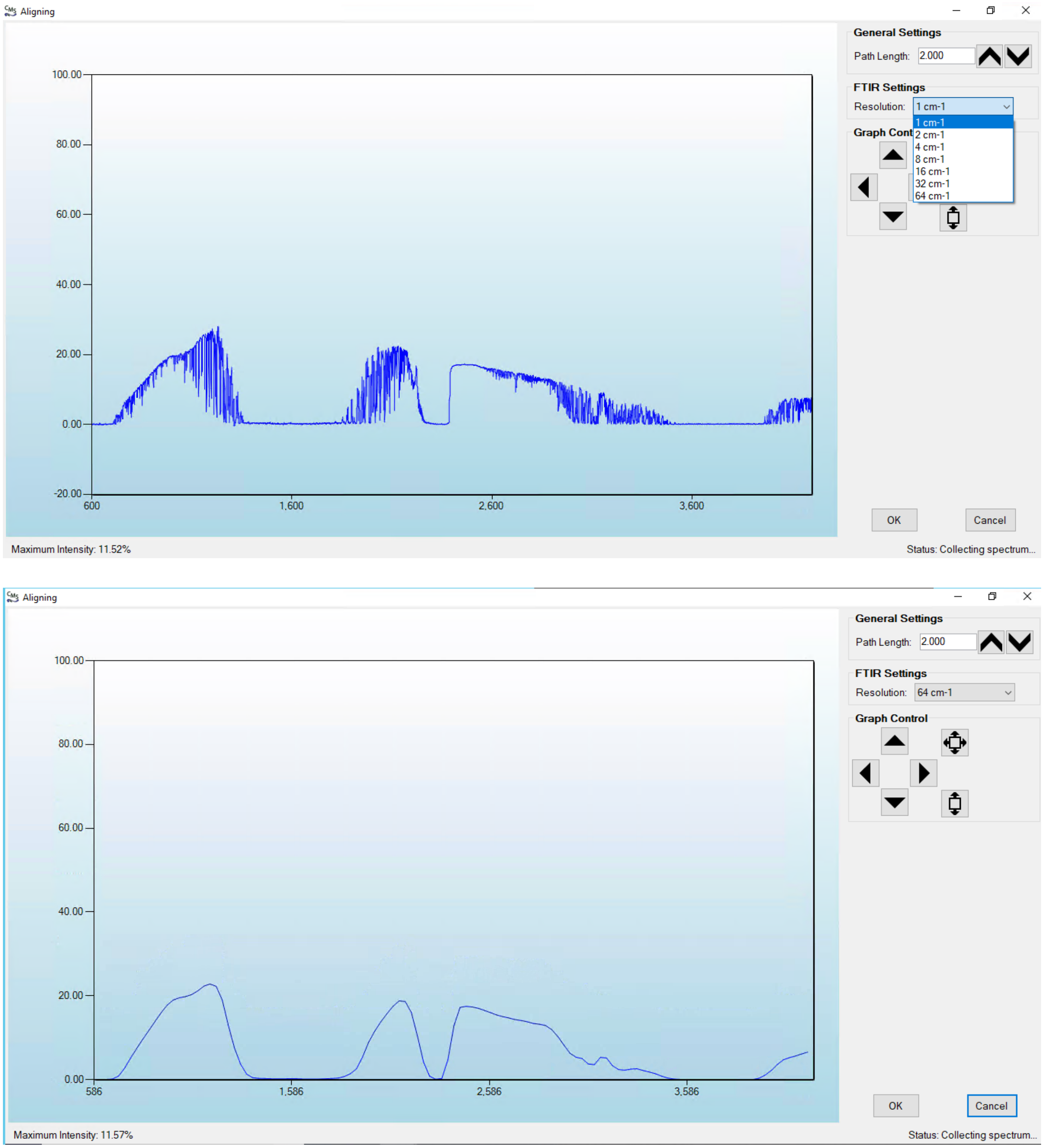


Figure 3. Screenshots of Align mode. The spectral resolution can be selected from the dropdown menu. In these particular screenshots, resolutions of 1 cm^{-1} (top) and 64 cm^{-1} (bottom) are selected.

3. Select a spectral resolution of 64 cm^{-1} and optimize the signal intensity by adjusting the pan-tilt head of the FTIR unit to adjust the position of the IR beam on the retroreflector.

4. Once sufficient alignment is obtained, exit the align mode by pressing **Cancel**.
5. Verify settings by left-clicking **Settings**.

Note: If you need to change any setting back to the original configuration, you must go to **File** and **Save**, then **Save As Default.** If you change settings, record why they were changed and what they were changed to in the instrument logbook. If settings are changed, they are automatically saved under the directory: C:\Users\CMS-USER\Documents\Cerex\CMS.

- RunTime
  - General
    - Operator Name: **Default** (these will change based on the path and site you are working on)
    - Sitename: **Cerex** (these will change based on the path and site you are working on)
    - Auto Run: **ON** (ON means the instrument will turn on automatically if the computer is running)
    - Auto Run Delay (s): **15** (time delay for CMS autostart)
  - File
    - File Type: **.CSV**
    - Primary Data Logging File: **ON**
      - C:\Users\CMS-USER\Documents\Cerex\Data (file path will vary by facility)
    - Secondary Data File Logging: **ON**
      - \\[SiteName]\STITempData\FTIR\OPT[Path#]
        - Note this path will change based on the computer and path you are working on. This is just a basic file writing path to show you what it should look like.
    - Single Data Folder: **OFF**
    - Primary Summary File Logging: **ON**
      - C:\Users\CMS-USER\Documents\Cerex\Data
    - Secondary Summary File Logging: **ON**
      - \\OPT1-PC1\VLOData\OPT1_Path1\UVSentry_POC1
        - Note this path will change based on the computer and path you are working on. This is just a basic file writing path to show you what it should look like.
    - Single Summary File: **OFF**
  - Library
    - Library File: C:\Users\CMS-USER\Documents\Cerex\Library\
  - UI
    - Sort Column: Compound Name
    - Data Summary Chart: **OFF**

        - Concentration Chart: OFF
        - Password Protection Settings: ON
        - Pump Control: OFF
        - Status Control: OFF
        - Testing Control: OFF
- <u>Analysis</u>
    - General
        - Moving Average Interval: **12**
        - Display Units: **PPM**
    - Concentration
        - Zero Readings on Non-Detect: OFF (zeros reading below threshold % match)
        - Zero Readings on Negative concentrations: OFF (zeros reading less than zero)
        - Display BDL: OFF
        - Quick Analysis MDL Wave length Range: **276-280** (not typically used)
        - Temperature/ Pressure Concentration: OFF
    - Filters
        - Absorbance Savitzky-Golay: OFF
        - Baseline Correction Savitzky-Golay: OFF
    - Background
            - Auto Background: ON (typically ON for fenceline monitoring projects reporting concentration above background)
            - Interval (Acquisitions): **5** (How far back the routine will search for a background)
            - Depth: **4**

- <u>Instruments</u>
    - FTIR
        - Operational;
            - FTIR: ON (sets instrument type)
            - Averages/Co-adds: **28** (how many spectra will be averaged together)
            - Path Length (m): **2** (2 for monostatic units)
            - Resolution: **1 cm-1** (spectral resolution)
        - Verification
            - Verification: OFF **(This inactivates all inputs)**
- <u>Controller</u>
    - General
        - Serial Port: **n/a**
        - Sensor Refresh Interval (s): **10**
    - Sensors
        - **Don't Touch Anything**

  - Alarms
    - **Don't Touch Anything**
- Email
  - General
    - Data Recipient: **Blank**
    - Email Sender: **Blank**
    - Email Period(s): **60 (the time does not matter as this setting is not used)**
    - Send Data: **OFF**
  - SMTP
    - Server: **smtp.gmail.com**
    - Port: **587**
    - Username: **Blank**
    - Password: **Blank**
    - Timeout (s): **100**
    - SSL Authentication: **ON**
- Auxiliary Coms
  - Modbus (these settings are specific to the data acquisition software used)
    - Modbus: **ON**
    - System Type: **Ethernet**
    - TCP Port: **502**
    - Unit ID: **2**
    - 16-bit unsigned int to: **ON** (does not greatly affect data)

6. After settings are verified and the instrument is aligned, you can place the instrument in run mode.

6. Equipment and Supplies

1. Field notebook
2. Tool kit, especially including: 7/64 hex driver, complete set of combination wrenches, adjustable wrenches, screwdrivers, etc.
3. Cleaning supplies designated to be safe for use on a Cerex FTIR
4. All relevant PPE, hardware, and procedural guidance per SOP, Safety Plan, and Safe Work Permit
5. Local or remote network link device (as required)
6. External laptop computer with network interface device to the Sentry unit (as required)
7. Cerex FTIR Sentry Unit equipped with CMS software

8. Isopropyl alcohol (≥80%)
9. Distilled water
10. Pressurized sprayers
11. Powder-free nitrile gloves
12. Cell bump test apparatus (including panels, regulators, valves, meters, etc.)
13. Tubing as required: 1/4" metal jacketed PTFE tubing for gas supply from the bottle to the QA cell
14. Tubing as required: 3/8" metal jacketed PTFE tubing with inline flow indicator from the QA cell to the scrubber
15. Flow regulation system capable of delivering gas 0.1 to 5 L/min at a total system pressure of 3 psig or less
16. Gas scrubber appropriate for gas used. Activated carbon treated with phosphoric acid may be used for benzene.
17. Reference standard traceable zero compressed air purge gas
18. Reference standard traceable gas blend in nitrogen for detection at about 5 times the instrument's theoretical detection limit or higher

7. Maintenance Activities

The following sections outline the routine checks to be carried out for each analyzer and sensor, followed by maintenance forms (see Section 8) used to indicate when the checks are completed and document any corrective actions taken. These activities are also expected, based upon the project plan, to be logged in a site logbook either in hard or electronic form and can reference this SOP and associated forms.

The following FTIR maintenance activities and performance checks are recommended by the manufacturer:

- Visually inspect the system.
- Confirm the alignment to verify there has been no significant physical movement. Note: this is automatically monitored as well.
- Download data older than 6 months from detector hard drive and if needed delete old files to free space.
- Ensure there are no obstructions between the detector and the retro-reflector.
- Check and replace air conditioner fans when needed.

- Change out the IR source.
- Realign system after service.
- Check system response (bump test). Take corrective action if % Error exceeds the level specified in the QAPP.
- Review and test light and signal levels.
- Verify system settings.
- Perform Cryocooler Check. Replace Cooler or swap detector module assembly if necessary.

7.1 Monthly Visual Inspections

1. Ensure that the instrument is running and the data look reasonable.
2. Clean and correct any obvious problems with the system (cobwebs, rodent nests, broken optics, etc.).
3. Inspect all electrical cables for wear; replace as needed.
4. Indicate these visual checks are complete on the form included at the end of this document.
5. Document any changes to the system in the course of these checks in the site logbook.

7.2 Light Level Check

For good visibility conditions, signal strength is normally >5%. If it is determined that these values are out of range, re-alignment may be needed. Check and record signal strength as reported by the instrument in align mode. If the value is <2%, corrective action should be taken. Common instrumental problems resulting in low signal strength include retroreflector fouling, poor internal alignment, suboptimal software and electronic gain, low source intensity, and failing detector.

Check for Stray Light

Ensure there is sufficient intensity at 966 cm^{-1} compared to the stray light intensity. If the stray light is problematic, advanced optical cleaning, replacement, alignment, or a bulb change may be necessary. To measure stray light, put the instrument in align mode and block the beam from exiting the analyzer with an opaque object (such as a black cloth) and measure the intensity at the wavenumber range of interest (in this case 966 cm^{-1}). Calculate stray light by dividing the intensity of the beam while blocked by the intensity of the unblocked beam and multiplying by 100:

$$\%stray\ light = \frac{Intensity\ of\ blocked\ beam\ (\%)}{Intensity\ of\ unblocked\ beam(\%)} \times 100\%$$

Note: the result of this stray light calculation in the form at the end of this document.

7.3 Data Management

7.3.1 Archiving and Deleting Older Data

Note: Data older than twelve months should be deleted from the instrument each month to prevent the instrument from filling its 125 GB internal hard drive.

Raw instrument data are stored on the analyzer computer, the site PC, and the hard drive attached to the site PC. Data consists of (aka "spectral data") spectral data containing two columns: one for wavelength and the other for intensity. There are also two types of "summary" files that contain data resulting from the classical least squares analysis of the spectral data as a function of time. These file formats are described in the CMS Software User Manual.[1] Spectral data and summary files are automatically written to the site PC and moved to the external hard drive after a regular interval. Deliver the external hard drive to the client on an annual basis. Data on the instrument must be deleted at monthly intervals. Details on the proper procedure for deleting data files from the instrument are as follows.

1. Confirm that the data files have been successfully written to the site PC and the external hard drive attached to the site PC.
2. Make a note of the amount of available space on the instrument internal drive on the maintenance form.
3. Locate files older than 12 months on the instrument file directory here: C:\Users\CMS-USER\Documents\Cerex\Data\.

   Note: This procedure excludes the Bump Test folder, which should always remain on the instrument computer.
4. Log into the brick PC located in the instrument shelter and locate the data files written from the instrument onto the external hard drive.
5. Confirm all Complete Data Summary files and Simple Data Summary files for the desired month have transferred over completely to the external hard drive attached to the brick PC.
6. Once you have confirmed that those files have been transferred over to the external hard drive, delete those exact Complete Data Summary and Simple Data Summary files from the instrument data folders.
7. For each individual day of single beam folders, ensure that the amount of single beam files are the same on both the external hard drive located on the brick pc and the internal hard of the instrument.
8. If both folder locations match and you have ensured proper file download, you may permanently delete the Single Beam folders from the instrument computer.

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[1] CMS Software User Manual Rev 4. CMS Version 4.0.298.1, CEREX Monitoring Solutions, December 5, 2017.

9. After all data older than 12 months have been deleted, note how much free space is now available on the instrument's internal drive. If removal of the files does not result in enough free disk space, the disk drive may need to be reindexed (see Section 7.3.2).

7.3.2 Rebuilding the Instruments Indexing Preferences

If deleting data from the instrument does not increase available storage space on the instrument, you may need to reindex files. To rebuild the index preferences, follow these steps.

1. Navigate to the **Control Panel Menu** by using the search function in the lower left-hand corner of the task bar.
2. Once in the control panel menu, click **Indexing Option.**
3. Click on the **Advanced** tab with the shield logo.
4. Click **Rebuild**.

Note: Once rebuild has been selected, a message saying that it might slow user activity will appear. This will not affect the instruments' ability to perform data collection. On the original indexing option screen, the magnifying glass in the upper right-hand corner will move and the number of items indexed will slowly increase. Take note of the available space on the instrument's internal drive once the indexing has been completed.

7.4 Clean Optics on Detector and Retroreflector

Cleaning the retroreflector is an important part of the maintenance plan. Over time the retroreflector will collect debris that can alter the performance of the instrument. Caution should be taken, as there are electrical fan heaters that are used to keep moisture and particulates from collecting on the retroreflectors.

7.4.1 Retroreflector Cleaning

1. Power down any equipment to prevent electrical shock or damage to the system.
2. Use a gentle stream of distilled water, usually from a weed sprayer or other type of gentle delivery method, to remove any salt or dust build-up on the retroreflector.
3. Use a gentle stream of 80% isopropyl alcohol, usually from a weed sprayer or other type of gentle delivery method, to remove any salt or dust build-up on the retroreflector.
4. Once the retroreflector has been cleaned and dried, repower the any electrical equipment you have powered down, and clean any spills you have created while cleaning.

7.4.2 Window and Scope Cleaning

If light levels are low or visual inspection reveals soiled optics, cleaning optical surfaces can improve light throughput. On the FTIR, the window and scope are the most likely surfaces to need cleaning. In general, if the optic is not dirty, don't clean it. Excessive cleaning of optics can result in scratches and wear over time. If the optic is obviously soiled and the soil is affecting performance, take the following steps. Mirrors with metallic coatings should be treated with extra care because these surfaces are easily damaged on contact.

Window Cleaning

1. Place the instrument in maintenance mode.
2. Remove the scope from the instrument by loosening the two Allen screws on the side.
3. Slide the scope straight up, keeping it level to prevent it from jamming. Place the scope in stable ground, being mindful of any objects that could potentially fall inside the scope and damage it.
4. Once the scope is removed, you will be able to inspect the small round window.
5. Use compressed air to remove particles from the surface of the optic.
6. Use lens paper to lightly clean the surface of the window.

Scope Cleaning

1. Place the instrument in maintenance mode.
2. Remove the scope from the instrument by loosening the two Allen screws on the side.
3. Slide the scope straight up, keeping it level to prevent it from jamming.
4. Place the scope on the ground at a slight angle to allow the cleaning solution to drain out.
5. Use a pressurized sprayer with distilled water to lightly rinse any heavy dust or dirt off the primary and secondary mirrors of the scope.
6. Use a pressurized sprayer with 80% or higher isopropyl alcohol to lightly rinse any remaining contaminants from the primary and secondary mirrors of the scope.
7. Let the scope dry for about 20-30 minutes before placing it back on the instrument.

7.4.3 Replace AC Fans

Two AC fans are necessary to control the temperatures inside the FTIR. The preventative maintenance procedure of replacing the AC fans every 2-3 years is needed to ensure proper operations and prevent critical components from being damaged due to high heat exposure.

1. Turn off MDAs and place unit into Planned Maintenance mode.

2. Close CMS and shut down operating system.
3. Unplug power to unit.
4. Open FTIR lid.
    a. Note: (place barrier to prevent screws from falling into the FTIR assembly).
5. Remove shroud fan cover on the underside of the FTIR lid.
6. Make note of fan orientation before removal (i.e. front facing).
    a. Unplug each fan, then remove the four screws holding each fan for removal.
7. Install new fans with screws, then plug fans into power source.
8. Close FTIR lid.
9. Plug in the FTIR power source and begin operations.
10. Start CMS and align FTIR if needed.

7.5 Perform Bump Test

This section addresses the commissioning and performance test procedure for Cerex Monitoring Solutions AirSentry units. The procedure is intended to verify that the equipment is performing to expectations, and that the detection and communication links are functioning correctly.

***NOTE ***
THIS IS A WORKING DRAFT FOR INITIAL SYSTEM VALIDATION.
IT SHOULD BE REVIEWED FOR COMPLIANCE WITH LOCAL SAFETY AND QUALITY ASSURANCE PRACTICES.
This procedure should only be used by personnel with experience in the safe use of the analyzer and test equipment.

The purpose of the QA Test procedure is field verification of the factory calibration of the AirSentry. The QA Test process challenges the instrument using known concentrations of Hexane, Ammonia, and/or isobutylene to verify proper detection and quantification under field conditions.

7.5.1 Apparatus Setup

This procedure is to be carried out when using the Internal AirSentry FTIR QA Cell.

Set up the apparatus to enable, at a minimum, a) gas flow to the calibration cell of the instrument and b) flushing of the cell with zero/clean air. An example system is shown in Figure 4. The advantages of the system shown in Figure 4 are (1) the exhaust from the calibration cell is scrubbed, (2) there are check valves in place to prevent cell overpressure, and (3) the regulator attached to the compressed gas cylinder can be flushed with clean air.

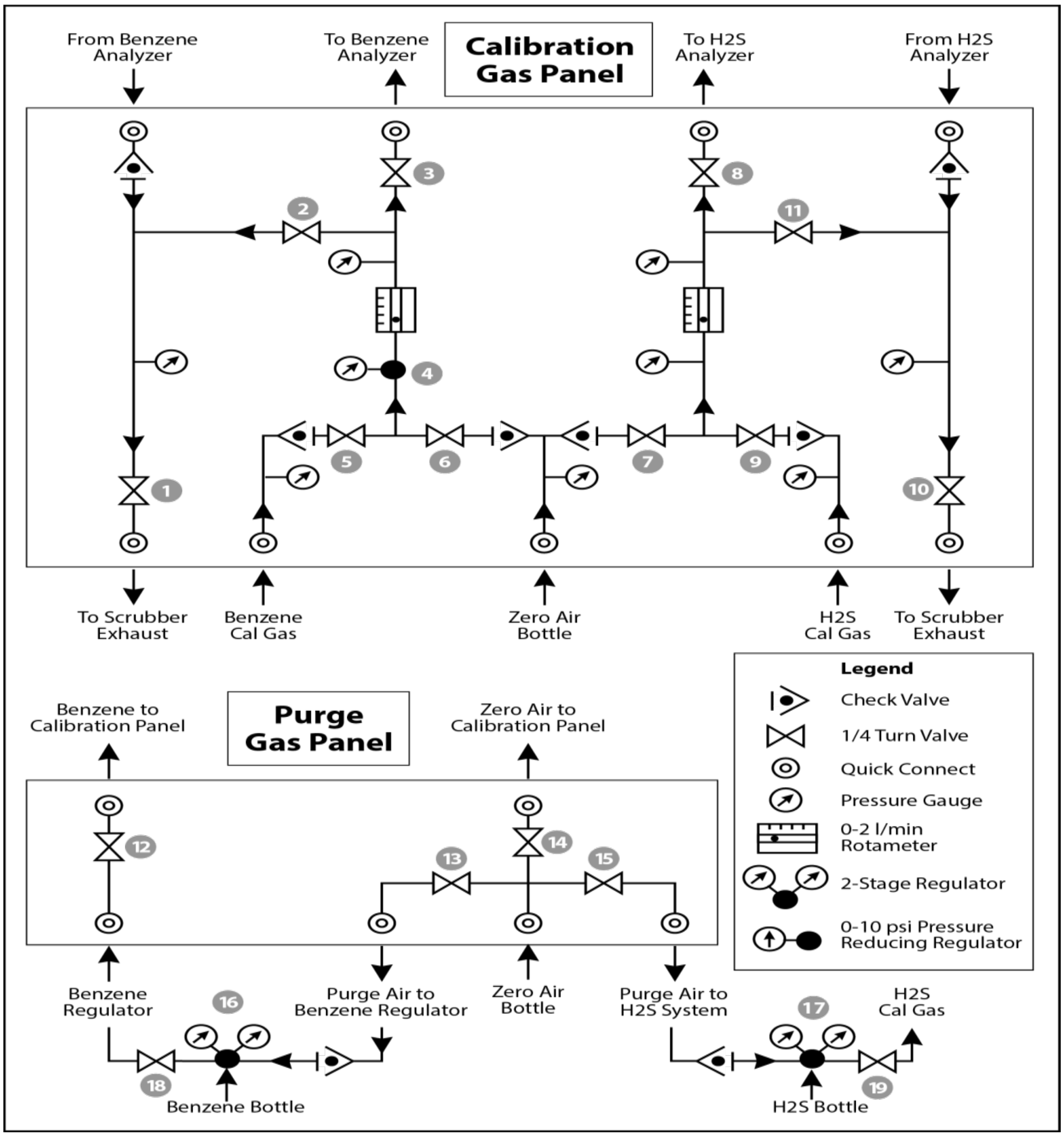


Figure 4. Diagram of the calibration gas panel (top) and purge gas panel (bottom) used for gas delivery. Note that the gas used will change depending on the instrument.

Materials Required

1. Operator-supplied Standard Operating Procedure approved by the End-User and in compliance with End-User's Health and Safety Plan.
2. Cell bump test purge apparatus, including:
    a. Tubing as required: 1/4" PTFE tubing for gas supply from the calibration gas panel to the QA cell.
    b. Tubing as required: 3/8" PTFE tubing for gas supply from the QA cell to the calibration apparatus.
    c. All necessary tubing for supplying calibration and zero reference gas to calibration gas panel.
    d. Flow regulation system capable of delivering gas 0.1 to 5 L/min at a total system pressure of 3 psig or less.
3. Purge gas; typically, Zero Air.
4. Reference standard traceable gas blend in nitrogen for detection at about 5 times the instrument's theoretical detection limit or higher.
5. All relevant PPE, hardware and procedural guidance per SOP, Safety Plan, and Safe Work Permit.
6. Local or remote network link device (as required).
7. External laptop computer with network interface device to the AirSentry FTIR unit (as required).

7.5.2 Configure CMS for Test (This may be done concurrently with Gas Purge System setup)

1. The analyzer should be powered on and running for <u>at least 30 minutes prior to testing</u>.
2. Stop CMS data collection by pressing the **STOP** button.

7.5.3 Gas Test System Setup

1. Connect the 1/4" reference cell line coming from the calibration apparatus to the 1/4" reference cell connection on the Cerex MS Air Sentry FTIR.
2. Connect the 3/8" reference cell line coming from the calibration apparatus scrubber to the 3/8" reference cell connection on the Cerex MS Air Sentry FTIR located just below the 1/4" refence cell inlet.
3. Ensure all valves on the calibration gas apparatus are in the closed position.
4. Make all necessary connections from Zero Air and calibration gas standard cylinders to the Gas Calibration apparatus.

7.5.4 Verify Proper AirSentry Alignment

1. Open the CMS window.
2. Click on the **FTIR** tab.
3. If **Run** is active, press **STOP**.
4. Click the **ALIGN** button at the bottom left of the plot display.
5. Select 32 cm^{-1} and wait for resolution change.
6. Aim the AirSentry FTIR at the retroreflector and adjust the alignment until the signal intensity is optimized.
    a. **The target intensity should be the highest achievable intensity, which varies based on instrument, but should be above 2% at minimum. Once a stable signal is obtained, select the desired operating resolution (1 cm^{-1} is required unless otherwise directed by Cerex).**
7. **Record** the signal intensity.
    a. **Optional – at this point you may wish to record the current field pathlength and create a backup of the existing configuration file.**
8. Press **OK** and **SAVE** or **ACCEPT** (when prompted) to exit the CMS Alignment window.

7.5.5 Leak Check (Optional, for use with the calibration panel)

1. Ensure that all tubing from the purging panel is connected to the calibration panel in the mobile van. Ensure gas cylinders are connected to the purge panel as depicted in Figure 4. Then attach the calibration panel to the analyzer connection in the analyzer shelter.
2. Connect the PTFE tubing containing the activated carbon scrubber to the analyzer exhaust.
3. Close all valves on the calibration and purging panel.
4. Verify that the regulators on the zero air and benzene cylinders are completely closed (**all the way to the <u>left</u>!**) to prevent any pressure buildup at the regulator.
5. Open high-pressure valves on both the calibration gas and zero air bottles.
6. Open valve (14) and slowly open the regulator on the zero-air cylinder to a pressure of 5-10 psi, observed on the calibration panel zero gas pressure gauge. Do this by making small adjustments at the cylinder regulator and watching the pressure on the calibration panel.
7. Open valve (12) and slowly open the regulator on the calibration gas cylinder to a pressure of 5-10 psi on the pressure gauge on the benzene calibration gas channel of the panel. Do this by making small adjustments at the cylinder regulator and watching the pressure on the calibration panel.
8. Open the bypass valve (2).

9. Open the zero-air valve (6) and slowly open the regulator (4) to a final pressure of about 2 psi (as read on cell and exhaust pressure gauges). **DO NOT pressurize above 3 psi**.
10. Now pressurize the cell. Slowly open the valve going to the cell (valve 3). Close the bypass valve (2) while carefully watching the cell pressure gauge after the regulator (4). If you note any sudden pressure increase, open the bypass valve (2) to relieve pressure on the cell. Wait until the same pressure is reached on the exhaust-side calibration panel pressure gauge.
11. Close the zero-air valve (6) going to the benzene regulator on the panel so the system is now fully closed off to external pressure.
12. Watch the system for a minimum of five minutes to ensure there is no drop in pressure and the system is leak free.
13. Open the leak check valve (1) to release the pressure from the system, and then close all the valves on both panels.
14. Record leak check.

7.5.6 Configure Test Files

1. Click **Advanced** on the left side of the CMS software window. The password is *advanced*.
2. Under **Advanced** -> **Settings** -> **Runtime** -> **File**, turn off **Secondary Logging**. Note current file logging paths.
3. Change both of the primary file logging paths to: C:\Users\CMS-USER\Documents\Cerex\Data\bumptest. Then select **File** and **Save**.

7.5.7 Bump Test Using Calibration Panel

Gas System Purge

1. Close the secondary pressure regulator (4) on the panel by turning all the way to the left.
2. Open the leak check (1) and bypass valve (2).
3. Open the zero-air valve (6).
4. Adjust the flow of purge air going through the bypass until the desired flow rate (1 lpm) and pressure are achieved by slowly increasing the pressure on the secondary pressure regulator (4). The backpressure on the scrubber (measured between valves [1] and [2]) is typically less than 1 psi.
5. Open the valve going to the cell (3) and close the valve on the bypass (2) while carefully watching the cell pressure gauge after the regulator (4). If you note any sudden pressure increase, open the bypass valve (2) to relieve the pressure on the cell. Wait until the desired flow rate has stayed the same and the pressure on the entire system has not increased.

6. Press **RUN** to start background acquisitions.
7. Allow the analyzer to complete **three** or more acquisitions.
    a. If after two acquisitions the absorbance graph shows negative features greater than 3 times the peak-to-peak baseline noise level, take another clean air background.
8. Repeat this process until the sequential absorbance acquisition seen in the absorbance graph remains near zero (straight baseline with only normal noise peaks).
9. Once the instrument has performed ten or more acquisitions, close the zero-gas valve (6).
10. Close all valves.
11. Close the secondary pressure regulator (4) on the panel.

Gas Span and QA Test

1. Open the leak check (1) and the bypass valve (2).
2. Open the calibration gas valve (5).
3. Adjust the flow of calibration gas going through the bypass and scrubber until the desired flow rate (1 lpm) and pressure are achieved by slowly increasing the pressure on the secondary pressure regulator (4). The backpressure on the scrubber (measured between valves [1] and [2]) is typically less than 1 psi.
4. Open the valve going to the cell (3) and close the valve on the bypass (2) while carefully watching the cell pressure gauge after the regulator (4). If you note any sudden pressure increase, open the bypass valve (2) to relieve the pressure on the cell. Ensure the desired flow rate has stayed the same and adjust as needed.
5. Wait 10 minutes to fill and condition lines and cell.
6. After 10 minutes of calibration span gas flow, press **Start** in CMS.
7. Collect span gas data.
    a. Observe the concentration reported on the **DATA** tab.
    b. After the concentration becomes stable, allow the analyzer **to run until at least seven stable measurements are made.**
    c. **Verify that the values meet the QA criteria. If the test fails QA criteria, follow the corrective actions listed at the end of this section (see: Data Evaluation, Reporting, and Corrective Action).**
    d. **Verify client system** is receiving and displaying instrument information correctly.
    e. After seven stable measurements are observed, **close the reference gas cylinder valve (6)**. Allow the pressure to fall to zero and the flow to stop.

Completion of Test and Purge of Instrument Calibration Cell

1. Close the calibration gas cylinder. You will see calibration gas pressure increase and/or fluctuate as the pressure on the bottle regulator drops. This is normal - be patient and wait for the benzene pressure to zero out.
2. Close all valves on the calibration and purging panel.
3. Open the zero-air valve (6).
4. Adjust the flow of purge air going through the bypass until the desired flow rate (1 lpm) and pressure are achieved by slowly increasing the pressure on the secondary pressure regulator (4). The backpressure on the scrubber (measured between valves [1] and [2]) is typically less than 1 psi.
5. Open the valve going to the cell (3) and close the valve on the bypass (2) while carefully watching the cell pressure gauge after the regulator (4). If you note any sudden pressure increase, open the bypass valve (2) to relieve the pressure on the cell. Wait until the desired flow rate has stayed the same and the pressure on the entire system has not increased.
6. **Verify that the target gas(es) concentration has returned to 0 ppm** with non-detect R^2.

   NOTE If the concentration has not returned to 0 ppm, this means ambient background target gas concentration has changed during the procedure and testing may need to be repeated to verify results.
7. Once a zero reading is indicated on the FTIR, close all valves.
8. Close the zero-air cylinder and allow all the pressure to be released from the system.
9. Close all valves and ensure there is zero pressure on the system.
10. Disconnect tubing to the analyzer and the activated carbon scrubber.
11. Remove the hoses and cap the connectors.

7.5.8 Bump Test Without Calibration Panel

Background Measurement

1. Attach 1/4″ PTFE tubing from the ambient air and Ammonia gas tank valve to the FTIR test cell.
2. Attach 3/8″ PTFE tubing with scrubber to the exhaust port on the FTIR test cell.
3. Flip the ambient air/gas tank valve to allow for flow from the ambient air pump and power on the pump. Adjust the flow from the ambient air pump until the desired flow rate (1 lpm) is achieved by slowly increasing the flow on the rotameter attached to the valve.
4. Press **RUN** to start background acquisitions.

5. Allow the analyzer to complete three or more acquisitions.
   a. If after two acquisitions the absorbance graph shows negative features greater than 3 times the peak-to-peak baseline noise level, take another clean air background.
6. Repeat this process until the sequential absorbance acquisition seen in the absorbance graph remains near zero (straight baseline with only normal noise peaks).
7. Press **STOP** to stop background acquisitions.

Span Test

1. Open the ammonia gas tank valve and flip the ambient air/gas tank valve to allow for flow from the ammonia gas tank. Adjust the flow from the gas tank until the desired flow rate (1 lpm) is achieved by slowly increasing the flow on the gas tank regulator.
2. Wait 10 minutes to fill and condition lines and cell.
3. After 10 minutes of calibration span gas flow, press **START** in CMS.
4. Collect span data.
   a. Observe the concentration reported on the **DATA** tab.
   b. After the concentration becomes stable, allow the analyzer **to run until at least seven stable measurements are made.**
   c. **Verify that the values meet the QA criteria. If the test fails QA criteria, follow the corrective actions listed at the end of this section (see: Data Evaluation, Reporting, and Corrective Action).**
   d. **Verify client system** is receiving and displaying instrument information correctly.

Completion of test

1. Flip the ambient air/gas tank valve to allow for flow from the ambient air pump. Maintain a flow of approximately 1 L/min.
2. Close the ammonia gas cylinder.
3. **Verify that the target gas(es) concentration has returned to 0 ppm** with non-detect R^2.

NOTE If the concentration has not returned to 0 ppm, this means ambient background target gas concentration has changed during the procedure and testing may need to be repeated to verify results.

4. Once zero reading is indicated on the FTIR, turn off the ambient air pump.
5. Disconnect tubing to the analyzer and activated carbon scrubber.

6. Re-align the analyzer if needed after disconnecting tubing from the analyzer test cell.
7. Label the bump test data file, and go to the "Restore Normal Operation" section of this procedure.

7.5.9 Restore Normal Operation

1. **Restore** Normal Operation.

   Note: When restoring normal operation, you will change the file storage path in the settings menu back to the normal file path (this is slightly different for each unit, so make a note when first setting up the instrument for the QA test). Once you restart CMS, you will see the file number located on the FTIR main menu of CMS. If the file count starts at file 1, you have the incorrect file writing path because it is starting a new folder for the entire day. If this happens:

   a. **STOP** CMS.
   b. Click **Advanced** on the left side of the CMS software window; password is *advanced*.
   c. Under **Advanced** -> **Settings** -> **Runtime** -> **File**, turn On **Secondary Logging**. Change the primary file logging paths (both of them) to: C:\Users\CMS-USER\Documents\Cerex\Data. Then select **File** and select **Save**.
2. **Check the system alignment** as previously described.
3. Press **RUN** to begin monitoring.

Test Suspension

In the event of a leak or plant alarm requiring suspension of work, the process should be safely suspended. If a plant or site alarm sounds during the validation, stop the test immediately as follows.

1. Close the reference gas bottle valve completely.
2. Allow the system to flow purge gas to the scrubber/vent.

7.5.10 Data Evaluation, Reporting, and Corrective Action

During these tests, a number (N) of replicated measurements (x_i) of a standard reference material of known magnitude (x_{std}) will be measured. Here, an acceptable number of trials will be defined as 7≤N≤15. The average value of these measurements is calculated as:

$$\bar{x} = \frac{\sum_i x_i}{N} \quad (1)$$

and the sample standard deviation (σ) as:

$$\sigma = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{N-1}}. \qquad (2)$$

From these definitions, % error (accuracy) is defined as:

$$\%\ error = \left|\frac{\bar{x} - x_{std}}{x_{std}}\right| \times 100\% \qquad (3)$$

and precision as the coefficient of variation expressed as a percentage (% CV):

$$Precision \equiv \%\ CV = \frac{\sigma}{\bar{x}} \times 100\% \qquad (4)$$

1. Concentration
   a. Average the concentration of 7 - 15 consecutive stable measurements.
   b. Report the % error between the average and the certified value. The acceptable % error is listed in the QAPP.

      Note: To calculate the certified value that will be seen on the Cerex instrument from the actual certified instrument calibration gas concentration, multiply the certified gas concentration by the calibration cell length (0.015 meters), and divide that answer by the path length set in the instrument software. For most Cerex instruments in operation by Sonoma Technology, the path length is set to 2 meters for monostatic instruments and 1 meter for bistatic instruments.
2. Calculate the Limits of Detection and Quantitation
   a. Calculate the mean (average), sample standard deviation, and %error (sometimes also referred to as % difference) of the selected results.
   b. Report the Detection Limit as three times the standard deviation.
   c. Report the Quantitation Limit as five times the standard deviation.
3. Compile all configuration files, spectra files, and log files into a single folder.
   a. The folder should be named "CUS LOC QATest IR# YearMoDy" where CUS is a three-letter designator for the customer, and LOC is a three-letter designator for the facility location.

The QAPP contains the acceptance criteria and warning levels to be used for the test.

Note:

- **If the test produces an error or precision greater than the warning level:** corrective action should be taken so that the precision and error are below the warning levels.
- **If the test produces an error or precision greater than the acceptance criteria:** corrective action should be taken so that the precision and error are below the warning levels. Equipment will not be placed into service until it meets all measurement criteria.

If the measurements do not meet the data quality objectives listed in the QAPP, repeat the procedure without adjustment. If the instrument still fails to meet the QA criteria, retest the following day with no adjustment. If these repeated tests continue to fail, initiate corrective actions, such as:

- Realign the system and perform the test again.
- Reviewing data for potential interferants, including a detailed check of absorbance spectra in the analysis regions configured for the analyte, noting any excessive noise or unexpected absorbance features
- Consulting with the project technical lead to identify abnormal changes to the background
- Check wavelength calibration
- Checking for large changes in stray light since the last test and adjusting calibration factors as necessary
- Reviewing gas testing apparatus for leaks or other similar problems
- Review and confirm specifications of standard calibration equipment and gases (expiration dates, concentrations, etc.)

In the event of a failed test after following all steps outlined above, inform the Sonoma Technology Project Manager and Quality Assurance Manager, who will review the instrument performance parameters in the list above.

If all parameters indicate that the instrument was performing properly since the last test, data since the last test will be flagged as suspect. If an issue with the instrument is identified, data since the date and time of the instrument issue will be flagged as invalid. All data flagging will be performed by Data Analysts in consultation with the Quality Assurance Manager.

7.6 Cryocooler Replacement and Calibration

1. Remove Cryocooler
    a. Turn off the power to the instrument. Please follow the proper shutdown procedure.
    b. Unplug the power connector (two-pin Molex with gray cable) from the cryocooler engine (**Figure 5**).

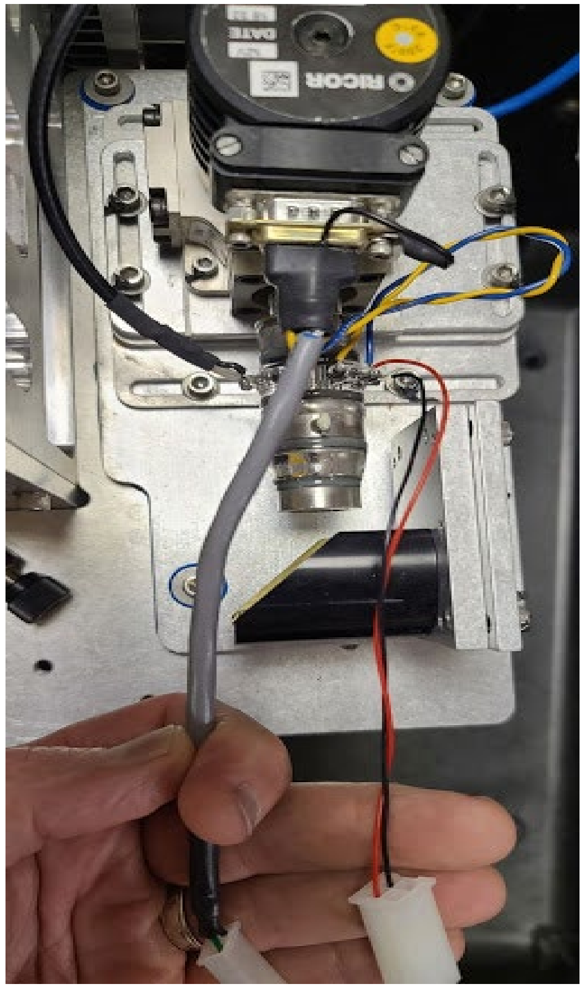


Figure 5. Detector assembly showing RICOR cryocooler, glass detector, DB9 connector, two white Molex connectors, and mirror.

c. Unplug the black and red cable molex connector coming from the glass detector assembly.

d. In some installations there is a ground cable coming from connector and going to the chassis. Remove the ground cable by unscrewing it from the chassis.

e. Take out the three #8 screws that hold the detector assembly to the baseplate - these will have blue grommets in the holes (See image below). Only remove three screws to release the entire assembly (**Figure 6**).

Figure 6. Image showing baseplate and screws with rubber grommets.

f. Follow the black coax connector to the small "Preamp" box - silver in color. This is held to the baseplate with 2 screws (**Figure 7**).

Figure 7. Preamp assembly (with orange, black and purple wires) between the heatsink (left) and interferometer (right).

g. Disconnect power to the preamp – this is a 4-pin molex connector that can be pulled apart. The connector has purple, orange, and black wires.

h. Follow the second black coax cable from the preamp over the 4" x 6" heatsink assembly. Remove the BNC connection to this heatsink by hand twisting 1/4" turn counterclockwise and pulling it off.

i. The detector assembly and the preamp will come out together as they are attached to each other by a coax cable.

j. Pack the detector assembly and the preamp in the same box. But wrap both items separately so they can not touch. Immobilize all items in the box. Use protective case to transport entire assembly securely.

2. Re-install cryocooler

   a. The installation process is the opposite of removal.

   b. Make sure all screws and connectors are secured and tightened.

3. Optics Calibration

   a. After replacing or installing a new detector and optics optimization is required using a small test retroreflector array.

      i. Place the test retroreflector array about 2 feet from the front of the FTIR scope. Alternatively, use a small "bike reflector" in the outgoing beam path, just before the light enters the bump test cell.

      ii. With the instrument powered on and using the Align window, set the resolution to 64 ms and align the scope to obtain the maximum signal strength possible.

      iii. Open the instrument and carefully use the beam splitter adjustment screws to maximize signal strength. This means making small adjustments to each screw until you reach the maximum signal strength (**Figure 8**).

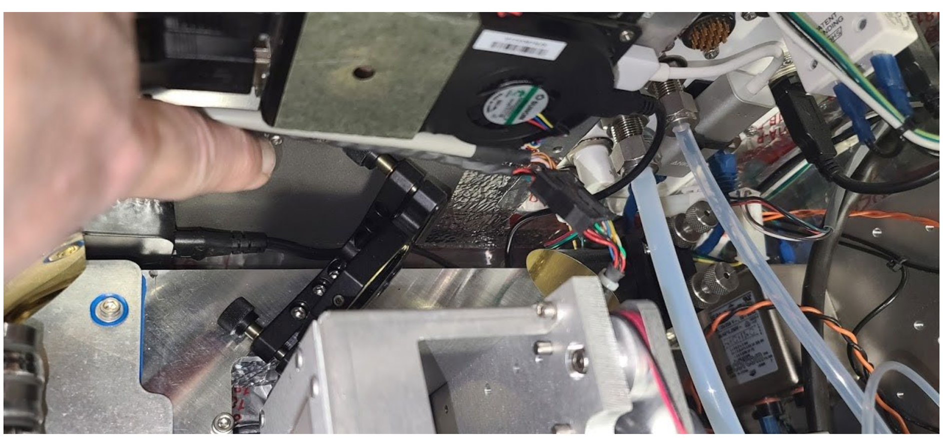


Figure 8. Beamsplitter (black object at 45-degree angle) with adjustment screws.

Repeat the same steps with the beam steering mirror. Keep in mind that the secondary mirror has two lower thumb screw nuts that lock the adjustment in place. You will have to unscrew those nuts before making any adjustments. Tighten the nuts once you have reached the desired adjustment.

The beam splitter and the beam steering mirror work in tandem, so you may have to go back and forth between the two to optimize the signal strength (**Figure 9**).

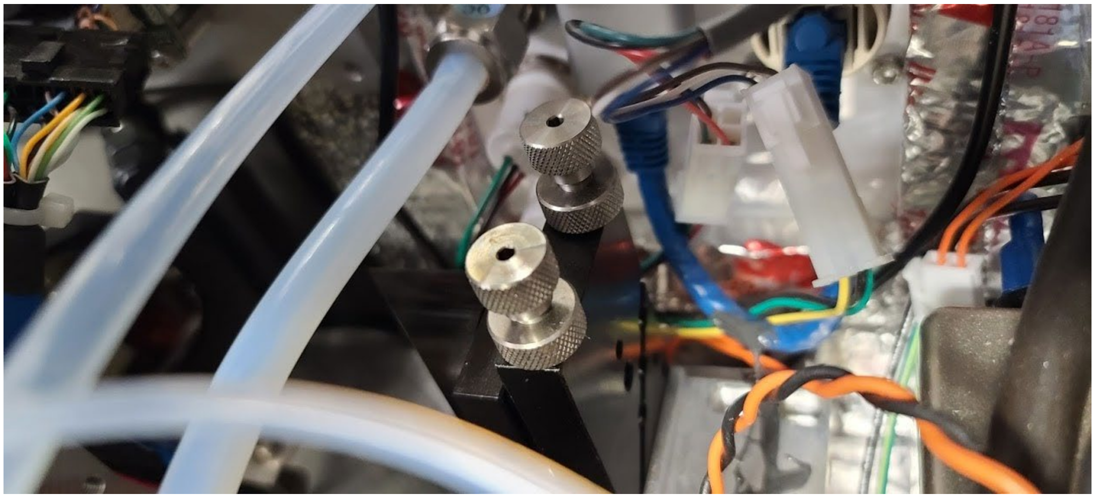


Figure 9. Beam steering mirror with sliver adjustment screws.

8. Monthly Maintenance Forms

Path:____

Technician:____

Date:____

Instructions: complete checks described below, and enter data or initial next to each one once complete. Make note of any corrective action.

Please check off the following steps before conducting maintenance. Doing so reduces the chances of false notifications to the public and clients.

- ❒ Notify the client and project manager of maintenance tasks.
- ❒ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.
- ❒ Confirm that the data is invalidated on the public website before proceeding with maintenance.
- ❒ When maintenance is complete check the public site <u>for at least 15 min</u> to ensure proper reporting (no missing data, no high values, etc.).
- ❒ Take out of maintenance mode.
- ❒ Notify the project manager and client when maintenance is complete.

Upon completion, sign and date:______________________________

Table 2. Maintenance activities and performance indicator checks for the FTIR.

Activity	Completed (Y/N)
Visually inspect the system.	
Current source service hours.	
Check light levels	
Confirm the alignment to verify there has not been significant physical movement. This is also automatically monitored.	
Ensure there are no obstructions between the detector and the retro-reflector (such as equipment, vegetation, or vehicles).	
Move data older than 1 week old into an archive folder & note location.	
Ensure data are backed up on external drive. Delete files older than 12 months from the instrument computer.	
Realign instrument.	
Perform bump test.	
Check system performance indicators.	
Inspect and clean optics on detector.	
Verify system settings.	
Inspect air conditioner heat sinks and clean, if necessary.	
Inspect and clean AC system interior heat sink.	
Review and test light and signal levels.	
Check average light intensity to establish baseline for IR Source.	
Change frequency and retro-reflector wear.	
Replace Cryocooler.	
Change out the IR source.	

Corrective Actions for FTIR:

Cerex FTIR Air Sentry Gas Test Summary

DATE: ________________________ Location: _________________________________

Test Technician 1:______________________________ 2:______________________________

Sentry Alignment

Signal Intensity (average) ___________________________

Signal Intensity at 966 cm^{-1} ___________________________

Blocked Beam Intensity at 966 cm^{-1} _________________________

% Stray Light ___________________________

Gas Purge System

Flow purge Start Time __________________________

Prepare CMS

Path length in the CMS Configuration _________________________ m

Configure Test Files

Site File (i.e., QA Audit UV# YearMoDy) ____

Baseline Check _______________________ init

Reference Gas

Concentration ______________________ ppm

Source ____

Date ____

NOTES:

Gas Test Summary – Cerex FTIR - Page 2

Purge Flow Conditions

Start Time ______________________

NOTES:

Check Gas Test

Initial Gas Flow ______________________ L/min

Start Time ______________________

Collect Check Gas Data Start Time ______________________

Data Record:

TIME	PPM	R^2
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________
___________________	_________	________

Verify Client ______________________ Init

Stop Time ______________________ Init

Open the PURGE Gas Time ______________________

Reference Concentration _________ ppm

Average Concentration _________ ppm

% error _________ %

% Spectral Match _________ %

Standard Deviation _________ ppm

Estimated MDL (3X Standard Dev) _________ ppm

Restore Normal Operation

Restore running data file ______________________ Init

Press **RUN** to begin monitoring. ______________________ Init

Standard Operating Procedure for Picarro G2204 H_2S Analyzer

August 27, 2024

STI-7539

Contents

Summary

This Standard Operating Procedure (SOP) describes the general operation and maintenance of the the Picarro G2204 hydrogen sulfide (H_2S) analyzer, and is adapted from the Picarro G2204 Analyzer User's Guide (Part Number 40041, Rev. A 8/24/11).

The Picarro G2204 is used to quantify Hydrogen Sulfide (H_2S) using cavity ring-down spectroscopy.

Safety

LASER SAFETY: The Picarro Analyzer is classified as a Class 1 Embedded Laser Product

WARNING: CLASS 3B INVISIBLE LASER RADIATION WHEN OPEN. AVOID EXPOSURE TO THE BEAM.

Analyzer Components

The G2205 Analyzer is comprised to the following main components:

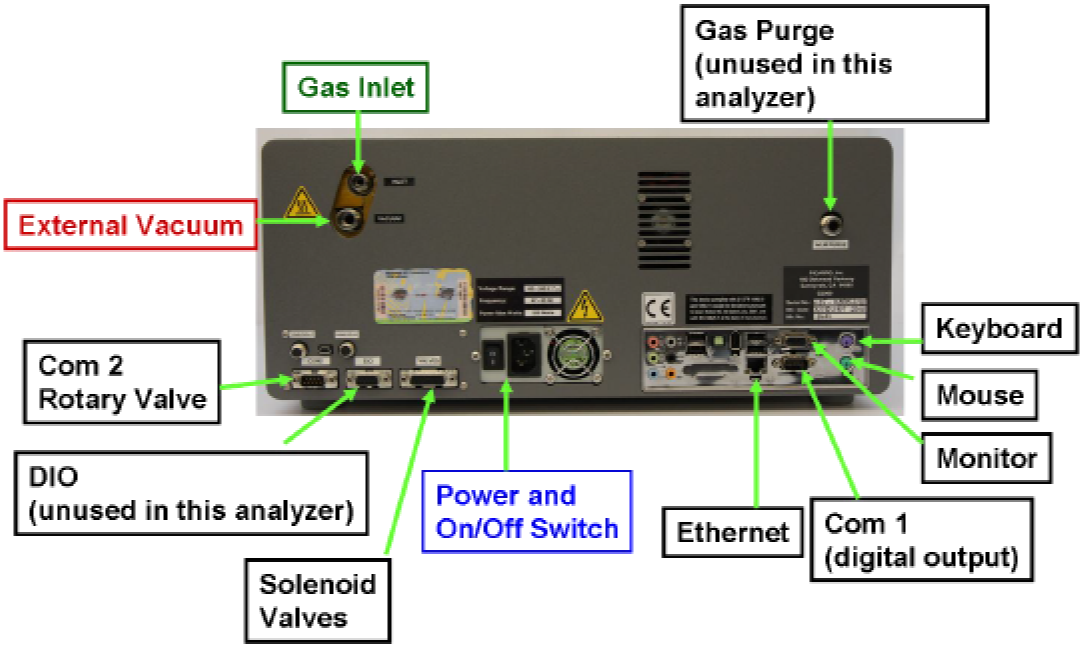
- Analyzer module – includes the data acquisition, control, and communications hardware and firmware to perform spectral collection and analysis.
- Pump module – provides vacuum required for sample gas flow into and out of the analyzer
- Accessories – includes 2 A/C Power Cables (one for the analyzer and one for the pump); one USB flash drive preloaded with back-up software; user manual; certificate of compliance.

Basic Analyzer Setup

1. The analyzer should be installed on a bench top or flat surface, with the external vacuum pump near-by or on the floor.
2. Remove the caps from the Analyzer gas connection inlet and vacuum connection ports.
3. Remove the caps from External Vacuum pump.

   Caps can be saved for later use and should be reinstalled if the analyzer or pump are stored, moved, or shipped. They should be reinstalled if the pump is stored, moved or shipped.
4. Connect a Teflon gas line between the Analyzer vacuum port and the External Vacuum Pump, as seen in the figure below. Nuts should be tightened with an 11/16" wrench.

5. AC power to the External Vacuum Pump can now be connected.
6. Attach a tube to the External Vacuum Pump exhaust port and direct to a safe place for venting the mixture of sample gases.
7. Attach a PS2 mouse, PS2 keyboard, Ethernet cable, and VGA monitor display cable to the computer connections on the back of the Analyzer.



Basic Analyzer Operation

When the main power is turned on, the analyzer will start operation automatically, including the Graphical User Interface (GUI).

Icons on the desktop of the analyzer include:

- Controller – provides instrument diagnostics and service information
- Picarro Mode Switcher – restarts analyzer in different measurement modes.

The analyzer will not begin producing data until all the measurement parameters have reached their operational set points (temperature, pressure, etc.), as indicated in the Status log window. Data are automatically saved once the analyzer begins producing data. The GUI provides a continuous, real-time data read out. Data are stored in on the local drive (C:\Userdata\DataLog_User \YYYY\MM\DD, where Y=year, M=month, D=day).

Shutdown Procedure

A flow of clean, relatively dry gas should always be directed though the instrument for several minutes prior to shut down. Check the moisture trap at the analyzer inlet connection to ensure the excess water is not getting into the sample cavity.

Selecting "**Shutdown in current state**" stops the gas flow and shutdowns the software. It does not shut off the main computer. You will be prompted to confirm the shutdown. Select the "OK" check box to initiate the shutdown procedure, then flip the analyzer main power switch to complete shutdown. This is the most common shut down procedure and works for short off periods (hours to days).

If "**Prepare for shipping**" is selected, the cavity pressure will increase until it reaches near atmospheric pressure. The status log will indicate the pressure as the cavity is filled. The proportional valves will be closed, software will terminate, and the instrument will power off completely. This should be selected if the analyzer will be unused for longer periods of time (weeks or more).

Note: If power to the analyzer is cut off, the analyzer will stop operation. However, when power id reapplied, the analyzer will restart automatically. The software will close out previous files and open new files for data collection.

Service and Maintenance

Equipment and Supplies

Before beginning the particulate filter replacement, make sure to have all of these materials:

- 1.5 mm hex driver
- 9/16" open-end wrench
- 5/8" open-end wrench
- 11/16" open-end wrench

Particulate Filter

There are two in-line, sub-micron particulate filters before the measurement cavity. The first is user-replaceable and replacement filters can be purchased from Picarro and installed by the user. It is important to **NEVER** remove the filter that is directly attached to the cavity. Only change the filter immediately following the inlet at the back of the analyzer.

Removing Old Particulate Filter

1. Power Down the Instrument following the "shutdown in current state" procedure outlined above.
2. Using the 1.5 mm hex driver, remove the analyzer top lid by removing six hex screws.
3. Remove the piece of foam from around the input bulkhead by sliding it towards the back of the analyzer.
4. Using the 5/8" wrench, loosen the retaining nut on the input bulkhead.
5. Using the 9/16" and 11/16" wrenches, disconnect the filter from the tube section near the front of the analyzer.
6. Slide the filter and bulkhead slightly towards the back of the analyzer and lift out.
7. Using the 9/16" and 11/16" wrenches, disconnect the filter from bulkhead fitting.

Installing the New Particulate Filter

Note: When re-attaching 1/4" Swagelok fittings, the nut should be hand-tightened and then turned an additional 1/8 of a turn using a wrench.

1. Using the 9/16" and 11/16" wrenches, remove the filter from its packaging and attach it to the bulkhead fitting. The arrow on the filter needs to point away from the bulkhead fitting.
2. Using the 9/16" and 11/16" wrenches, reposition the filter and bulkhead fitting, and reattach to the tube section
3. Using the 5/8" wrench, reposition the filter cover and tighten the retaining nut on the bulkhead fitting. The metal edge of the filter cover should be under the foam of the top of the enclosure.
4. Reposition the piece of foam around the input bulkhead fitting.
5. With the 1.5mm hex driver, replace the analyzer top and secure with 6 hex screws.

Maintenance Activities and Frequency

Maintenance Action	Frequency
Inspect sample line tubing and water trap.	Monthly, or during a site visit
Back up user data on C drive.	Quarterly
Perform gas test for analyzer response.	Quarterly
Replace particle filter at analyzer inlet.	Annually or as needed

Analyzer Calibration

The following procedure is intended to serve as a verification of the analyzer response to a known amount of H_2S reference gas, both when first installed and during routine calibrations. If there are problems with a calibration, support from the manufacturer will be provided until the problem is fixed..

CAUTION: Pressure and flow - When the analyzer is connected directly to a pressurized gas tank or a sample container, the user needs to be mindful of sample flow and pressure (1-3 psi range). If the pressure and flow are too high or too low, damage to valves and the cavity may occur.

Procedure for Using Calibration Gas Cylinders

This procedure pertains to using a dynamic gas calibrator capable of flowing varying concentrations of calibration gas to an instrument. The calibration cylinder contains high amounts of H_2S, use caution when handling.

1. Connect calibration gas cylinder and zero gas cylinder to the appropriate ports on the dynamic gas calibrator.
2. Connect the outlet of the dynamic gas calibrator to the analyzer sample inlet.
3. Route the instrument exhaust outside of the analyzer shelter, with the Sulfursorb scrubber attached.
4. Open all calibration gas bottles and ensure you are not over-pressurizing the dynamic gas calibrator.
5. Configure the gas calibrator with the appropriate calibration concentrations and desired flow.
    a. Multiple calibration concentrations should be used, including a zero.
    b. The following describes a typical range of concentrations that can be used:

Target Calibration concentrations
0 ppb
200 ppb
150 ppb
50 ppb
0 ppb

6. Ensure the sample vent is open and unobstructed to the atmosphere by monitoring vent flow and sample pressure.
7. Start flowing calibration gas by selecting the desired concentration or zero gas on the

dynamic gas calibrator.

8. Collect calibration gas data.
    a. Observe the concentration reported on the analyzer readout (GUI).
    b. After the concentration becomes stable, allow the analyzer **to run until 10 minutes of stable measurements are made.**
    c. Verify that the value is near the expected concentration. If the measurements do not meet specifications, repeat the procedure. If repeated measurements appear nonconforming, initiate corrective action investigation. Use the Picarro User's Guide for reference.
    d. Verify system is receiving and displaying instrument information correctly.
9. After 10 minutes of stable measurements are observed, the next calibration gas concentration can be selected.
10. Repeat Step 8 for all concentrations of calibration gas.
11. Close the calibration gas cylinder. Allow the pressure to fall to zero and flow to stop.
12. Once calibration is complete, purge the sample inlet line.
    a. Flow zero air through the system.
    b. Purge the sample inlet with zero air for at least 2 minutes.
    c. **Verify that the target gas concentration has returned to baseline**.
    d. Remove the hoses and cap the connectors.

Picarro G2204 Analyzer Response Summary

Date: ___________________________________ Location: _________________________________

Gas Purge

Flow purge gas — Start Time ______________________

End Time ______________________

H_2S Calibration Gas Check

Concentration set points

______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb

Average Measured Concentration	% Error
______________________ ppb	___________________ %
______________________ ppb	___________________ %
______________________ ppb	___________________ %
______________________ ppb	___________________ %
______________________ ppb	___________________ %

Overall Percent Error ______________________ %

NOTES:

Sonoma Technology

Standard Operating Procedures for the Magee Scientific Aethalometer Model AE33

July 24, 2024

STI-7036

Contents

1. Purpose and Method

This Standard Operating Procedure (SOP) describes the general maintenance of the Magee Scientific Aethalometer Model AE33 black carbon analyzer.

This manual is adapted from Magee Scientific's User Manual, version 1.54, which is available at http://www.mageesci.com/EACworkshop2016/MANUALS/AE33/AE33_UsersManual_Rev154.pdf.

The Magee Scientific Aethalometer Model AE33 is used to quantify black carbon (BC) in the air. The Aethalometer draws air through a spot on filter tape and then analyzes the aerosol present in the sampled air by measuring the transmission of light through the tape. The sample spot transmission is compared to an unloaded portion of the filter tape which acts as a reference. This analysis is performed at seven optical wavelengths, from the near-infrared to the near-ultraviolet. The Aethalometer calculates the instantaneous concentration of optically absorbing aerosols from the rate of change of the attenuation of light transmitted through the particle-laden filter. Two measurements are obtained simultaneously from two sample spots with different rates of accumulation of the sample. Both spots derive their samples from the same input air stream. The two results are combined mathematically to eliminate nonlinearities common in previous instrument measurements to provide the compensated particle light absorption and BC mass concentration.

The instrument will be operated with 1-min time resolution.

2. Equipment and Supplies

Maintenance for the Magee AE33 is carried out with the following equipment:

- Instruments for flow checks
- New roll of filter tape
- Adhesive tape
- Screwdriver
- Flow calibration pad (black rubber)
- Flow meter

3. Personnel Qualifications

Installation, operation, maintenance, repair, or calibration of the instrument and all support equipment should be performed by properly trained personnel. Personnel should meet all minimum STI requirements and qualifications for an Air Quality Field Technician.

4. User Interface and Operation

4.1. User Interface

The four top-level tabs in the touch screen user interface are: **HOME**, **OPERATION**, **DATA**, and **ABOUT**. They are described as follows:

HOME has the following parameters:

- BC – the measured values for Black Carbon (measured at 880 nm)
- UVPM – UV particulate matter (calculated at 370 nm)
- REPORTED FLOW – Measured flow (in LPM)
- TIMEBASE – Timebase setting (in seconds)
- TAPE ADV. LEFT – The amount of remaining tape (in)
- STATUS – Instrument status: green (all OK), yellow (check status), and red (stopped) with a Status Condition (see Section 4.2, Instrument Status)
- Bottom of HOME screen shows date and time

Note: The BC and UVPM values are typically similar, but not exactly the same. When aromatic compounds are present in the sampled air (such as when sampling fresh wood smoke, for example), the UVPM concentration can exceed the BC mass concentration value significantly, depending upon the amount and type of organic material present.

OPERATION has four sub-tabs: GENERAL, ADVANCED, LOG, and MANUAL.

- GENERAL – with the following settings:
  - Flow (LPM) (see Note below on flow-reporting standard)
  - TimeBase (seconds)
  - Select one of three radio buttons:
    - TA ATNmax – maximum attenuation at which the Aethalometer advances tape
    - TA INT – the time interval at which the Aethalometer advances tape (hours)
    - TA Time – the time at which the Aethalometer advances tape
  - Start, Stop, Stability, Clean Air, and Change Tape buttons
- ADVANCED – All parameters which can be set in the Aethalometer
- LOG – The last operational reports of status, parameter changes, data download
- MANUAL – Basic commands to operate hardware (solenoids, pump, chamber, TA)

DATA has two sub-tabs: TABLE and EXPORT.

- TABLE – Raw measurement values, BC concentration calculated from each individual spot (BC1, BC2), and the compensated BC concentration. All three concentrations have the unit ng/m^3.
- EXPORT – Selection data to be copied to USB

ABOUT – Features and contact information.

4.2. Instrument Status

The instrument's current status condition is displayed in decimal format on the front panel **HOME** screen and in the **Status** column of the data download. The status condition relates to various subcomponents of the instrument (Detector, Flow, LED, etc.). The decimal number represents a sum of all of the status conditions occurring at any given time. Multiple status conditions are interpreted using subtraction of the largest possible Status Condition value using the table below.

Table 1. Status Conditions and Descriptions

Parameter	Status Condition	Description
Detector	0	Measuring
	1	Not measuring (due to tape advance, fast calibration in progress)
	2	Calibrating (LED, Flow, Tape Sensors)
	3	Stopped
Flow		Flow OK
	4	Flow low/high by more than 0.25 LPM
	8	Flow check status history
	12	Flow low/high and check status history
LED		LEDs OK
	16	Calibrating
	32	Calibration error in one or more channels (at least one channel OK)
	48	LED error (all channels calibration error, COM error)
Tape Advance		Tape advance OK
	128	Tape warning (less than 10 spots left)
	256	Tape last warning (card box visible, less than 5 spots left)
	384	Tape error (tape not advancing, end of tape)
Tests		No test
	1024	Stability test
	2048	Clean air test
	3072	Change tape

When Status Condition 3 is encountered, the Aethalometer stops. In all other statuses, it continues to operate with a warning, and the data is flagged accordingly. The status is represented by one value, which can point to one parameter or a combination of parameters.

4.2.1. Single Status Condition

If the value displayed matches a value in the **Status Condition** column, it indicates only one parameter and its description. Examples:

- Status = 0, all OK; front panel LEDs GREEN
- Status = 1, all OK, tape advancing; blinking GREEN LED
- Status = 128, machine is running, tape advance warning flag is set; YELLOW

4.2.2. Multiple Status Conditions

If the Status displayed does not match a value in the table, it means that there are multiple parameters whose Status Conditions are added together, forming a sum that must be broken down by subtraction. First, find the largest value in the **Status Condition** column that does not exceed the Status value, and subtract it from the sum. Then find the next largest value in the **Status Condition** column that does not exceed the remainder, and subtract again. Continue finding the next largest number and subtracting it until the remainder matches a value in the **Status Condition** column. Examples:

- Status = 289, which breaks down as follows: 289 − 256 = 33; 33 − 32 = 1; therefore, the Status Conditions are 256, 32, and 1. This means the machine is not measuring (1), the LED calibration had errors in 1 or more (but not all) channels (32), and less than 5 tape advances are left (256).
- Status = 145, which breaks down as follows: 145 − 128 = 17; 17 − 16 = 1; therefore, the Status Conditions are 128, 17, and 1. This means the machine is not measuring (1), the LED calibration is in process (16), and less than 10 tape advances are left (128).

4.3. Downloading or Viewing Data

To download data, insert the USB stick in either of the front USB ports. Do not use the rear ports, as they are intended for the mouse and keyboard only and not for data transfer (surge protection).

Go to the "**DATA/EXPORT**" menu and press **Export to USB**. The data will be stored in a text file with a header. The file name is:

AE33_Sss- nnnnn_yyyymmdd.dat

where *ss* is the production series number, *nnnnn* is the serial number, and *yyyymmdd* is the date (for example, 20120901 means 1 Sept 2012). Please make sure that the transfer is finished before removing the USB stick from the USB port on the Aethalometer. The data file can now be transferred to a personal computer like any other file and processed with any preferred data processing application.

5. Field Maintenance

Table 2 describes maintenance actions, including cleaning and inspections and their required frequencies for routine system management.

Table 2. Regular maintenance schedule.

Maintenance Action	Frequency
Inspect sample line tubing	Monthly, or during a site visit
Visually inspect the tape	Monthly, or during a site visit
Inspect and clean the size selective inlet	Monthly, or during a site visit
Inspect and clean the insect screen assembly	Monthly, or during a site visit
Perform leak test	Monthly, or after maintenance or repair
Flow verification test	Monthly, or after maintenance or repair
Flow calibration	Monthly, or if any flow from the flow verification summary is >10%
Check/set the instrument date and time	Monthly
Install new filter tape roll	As needed upon instrument warning
Biannual to Annual Actions	
Inspect optical chamber, clean if necessary	Every six months (or as needed)
Clean air test	Every six months
Stability test	Every six months
Inlet leakage test	Annually
Neutral Density (ND) filter test	Annually
Lubricate optical chamber sliders	Annually
Change bypass cartridge filter	Annually

5.1. Inspect Sample Line Tubing

Visually inspect the sample line tubing for condensation, cracks, kinks, or other structural damage. Replace if needed.

5.2. Inspect and Clean the Insect Screen Assembly

The insect and water trap is installed in the sample inlet line, at a point close to the instrument and clearly visible. This trap prevents the entry of contamination (which will compromise the data); or entry of water (either rain or condensation), which can lead to serious damage of the flow sensors. Visually inspect the trap and remove and clean as necessary.

5.3. Install New Filter Tape Roll

Supplies for this procedure: new roll of filter tape, adhesive tape. See Section 9.2 of the user's manual for reference.

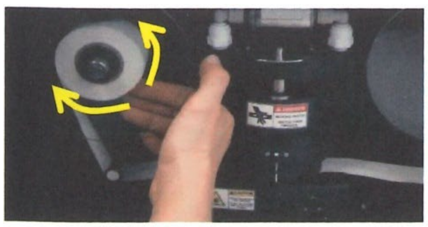
When you observe an instrument warning of tape change needed, follow these instructions to change the tape. This should occur roughly every 6 weeks or so.

1. If the instrument is running, press **Stop** on the front panel.
2. Open the front door of the instrument.
3. Loosen the thumb screws and remove the transparent plastic covers from both the "supply" spool (on the left hand side), and the "collection" spool (on the right-hand side).
4. Using thumb and fingers on both sides of the optical chamber, lift the chamber upwards against its springs.
5. When the chamber is fully raised, lock it in place by pushing the metal latch.
6. Remove the used tape from both spools. Place used tape in a Ziploc bag.
7. Take the new filter tape and place it on the supply spool. Take note of the metal spring leaf, which stabilizes the top surface of the roll.

8. Make sure the roll is correctly oriented—the tape must unroll from the left-hand side.
9. Take the other cardboard spool center and attach the end of the filter to it using adhesive tape.
10. Place the empty center on the "take-up" spool axis (the right-hand side of the collection spool).



11. Make sure that the tape is fed beneath both the left and the right guide posts, and passes under the optical chamber.
12. Release the optical chamber by lifting up with thumbs and fingers on both sides. The spring-loaded latch will automatically release.
13. Replace both transparent plastic covers. Tighten the thumb screws by hand only.
14. Check that the left-hand supply spool can turn freely.
15. Make sure that the right-hand collection spool is firmly clamped to its axis: test by gently pulling the tape, and make sure the spool center does not move.




16. The filter tape replacement procedure is now completed. Press **Start** to resume operation.

5.4. Perform Leak Test

Supplies for this procedure: flow calibration pad, flow meter.

1. If the instrument is running, press **Stop** on the **Operation/General** screen.
2. On the **Operation/General** screen, press **Leakage test** to start the test.
3. A new screen appears. Choose **Manual**.
4. The instrument will measure the flow through the filter tape. Confirm by pressing **OK**.
5. Connect your external mass flow meter to the inlet port.
6. Connect the flow meter using well-sealed tubing and fittings. Make sure the connections are tight.
7. Press **OK**.
8. Choose the flow at which you want to perform the test. Normally this test is conducted at 5 LPM. Press **OK**.
9. Observe the flow measured by your flow meter.
   IMPORTANT! Make sure that your flow readings are reported at the same "Standard" reporting conditions of Temperature (25°C) and Pressure (101325 Pa) that you are using in the Aethalometer. Many flow meters display flow at "actual" conditions (i.e. local T and P); and also display the same result corrected to "standard" conditions.

10. Press the input box field and enter the flow from the external flow meter.
    IMPORTANT! Units are milliliters per minute (mLPM), not liters per minute (LPM).
11. Confirm by pressing **OK**.
12. Now measure the flow once again, but through the rubber flow calibration pad rather than the filter tape.
13. When prompted, remove the filter tape and install the rubber flow calibration pad with the notch facing toward you.
14. When ready, press **OK**.
15. Repeat the procedure as before when measuring the flow through the filter tape (Steps 4-11).
16. When finished, remove the flow calibration pad and replace the filter tape. Press **OK**.
17. The test is now complete. The report shows:
    - Instrument serial number
    - Date and time of the test
    - Results of the test: selected flow and flows through the filter tape and calibration pad

    This report is also saved on the CF card and is available for download with data files.
18. The leakage should be less than 10%. If the reported leakage is larger than 10%, contact Magee Scientific or your authorized distributor.

5.5. Perform Flow Verification Test

Supplies for this procedure: flow calibration pad, flow meter. See Section 9.3 in the user's manual for reference.

1. If the instrument is running, press **Stop** on the **Operation/General** screen.
2. Press the **Verify flow** button to start the test.
3. A new screen will appear. Choose **Manual**.
4. Measure the flow through the flow calibration pad.
5. Wait for the chamber to lift. When prompted, remove the filter tape and install the rubber flow calibration pad with the notch facing toward you.
6. When the pad is installed, press **OK**.
7. Connect the external flow meter to the inlet port using well-sealed tubing and fittings. Make sure that the connections are tight.
8. Press **OK**. The Flow Verification routine will measure the flow at three different values (approximately 1 LPM, 3 LPM, and 5 LPM), and compare the "internal" value (from the instrument's flow sensors) with the "external" value measured by the external flow meter.
9. Note the flow on your external mass flow meter.
   IMPORTANT! Make sure that your flow readings are reported at the same reporting conditions of T and P as the instrument's setting.
10. Press the empty box marked **Flow** and enter the flow from the external flow meter.
    IMPORTANT! Units are milliliters per minute (mLPM).
11. Confirm by pressing **OK**. The process will repeat at the three flow values.

12. After entering the last value (@5LPM) and pressing **OK**, the instrument will show the flow verification report. This report is also saved on the CF card and is available for download with data files.
13. The test is satisfactory if the difference of flow readings is less than ±10%. If the difference is larger, re-calibration of the flow sensors is needed (see section 9.3 of the user's manual).
14. Confirm by pressing **OK**.
15. When prompted, remove the rubber flow calibration pad and re-install the filter tape. Press **OK** when done.

5.6. Perform Flow Calibration

Supplies for this procedure: Flow calibration pad (black rubber), flow meter.

1. If the instrument is running, press **Stop** on the **Operation/General** screen.
2. Press the **FlowCal** button to start the test.
3. A new screen will appear. Choose **Manual**.
4. The instrument will run through several procedures. The first is to measure the flow through the flow calibration pad.
   - If the rubber pad is already in place, you can press Skip.
   - If not, please wait for the chamber to lift. When prompted, remove the filter tape and install the rubber flow calibration pad with the notch facing toward you.
   - When the pad is installed, press OK.
5. Connect the external flow meter to the inlet port.
6. Connect the flow meter using well-sealed tubing and fittings. Make sure that the connections are tight. Press **OK**.
7. The instrument will measure the flow at three different points: close to 1 LPM, 3 LPM, and 5 LPM.
8. Observe the flow measured by your flow meter.
   IMPORTANT! Make sure that your flow readings are reported at the same "Standard" reporting conditions of Temperature and Pressure that you are using in the Aethalometer.
9. Press the input box field and enter the flow from the external flow meter.
   IMPORTANT! Units are milliliters per minute (mLPM), not LPM.
10. Confirm by pressing **Enter**.
11. After entering the last value (@ 5LPM) and pressing **OK**, the procedure is completed.
12. Remove the flow calibration pad and replace the filter tape. Press **OK** when done.
13. Press **Start** to resume sampling.
14. Repeat flow verification test.

6. Biannual Maintenance

Table 3. Biannual maintenance schedule.

Maintenance Action	Frequency
Inspect optical chamber; clean if necessary	Every six months (or more frequently if needed)
Clean air test	Every six months
Stability test	Every six months
Inlet leakage test	Annually
Neutral Density (ND) filter test	Annually
Lubricate optical chamber sliders	Annually
Change bypass cartridge filter	Annually

6.1. Clean Optical Chamber

The optical chamber should be inspected if the data are uncharacteristically noisy. This procedure will ensure that there is no dust or contamination in the optical path. See Section 9.1 in the user's manual for reference.

Supplies: Can of compress air such as Dust-Off or similar, technical-grade ethanol, cotton swabs.

1. If the measurements are running, press **Stop**. This procedure can also be done when the instrument is powered off.
2. Open the front door to access the optical chamber.
3. Using thumb and fingers on both sides of the optical chamber, lift the chamber upward against its springs. When the chamber is fully raised, lock it in place by pushing the metal latch. The chamber is now locked.
4. Find the release button on the front of the chamber.
5. While pressing the release button upward, grasp the lower portion of the optical head and turn it clockwise so the front of the chamber moves to the left. The lower portion will loosen from its bayonet fitting and can be removed.
6. The lower portion of the optical head consists of a translucent block. Clean all surfaces with ethanol. Put a few drops of ethanol in the openings and remove any dust or debris by using soft cotton swabs.
7. Repeat this procedure from both sides.
8. Use compressed air to remove any debris from the openings.
9. To re-install the optical head, first align the notched marker to the left of center; push the optical head upwards to engage the three bayonet fittings; and turn counter-clockwise (so the front of the chamber moves to the right).

10. When the chamber is fully installed, the marker line will be at the front, and the locking pin will click back into place.
11. Using thumb and fingers on both sides of the optical chamber, lift the chamber upward. The locking latch will automatically release. Allow the chamber to return down to the tape.
12. Restart the instrument and resume measurements.

6.2. Perform Clean Air Test

The Clean Air test is conducted using the built-in filter to determine the stability and performance of the Aethalometer under the air flow conditions. The Clean Air test lasts for 20 minutes, during which time a Status Code of 2048 is shown. At the end of the test, a report is generated and saved to the CF card.

1. If the measurements are running, press **Stop**. If the Aethalometer is off, turn it on and wait a minimum of one hour for average BC values to stabilize.
2. Go to the **Operation/General** screen, and press the **Clean Air** button to start the test. **IMPORTANT: if you want the instrument to automatically proceed with BC measurements after the Clean Air test, please be sure to check the box "continue after test" before starting.**
3. A new screen lists all relevant information about the test settings (test duration, flow, and timebase). When ready, press **OK**.
4. The instrument begins the test. The Clean Air test uses a built-in filter to determine the stability and performance of the Aethalometer under dynamic conditions of air flow. Air is drawn through a cartridge filter (mounted on the top of the optical chamber), and this particle-free air then flows through the analytical system.
5. After 20 minutes, the test stops automatically.
6. The Clean Air test procedure report is generated and appears on the screen. A separate report is generated and saved on the CF card for later download.
7. The test result is acceptable if the value of PPBC on Spot1 is lower than 550 ng/m^3 for Channel 6. If the measurements do not meet the data quality objectives listed in the QAPP, repeat the procedure. If repeated measurements appear nonconforming, initiate corrective action investigation.
8. Confirm completion of the test by pressing **OK**. The **Average BC** values should be close to zero (less than ±100) if the Aethalometer is warmed up and stabilized for at least one hour. Occasionally, a short transient may be seen at first, due to a filter compression artifact.

6.3. Perform Stability Test

The stability test determines the performance of the light source and detector, without air flowing through the system. The Stability Test lasts for 20 minutes, during which time a Status Code of 1024 is shown. At the end of the test, a report is generated and saved to the CF card.

1. If the measurements are running, press **Stop**. If the Aethalometer is off, turn it on and wait a minimum of one hour for average BC values to stabilize.
2. Go to the **Operation/General** screen, and press the S**tability Test** button to start the test. **IMPORTANT: if you want the instrument to automatically proceed with BC measurements after the Stability Test, please be sure to check the box "continue after test" before starting.**
3. A new screen lists all relevant information about the test settings (test duration, flow, and timebase). When ready, press **OK**.
4. The instrument begins the test.
5. The test stops automatically after 20 minutes.
6. The Stability Test procedure report is generated and appears on the screen. A separate report is generated and saved on the CF card for later download.
7. The test result is acceptable if the value of PPBC on Spot1 is lower than 450 ng/m^3 for Channel 6. If the reported value of PPBC on Spot 1 is larger than this value, please contact Magee Scientific or your authorized distributor. If the measurements do not meet the data quality objectives listed in the QAPP, repeat the procedure. If repeated measurements appear nonconforming, initiate corrective action investigation.
8. Confirm completion of the test by pressing **OK.** The **Average BC** values should be close to zero (less than ±100) if the Aethalometer is warmed up and stabilized for at least one hour.

6.4. Perform Inlet Leakage Test

Supplies: External flow meter.

The Inlet Leakage test is used to test the integrity of the inlet system, from the point of sample entry to the instrument's analytical area. In many cases, the sample entry point is outdoors, while the instrument is indoors. This test detects any leakage throughout the system.

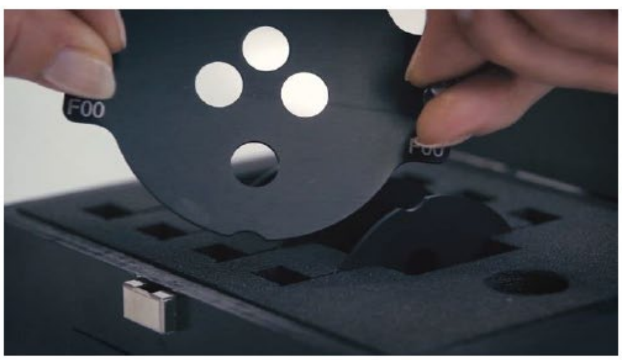
The test routine compares two measurement values from an external flow meter: one taken at the rear port of the instrument, and the other taken at the sample point of entry (which may be outdoors). The routine requires the use of the black rubber Flow Calibration Pad. During this test, data will be flagged by status code 6144.

1. From the **Operation/General** screen, press **Inlet Leakage Test**.
2. Follow the instructions on the screen to insert the Flow Calibration Pad.
3. Measure the flows with an external flow meter at the two points.
4. When the test is finished, a report is generated. The leakage should be less than 10%. If the reported leakage is larger than 10%, please contact Magee Scientific or your authorized distributor. If the measurements do not meet the data quality objectives listed in the QAPP, repeat the procedure. If repeated measurements appear nonconforming, initiate corrective action investigation.

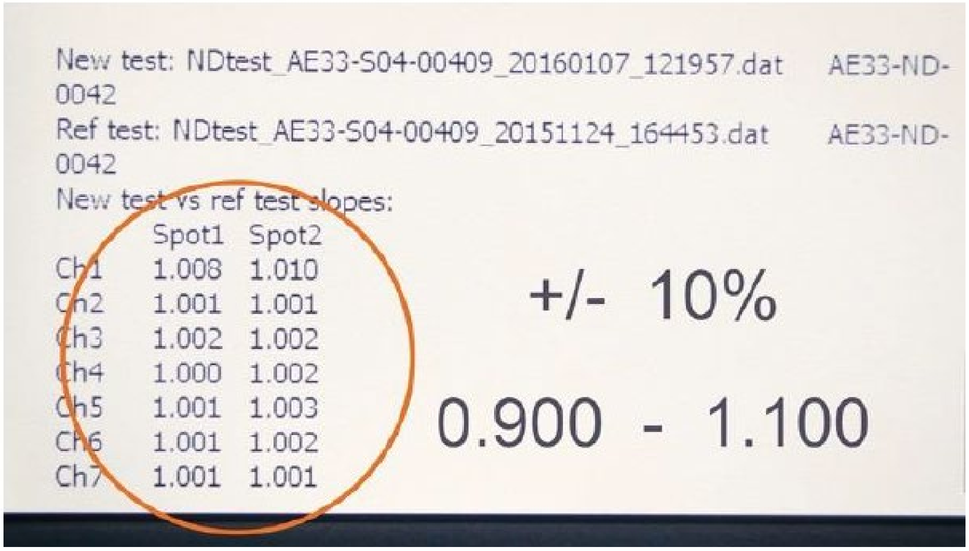
6.5. Perform Neutral Density (ND) Filter Test

Supplies: ND filter test kit.

1. Go to the **Operation/General** screen on the Aethalometer. If the measurements are running, press **Stop**.
2. Press the **ND test** button to start the test.
3. A new screen prompts you to enter the ND Kit Serial Number, which is marked on the test kit box.
4. After entering the Serial Number of the ND Kit, confirm by pressing **Enter** and **OK**.
5. If this is the first time the ND Test has been performed on this instrument, you will be prompted for calibration parameters. These must be uploaded from the USB memory stick that is included in the ND kit box. Insert the USB stick into the USB port on the front panel, and press **Yes**.
6. The instrument will copy the calibration parameters file and then begin the test procedure.
7. Always keep the filter tape in position across the analytical area. When prompted, insert ND element No. 0 (zero) on top of the filter tape, with the "V" notch facing forward (see below). Do not touch the glass—hold the element by the metal studs.



8. Press OK when inserted. Watch the screen, and remove the filter disk when prompted.
9. Repeat the same procedure when prompted for ND elements Nos. 1, 2, and 3.
10. The test is complete after ND element No. 3 is removed.
11. The instrument will generate a report that shows the instrument serial number, the date and time of the test, and the results of the test. This report is also saved internally and is available for future download.
12. Report values on both Spot1 and Spot2 should be within ±10% of 1.000: i.e., between 0.9 and 1.1, for all seven wavelengths (Ch1 to Ch7). See below.
13. If the results fall outside this range, repeat the test. If the results still fall outside the range, contact Magee Scientific. If the measurements do not meet the data quality objectives listed in the QAPP, repeat the procedure. If repeated measurements appear nonconforming, initiate corrective action investigation



6.6. Lubricate Optical Chamber Sliders

Supplies: silicon grease, a cotton swab.

1. If the measurements are running, press **Stop**. This procedure can also be done when the instrument power is switched off.
2. Open the front door of the Aethalometer.
3. Put a small amount of grease on the cotton swab.
4. Apply the grease on all three sliders (vertical shafts) of the optical chamber (see below). Try to apply the grease uniformly over the whole length of the sliders.

5. Grasp the optical chamber with thumb and fingers on both sides, and move it up and down against its springs several times. This will distribute the grease over the full range of the sliders.

7. Troubleshooting

If there is an error code on the startup screen, refer to Section 13 of the manual for an extensive list of codes. Identify the code and problem from the list. Then, call STI.

8. Maintenance Forms

8.1. Magee Aethalometer Checklist

Schedule of maintenance activities for Magee AE33 Aethalometer.

Activity	Monthly
Inspect sample line tubing.	
Visually inspect the tape, replace if necessary.	
Inspect and clean the size selective inlet.	
Inspect and clean the water trap/insect screen assembly.	
Perform leak test.	
Flow verification test.	
Activity	**Biannually**
Inspect optical chamber, clean if necessary.	
Perform clean air test.	
Perform stability test.	
Activity	**Annually**
Perform neutral density (ND) filter test.	
Lubricate optical chamber sliders.	
Change bypass cartridge filter.	

Corrective Actions for Aethalometer:

8.2. Magee Scientific Aethalometer Response Summary

DATE: ______________________________ Location: ______________________________

Clean Air Test

Start Time ______________________ End Time ______________________

Spot 1 PPBC ____________________ ng/m^3

Value less than 550 ng/m^3 ____________________ (Yes/No)

Neutral Density Filter Test

Start Time ____________________ End Time ____________________

Test Results

Channel 1	Spot 1	____________	Spot 2	____________
Channel 2	Spot 1	____________	Spot 2	____________
Channel 3	Spot 1	____________	Spot 2	____________
Channel 4	Spot 1	____________	Spot 2	____________
Channel 5	Spot 1	____________	Spot 2	____________
Channel 6	Spot 1	____________	Spot 2	____________
Channel 7	Spot 1	____________	Spot 2	____________

Values between 0.9 and 1.1 ____________________ (Yes/No)

NOTES:

Standard Operating Procedures for the Teledyne Model 640x Real-Time Continuous PM Monitor

July 31, 2024

STI-8184

Contents

1. Summary of Method

The Teledyne API Model T640x is a real-time, continuous particulate matter (PM) mass monitor that uses scattered light spectrometry; specifically, it employs broadband spectroscopy using 90° white-light scattering with a polychromatic light-emitting diode (LED).

There are two designated methods using the T640 instrumentation. The model T640 with the 640x option (i.e., the T640x) is an approved Federal Equivalent Method (FEM) for PM_{10} [EQPM-0516-239], $PM_{2.5}$ [EQPM-0516-238], and $PM_{10-2.5}$ [EQPM-0516-240] measurements. The T640x operates at a total flow rate of 16.7 liters per minute (lpm), and this Standard Operating Procedure (SOP) document focuses on this method. The model T640 is an approved FEM for $PM_{2.5}$ [EQPM-0516-236]. The T640 also measures PM_{10} and $PM_{10-2.5}$, but only the $PM_{2.5}$ fraction meets FEM requirements. The T640 operates at a total flow rate of 5.0 lpm. This SOP is based on the Environmental Protection Agency's (EPA) SOP for the Teledyne T640x.

1.1 Principles of Operation

The Model T640x PM mass monitor is an optical aerosol spectrometer that converts optical measurements to mass measurements by determining sampled particle size via scattered light at the single particle level according to Lorenz-Mie theory. Briefly, the sampling head draws in ambient air, which is dried (i.e., brought below 35% relative humidity [RH]) with the Aerosol Sample Conditioner (ASC) and moved into the optical particle sensor. There, the scattered light intensity is measured to determine particle diameter. The particles next move separately into the T-aperture through an optically differentiated measurement volume that is homogeneously illuminated with polychromatic light. The polychromatic light source, an LED, combined with a 90° scattered light detection, yields a precise and unambiguous calibration curve in the Mie range that allows particle sizes to be determined to a high level of precision.

Each particle generates a scattered light impulse that is detected at an 85° to 95° angle where amplitude (height) and signal length are measured; the amplitude of the scattered light impulse is directly related to the particle diameter. The T-aperture and simultaneous signal length measurements eliminate border zone error, which is characterized by the partial illumination of particles at the border of the measurement range.

1.2 Method Requirements

The method requirements for the T640x were published in the Federal Register in Volume 81, page 45285 on July 13, 2016, as part of the FEM designation. These requirements were published as: *''Teledyne Advanced Pollution Instrumentation Model T640 PM mass monitor with 640X option,'' continuous ambient particulate monitor operated at a volumetric flow rate of 16.67 Lpm equipped with the louvered PM10 inlet specified in 40 CFR 50 Appendix L, Figs. L–2 thru L–19, TAPI aerosol sample* *conditioner (P/N: 081040000), configured for operation with firmware version 1.0.2.126 or later, in accordance with the Teledyne Model T640 Operations Manual.*

Additional requirements of operating the method may not be explicitly included as part of the method designation; however, they would apply for consistency with standard monitoring practices and use of the data for comparison with the National Ambient Air Quality Standards (NAAQS). For example, the sample volume for the method is reported in actual conditions (local conditions; LC) for $PM_{2.5}$ and in Standard Temperature and Pressure (STP) for PM_{10}. Each of these quantities (i.e., LC and STP) is calculated using the instrument's ambient temperature and barometric sensor data.

2. Definitions

$PM_{2.5}$ is particulate matter with an aerodynamic diameter less than or equal to 2.5 µm. PM_{10} is particulate matter with an aerodynamic diameter less than or equal to 10 µm. $PM_{10\text{-}2.5}$ is coarse particulate matter with aerodynamic diameter in the range of 2.5-10 µm. Technical terms in this SOP are defined as they are introduced, and important definitions are provided in **Table 1**.

Table 1. Terms and definitions.

Term	Definition
Accuracy	The degree of agreement between an observed value and an accepted reference value; includes a combination of random error (precision) and systematic error (bias) components due to sampling and analytical operations.
Actual conditions	The actual ambient temperature and pressure of a gas at the time its volume (or volumetric flow rate) is measured.
Bias	The systematic or persistent distortion of a measurement process that causes errors in one direction.
Calibration	The act of adjusting an instrument after comparison with a standard.
Chain-of-custody	The unbroken trail of accountability that verifies the physical security of environmental samples and documented information.
Coefficient of variation	A standardized measure of dispersion of a probability distribution or frequency distribution; defined as the ratio of the standard deviation to the mean.
Downtube	The vertically oriented tube that connects the $PM_{2.5}$ sampler inlet to sampler components inside the sampler case. To check the sample flow rate, the sampler inlet is removed from the downtube and a flow rate standard is connected in its place.

Term	Definition
Flow adapter	A tight-fitting connecting device, with an isolating valve, that is inserted in place of the $PM_{2.5}$ sampler inlet on the upper end of a sampler's downtube and used to connect a flow rate calibration or audit device to check the sample flow rate. In some cases, the device may also be used for leak checks. Sometimes referred to as the flow shut-off valve.
Flow calibration device	A National Institute of Standards and Technology (NIST)-traceable flow determining apparatus (also called a flow rate standard) that is attached to the flow adapter device and used to assist in measuring and setting the volumetric flow rate of air into the sampler.
Impactor	An inertial particle-size separator. A $PM_{2.5}$ reference method sampler uses a specially shaped inlet followed by an impactor that allows only PM of well-defined size ranges to penetrate to the filter collection portion of the collector.
Leak check	A test to determine if any post-inlet air is passing through the instrument.
Off scan	When the data stream from the monitor is disabled from logging to the data system. This process is typically conducted during periods of maintenance, verifications, or calibrations.
Orifice flow rate check device	One type of flow rate calibration or check device (transfer standard), based on an established relationship between flow rate and pressure drop across the orifice plate. Orifice flow rate check devices generally make the needed temperature and pressure corrections for the user. The orifice flow rate check device most commonly used on $PM_{2.5}$ samplers may also be called a venturi.
Precision	A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions, expressed as standard deviation.
Verification	The act of checking or verifying an instrument against a standard; it does not involve adjustment of the instrument.
Zero Test	A way to check for leaks that does not involve pulling a vacuum on the system.

3. Health and Safety Warnings

To avoid damage to the monitor, ensure that the AC power voltage matches the voltage indicated on the monitor's model/specifications label located on the rear panel before plugging the T640x into line power. High voltages are present inside the instrument. Ensure that the power cord being used is capable of carrying the power rating of the instrument (see the rear panel label). Note:

- The power connection must have a functioning ground connection.

- Do not defeat the ground wire on the power plug.
- Turn off instrument power before disconnecting or connecting electrical subassemblies.
- Do not operate the monitor without its cover.

Some repair and troubleshooting operations need to be carried out with the monitor open and running. Use common sense when working with a running monitor. Exercise caution to avoid electrical shocks and electrostatic or mechanical damage to the monitor. Do not drop tools into the monitor or leave them behind after your procedures. Do not short or touch electric connections with metallic tools while operating inside the monitor. For monitors installed in small shelters, beware of external elements (e.g., weather conditions) when performing maintenance exposing the monitor.

4. Interferences

There are no known interferences to the collection of $PM_{2.5}$ and PM_{10} using this method; however, surface roughness and other variables do affect sizing algorithms in all light scattering instruments. Since the PM concentration output is based on a calculation using the last 10 min of data, the operator should wait a minimum of 10 min after reassembly of the instrument before turning the data system to “On Scan.”

5. Equipment and Supplies

5.1 For Installation

Installation requires hand tools (flat blade screw driver, and adjustable wrench) and silicone sealant. Most shelters have the necessary roof perforation needed. If not, it may be necessary to work with the shelter manufacturer on the appropriate method for making the perforation. Most of the routine equipment and supplies listed in Section 5.2 will be needed for the initial installation to ensure the instrument is operating properly.

5.2 For Routine Operations

The following equipment, supplies, and expendables are required for sensor checks, adjustments, and operation:

- High-efficiency particulate air (HEPA) filters (×2) configured with an adapter to connect to the downtube for Zero Testing.

- Auditing device (NIST-traceable pressure and temperature standard and flow standard) used for pressure, temperature, and flow verifications and calibrations. The auditing device is required to have been certified within the last 12 months.
- SpanDust™ used for verifying the photomultiplier tube (PMT)
- O-ring grease packets or tube of vacuum grease.
- Canned air for electronic use (e.g., DustOff™, BlowOff™ electronics dusters)
- Lint-free washable microfiber rags or lint-free disposable wipes
- Distilled water in a spray bottle
- Mild detergent
- Swagelok® Cap for ¼" tubing
- Allen wrench
- Philips screwdriver
- Cleaning brushes
- Cotton-tipped applicators
- Pull rope assembly (used for pulling cleaning rags or a tube brush through the inlet tube)
- Disposable Filter Units (DFUs)
- USB flash memory drive (for firmware updates [when necessary] and manual data downloads)

6. Procedures

6.1 Operation

Sampling begins upon startup. Allow a minimum of a 10-min warming period for reliable readings. Doing so allows the temperature of the LED to stabilize.

6.2 Maintenance and Service

6.2.1 Maintenance Schedule

As a part of routine system management, preventive maintenance includes inspections, cleaning, verifications, and calibrations. **Table 2** provides a list of actions and their frequencies. Section 5.2 of the instrument manual describes the procedures.

Table 2. T640x maintenance and quality control (QC) check schedule.

Maintenance or Check Action	Tolerance	Frequency
Check pump performance	PWM[1] value < 80% PID[1] value < 85%	Monthly
Check for leaks with zero filter	Acceptance criterion is 0.0–0.3 $\mu g/m^3$ Action level is 0.1-0.3 $\mu g/m^3$	Monthly
Clean inlet	NA	Quarterly
Clean PM_{10} well	NA	Monthly
Check/adjust PMT with SpanDust™ 1.28 (measured peak, limit value displayed on bottle ± 0.5)	Stated value on SpanDust™ bottle + 0.5 (e.g., 11.3 with a tolerance of 10.8-11.8)	Monthly at + 0.5. Avoid over performing this procedure. If problems persist, wait 10 min and retry.
Ambient pressure	+ 10 mmHg	Monthly
Ambient temperature	+ 2°C	Monthly
Flow rate verifications		
Total flow: 16.67 lpm	+ 5% of standard compared to current reading on T640x. (e.g., 15.87-17.54 lpm if T640x reads 16.7).	Monthly
Sample flow: 5.0 lpm	+ 5% of standard compared to current reading on T640x; (e.g., 4.75-5.25 lpm if T640x reads 5.00).	Monthly
Bypass flow: 11.67 lpm	+ 5% of standard compared to reading on T640x; (e.g., 11.12-12.29 lpm if T640x reads 11.7).	As needed if total or sample flow does not meet the criterion. Use same tolerance as total and sample flow.
Inspect and clean optical chamber and relative humidity/temperature (RH/T) sensors	NA	Every six months or as needed (e.g., high dust load).
Change DFU for 5.0-lpm sample flow and 11.67-lpm bypass flow (if installed)	NA	Annually or when pump PWM value approaches 80%.
Inspect inner and outer sample	NA	Monthly or as needed.

[1] Pulse width modulation (PWM); proportional, integral, differential (PID) loop

6.3 Maintenance Procedures

This section outlines cleaning and maintenance information for the inlets and filters. Always allow at least 10 min of operation after a procedure to ensure reliable operation.

6.3.1 Cleaning the T640x Inlet

When cleaning the T640x inlet (shown in **Figure 1**), ensure data are "Off Scan."

1. Power off the pumps from the Setup>Vars>Pump Control menu. Pump choices are auto, off, and cleaning cycle. Press 'edit' and then 'off' to turn off the pumps.
2. Remove the sampling inlet from the downtube.
3. Place flow audit adapter or HEPA filter on downtube to minimize dust entering the monitor.
4. Disassemble the sampling inlet (four screws on the underside of inlet base plate).
5. Carefully and thoroughly remove any dust from inside the inlet.
6. Remove any insects or other debris from the filtering screen.
7. Clean all the components using water and a mild detergent, if necessary.
8. Dry all components thoroughly with a clean cloth and blow canned air through the nozzles.
9. Check and, if needed, replace the O-rings located on the outside and the inside of the base plate and grease them with vacuum grease.
10. Re-assemble the sampling inlet, sliding the baseplate back into the base of the inlet body, making sure to line it up with the screw holes. The screws should be put back in to hand-tight pressure.
11. Reconnect the sampling line.
12. Power up the pumps from the Setup>Vars>Pump Control menu. Press 'edit' and then 'auto' to turn the pumps back on. Allow 10 min for the system to return to reliable operation. Ensure the data acquisition system is reengaged.

This procedure should be repeated per the schedule outlined in **Table 2**.

Figure 1. PM_{10} inlet.

6.3.2 Cleaning the PM_{10} Well

For this procedure, ensure data are "Off Scan."

1. Power off the pumps from the Setup>Vars>Pump Control menu. Pump choices are auto, off, and cleaning cycle. Press 'edit' and then 'off' to turn off the pumps.
2. Remove the sampling inlet from the downtube.
3. Unscrew the top of sampling inlet from the base of the inlet to expose the PM_{10} well.
4. Using a moist, lint-free towel or wipe, clean the inside base of the PM_{10} well.
5. Using cotton-tipped applicator (or similar), saturate the tip of the applicator with deionized water and clean out each of the three nozzles in the PM_{10} well.
6. Carefully inspect and remove any insects or spider webs. If there is a spider web present, make note of it on the "Monthly QC and Maintenance Checklist" sheet.
7. If needed, dry all components thoroughly with a clean cloth.
8. Blow canned air through the three nozzles.
9. Inspect and clean, as necessary, the bottom connection of the downtube with a lint-free towel or wipe.
10. Inspect and clean the water collector if any debris or water are present.
11. Check and, if needed, replace the O-rings located on the outside and the inside of the base plate, and grease them with vacuum grease.

12. Carefully re-assemble the top and base of the sampling inlet, but do not overtighten them.
13. Reconnect the sampling line.
14. Power up the pumps from the Setup>Vars>Pump Control menu. Press 'edit' and then 'auto' to turn the pumps back on. Allow 10 min for the system to return to reliable operation. Ensure the data acquisition system is reengaged.

This procedure should be repeated per the schedule outlined in Table 2.

6.3.3 Changing the Disposable Filter Units (DFUs)

There are two DFUs on the T640x, one internal filter for the 5.0-lpm pump and one external filter for the 11.67-lpm pump. If changing one filter, it is recommended that the other filter also be changed. For this procedure, ensure data are "Off Scan."

Internal Pump Filter:

1. Power off the internal pump from the control menu: Setup>Vars>Pump>Edit>Off>Done.
2. Remove screws at sides of front panel, if installed.
3. Pull open the instrument's front panel using the front panel finger grips (**Figure 3**).
4. Write "New" and today's date on the filter with a sharpie (recommended).

Figure 2. Disposable filter unit.

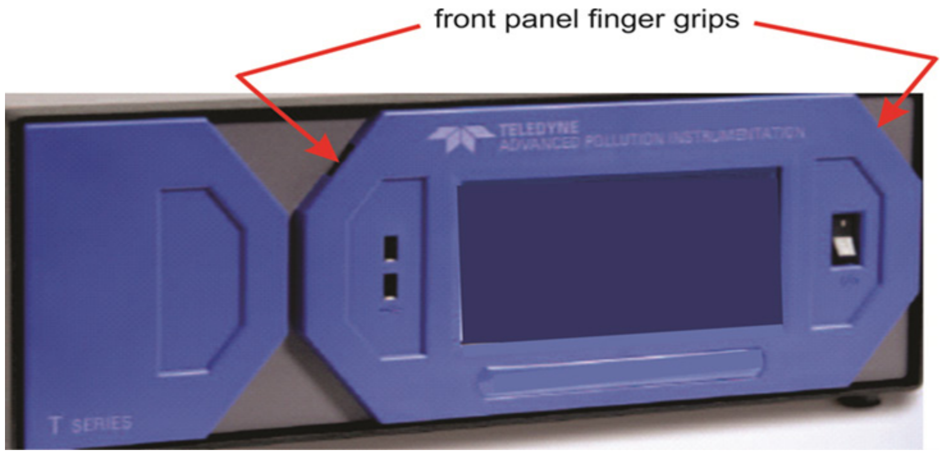


Figure 3. Opening the front panel.

5. Noting its orientation, remove the old DFU by detaching it from the pneumatic quick-connect fittings, and replace it with a new DFU in the same orientation (**Figure 4**).

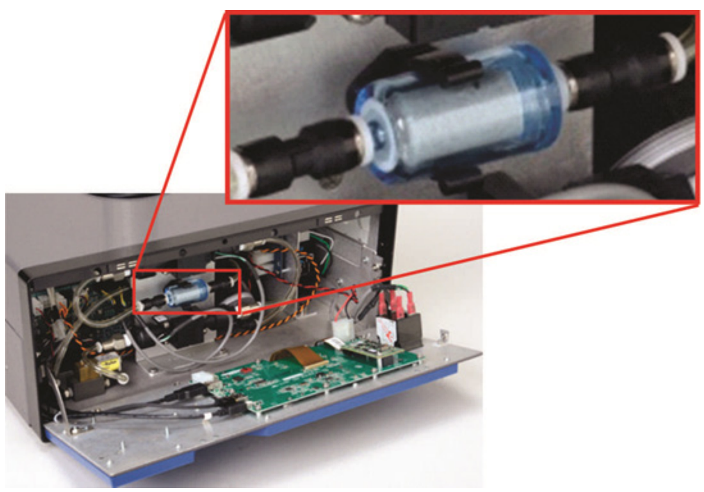


Figure 4. Internal DFU.

6. Power on the internal pump from the control menu: Setup>Vars>Pump>Edit>Auto>Done.
7. Review the internal pump flow in the Dashboard (>Main Menu>Home>Dashboard) or home screen to ensure the 5.00-lpm flow is reading as expected.

External Pump Filter:

8. Unplug or turn off electrical switch, if available, to the external pump (operates at 11.67 lpm).
9. Write "New" and today's date on the filter with a sharpie (recommended).
10. Noting its orientation at the back of instrument, detach the filter from the quick-connect fittings and replace it with new filter (**Figure 5**).

11. Ensure the filter is seated snugly with no gaps.
12. Plug the bypass pump electrical cord back in or otherwise turn on the pump.
13. Review the internal pump flow in the Dashboard (>Main Menu > Home >Dashboard) or home screen to ensure the 11.67-lpm flow is reading as expected.
14. Allow 10 min for the system to return to reliable operation. Ensure the data acquisition system is reengaged.

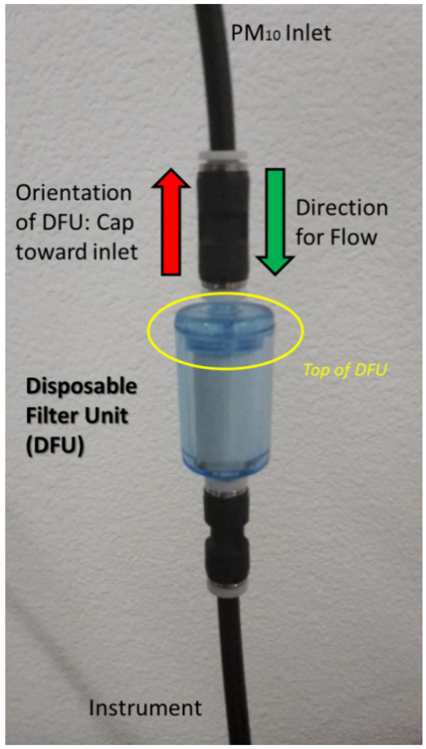


Figure 5. External DFU.

6.3.4 Checking Pump Performance

There are two pumps associated with the T640x. One pump is internal (operating at 5.0 lpm). The second pump is external (operating at 11.67 lpm). The 5.00-lpm pump must maintain proper flow for measurement accuracy; the combined flow of the internal and external pumps (i.e., 16.67 lpm) ensures that the PM_{10} inlet is operating at its designed flow for a PM_{10} cut-point. Check performance levels in the Dashboard (If these parameters are not found in the Dashboard, configure the Dashboard to add them; see Section 3.1.9 of the T640 User Manual).

- Pump PWM should be running between 35% and 80%.
- Valve PWM should be running between 35% and 85%.

If the performance levels are out of range, refer to **Table 3** in Section 6.6 for troubleshooting guidance.

6.3.5 Checking the Flows

Check the Sample Flow levels in the Dashboard. If not found in the Dashboard, add it through the Dashboard configuration page; see Section 3.1.9 of the T640 User Manual. If out of range (outside of 16.67 + 0.83 lpm for total flow and 5.00 + 0.25 lpm for sample flow), refer to **Table 3** in Section 6.6 for troubleshooting guidance.

For the T640x, also check the Bypass Flow levels in the Dashboard. (If not found in the Dashboard, add it through the Dashboard configuration page; see Section 3.1.9 of the T640 User Manual). If out of range (outside of 11.67 + 0.58 lpm), refer to **Table 3** in Section 6.6 for troubleshooting guidance.

6.3.6 Cleaning the Optical Chamber and the RH/T Sensor

The optical chamber and sample lines connecting to the chamber should be cleaned at least every 6 months, and more often if issues are suspected; however, cleaning can be a somewhat tedious procedure, especially for installations in small shelters located outside. Before starting, carefully consider and plan for an appropriate amount of time to perform this procedure, including disassembly and reassembly, as well as all associated verifications and calibrations. For outdoor shelters, additionally consider if any precipitation or extreme weather is forecasted. Up to 4 hr may be necessary to fully complete the procedure for outside installations; up to 2 hr may be required for indoor installations when using a slip coupler. It is highly recommended to take a few photos with a smart phone or similar device prior to disconnecting any of the sample lines inside the monitor.

Figure 6. Bypass connection to top of ASC.

For this procedure, ensure data are "Off Scan."

1. Power down the monitor and unplug it.
2. Power down the bypass pump.
3. Disconnect the ASC power line from the back of the instrument.
4. Disconnect the bypass flow line from top of ASC using a 9/16" wrench (**Figure 6**).
5. Adjust the slip coupler and move the monitor to the side so that there is enough room for ASC to be removed (see procedure 6.4.2).
6. Remove and clean both the extension tube and upper inlet tube that sit directly above the ASC (**Figure 24** in Section 9).

7. Remove the ASC by carefully lifting up the monitor chassis.
8. Remove and clean the aluminum adapter (**Figure 22** in Section 9) that fits over the black inlet nozzle. Check the O-ring that sits on the adapter for cracks or breaks; clean and/or replace as necessary.
9. Remove and clean the black inlet nozzle (**Figure 21** in Section 9) sample tube that fits on top of the optical cell.
10. Unscrew the monitor lid (it may have four screws, two on each side) and lift the lid off of the monitor chassis.
11. Take photos of the sample line connections with a smart phone or similar device. Then disconnect the sample lines leading to the components on the ASC support.
12. Remove the ASC support, which straddles the sensors. Four screws secure that support to the floor of the instrument, two on each footing (**Figure 7**). Note: it is possible to clean the optics without removing the ASC support; however, removing the ASC support will allow more room to access the tubing lines and optical chamber.

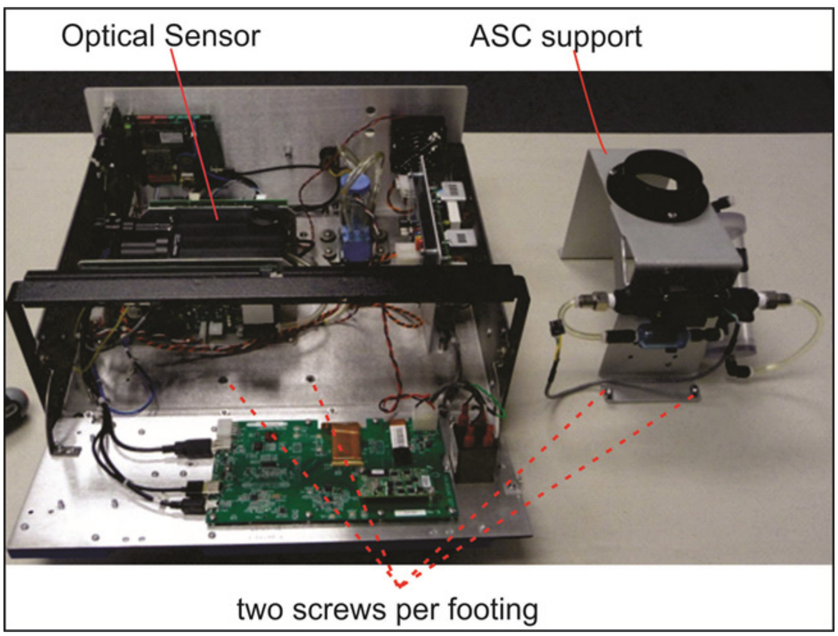


Figure 7. Maintenance of the optical chamber and RH/T sensor access.

13. Locate the optical cell, the cup at the bottom of optics chamber and its tubing, and the RH/T sensor (**Figure 8**).

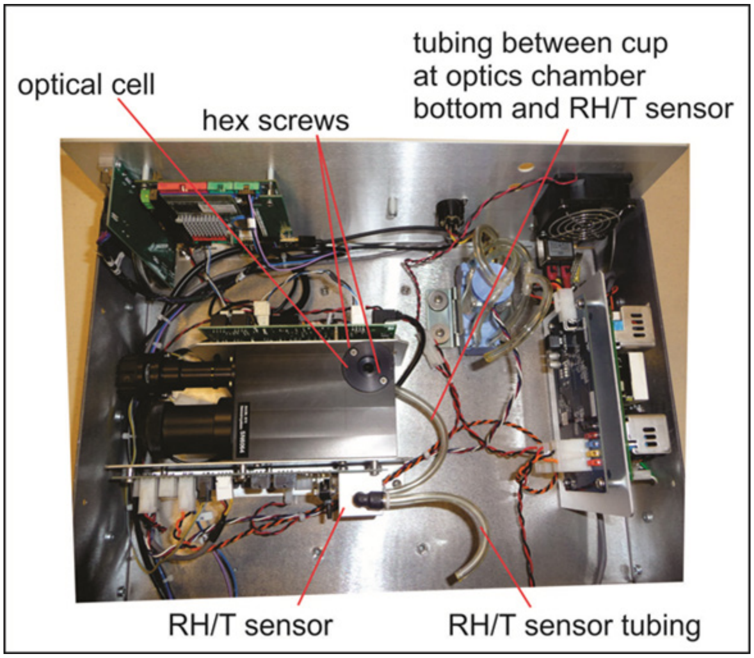


Figure 8. Maintenance: location of the optics chamber and RH/T sensor.

14. Remove the optical cell from the optics chamber and remove the cup, including its tubing, from the bottom of the optics chamber; detach the RH/T sensor tubing from the DFU filter (**Figure 9**). It is very important that all components are disassembled before blowing air into the chamber.

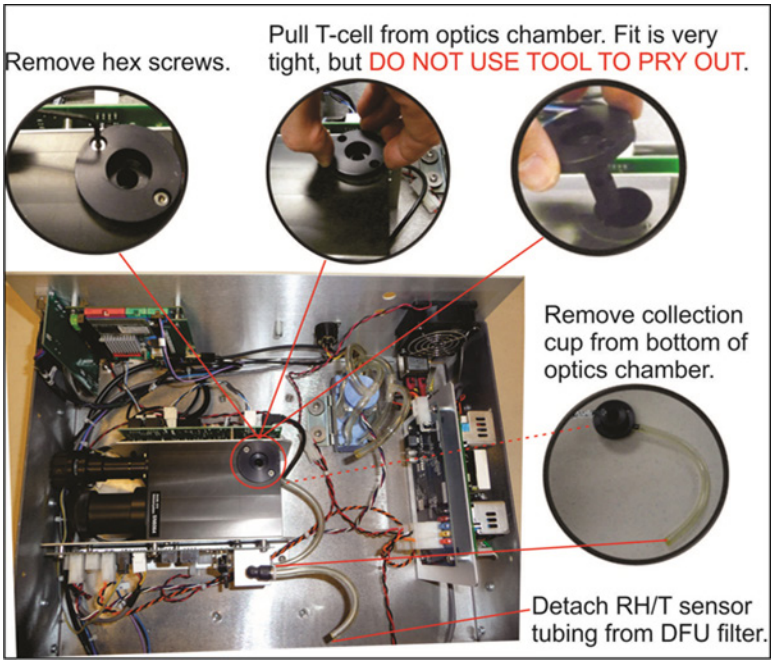


Figure 9. Maintenance: Optical Chamber Disassembly

15. Clean the optics chamber interior surfaces, including the windows, with a lint-free cloth (**Figure 10**).

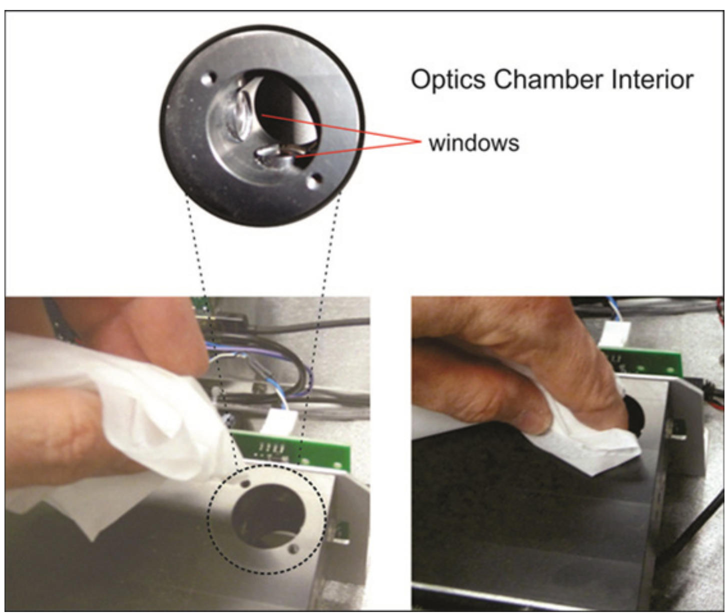


Figure 10. Maintenance: optics chamber windows.

16. Use canned air made specifically for dusting electronics to blow dust and other debris from the optics chamber, the cup, the bottom of the optics chamber, and the tubing (**Figure 11**).

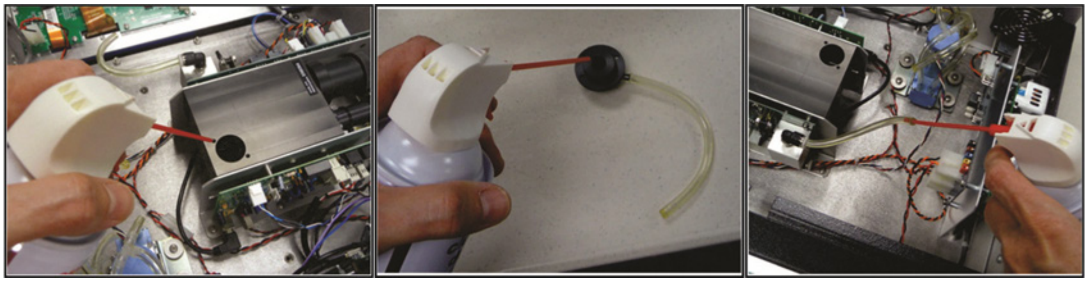


Figure 11. Maintenance: final dusting.

17. Reassemble the optics chamber components; reinsert the cup on the bottom of the optics chamber; reconnect the tubing from the cup in the bottom of the chamber to the RH/T sensor and from the RH/T sensor to the DFU filter, reinstall the ASC support, re-connect all power and flow lines, and move monitor back in line so that the slip coupler can be reconnected.
18. Close the instrument and power on both the bypass pump and monitor.
19. Perform a Zero Test (**Section 6.4.1**).
20. Perform a PMT sensor check with SpanDust™ (**Section 6.4.5**).

6.3.7 Inspecting the Sample Tubes

Look inside the sample tubes for debris or dust on the walls. If needed, push a rag or a paper towel through the tubes; then use canned air made specifically for electronics to blow through the line for a final cleaning. However, do not completely block a sample tube still under vacuum; the sample flows should never be blocked while the unit is still operating.

6.4 Instrument Verifications

Five basic verification checks are listed below. All verifications should be conducted first before any calibrations, and then calibrations can be conducted when necessary (**Section 6.5**). Verifications are conducted before calibrations; it is necessary to document the "as-found" conditions of the instrument. Three of the verifications can be calibrated, if necessary. There is no adjustment for either the Zero Test or ambient temperature and as such failure of one or both of these checks results in the need to troubleshoot rather than adjust a setting. Also, the procedure calls to verify the total flow (16.67 lpm) and then the sample flow (5.0 lpm); however, the total flow cannot by itself be calibrated. If the total flow does not meet its required tolerance, the sample flow and bypass flow can be calibrated, if necessary. The five checks should always be performed in the specific order listed below:

1. Zero Test;
2. Pressure sensor verification;
3. Temperature sensor verification;
4. Flow sensor verifications;
5. PMT verification using SpanDust™.

Once all verifications are completed, calibrations may be conducted (Section 6.5) for pressure, flow, and the PMT. For the Pressure Cal and the two Flow Cal menus, note that the "Measured" parameter provides the value measured by the T640x and the "Actual" parameter is the value that is to be input from the reading measured by the external auditing device.

6.4.1 Zero Test

The internal components of the T640x are not meant to be under strict vacuum (i.e., what would normally be done in a leak test). To avoid damaging internal components, the inlet should never be capped (air tight) while the instrument pumps are running.

The Zero Test is a way to check for leaks that do not involve pulling a vacuum on the system. Note: no adjustment is made if the Zero Test is not acceptable; instead, troubleshoot the instrument until the issue is resolved. For this procedure, ensure data are "Off Scan."

1. Remove the inlet and fit a HEPA filter to the sample port. Ensure the tubing is not kinked.
2. Observe the PM values on the front panel display. Press either "Home" or the  key.
3. Within approximately 10 min, the PM values should be at zero (0.0) for each PM metric. If the data reach 0.0, accept the zero test and move to Step 5. If the data are in the range of 0.1-0.3, accept the data and troubleshoot. If after 10 min the data are still at 0.4 or greater, identify the data as suspect on the Monthly QC and Maintenance Sheet and troubleshoot. If the PM values are not reading zero, then one of two issues is likely:
    a. There may be a leak in the system above the optical sensor (i.e., from the optical sensor nozzle up to where the HEPA filter was fitted). Troubleshoot by checking each connection between the monitor and HEPA filter and ensuring there is a good seal.
    b. It is possible the HEPA filter is either bad or leaking. It is recommended having a second filter handy to check.
4. If values do not reach zero (0.0) within 10 min of an adjustment, troubleshoot and repeat the steps above.

5. Once PM values reach zero (0.0) for each PM metric, disconnect the HEPA filter.
6. Record all actions and readings on the Monthly QC and Maintenance Sheet.

6.4.2 Alternative Procedure for Walk-In Shelters

For walk-in shelter installations, a single operator will be challenged to review the data on the front panel of the monitor while performing QC verifications and calibrations on a roof. Two operators could be used; however, in most cases having two people on hand is not practical. To enable verifications and calibrations for walk-in shelter applications, Teledyne has a slip coupler that can be employed to allow audit devices and SpanDust™ to be used from inside the shelter. The procedure for use of the slip coupler does not apply to Zero Tests; the HEPA filter should be installed on the downtube where the PM_{10} inlet is normally connected to the downtube on the roof. Also, the procedure for verifying ambient temperature needs to be conducted on the roof so that the routine ambient temperature probe can be checked. For all other verifications and calibrations, where necessary, the following applies to using a slip coupler. For this procedure, ensure data are "Off Scan."

1. Holding the downtube above the slip coupler with one hand, lift the slip coupler with your other hand from its current position to a height just high enough so that the slip coupler is no longer touching the aluminum downtube below (**Figure 12**). The downtube above the slip coupler should be held in a consistent vertical position so that the seal between the downtube and roof flange is maintained.

Figure 12. Slip coupler in the normal position and lifted vertically.

2. Carefully move the T640x monitor chassis and ASC away from the downtube so that there is enough clearance for the audit device to be attached. Doing so requires moving the base of the monitor (**Figure 13**).

Figure 13. Slip coupler moved to the side to allow monitor use with audit devices.

3. Detach the ambient temperature probe on the back of the monitor and temporarily attach the short cable temperature probe so that the temperature inside the shelter is being used for flow calculations.
4. Perform remaining verifications and, where applicable, calibrations. A verification of the short temperature probe is also recommended.
5. With all verifications and calibrations complete, detach the short cable temperature probe and re-attach the ambient temperature probe from the roof.
6. Align the T640x monitor chassis so that the ASC is directly below the slip coupler.
7. Holding the downtube above the slip coupler with one hand, re-engage the slip coupler back to its original position with your other hand. The downtube above the slip coupler should be held in a consistent vertical position so that the seal between the downtube and roof flange is maintained.

6.4.3 Pressure Verification

The pressure measurement of the T640x is for the ambient pressure at which the instrument is operated. No direct pneumatic connection to the instrument needs to be made to perform this check, and the data are not affected. To change pressure units to mmHg, go to Setup>Vars>Pressure Units>mmHg.

1. With the Pressure Standard operating and measuring the ambient pressure in the same room as the T640x monitor, navigate to the Pressure Cal menu: >Calibration>Pressure Cal. Alternatively, pressure can be obtained through the Dashboard on the main screen.
2. Compare the "Measured Pressure" on this screen the the Audit Pressure Standard (**Figure 14**).
3. If the two values differ by more than 10 mmHg, note this fact on the Monthly QC and Maintenance Sheet and continue with the remaining verifications.

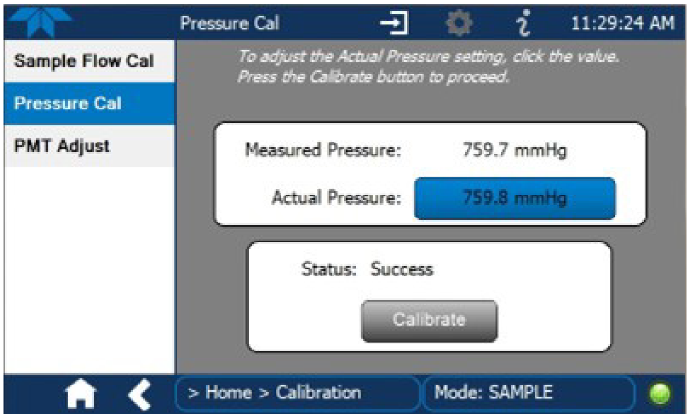


Figure 14. Pressure calibration screen.

6.4.4 Ambient Temperature Verification

The ambient temperature probe can be verified; however, there is no available way to calibrate this sensor. Temperature probes that do not meet the expected tolerance of + 2°C from a temperature standard should be inspected and cleaned. Cleaning the gill screen may also help to ensure air can pass freely to the probe. A spare temperature probe should be available in case the verification continues to fail the acceptable tolerance. The following procedure applies to a temperature verification:

Temperature verifications can be conducted either with the instrument in normal operation or with the unit operating. However, ensure data are "Off Scan."

1. Obtain the ambient temperature reading from the front panel of the T640x monitor. Alternatively, ambient temperature can be obtained through the Dashboard on the main screen.
2. Hold the temperature probe of the audit device in close proximity to the gill screen holding the ambient temperature probe of the T640x. If the monitor is in direct sun, ensure the audit probe is held behind the gill screen relative to the sun so that the gill screen casts a shadow on the audit device temperature probe.
3. Wait at least 1 min for the audit device temperature to stabilize.

4. Record the audit device ambient temperature and the T640x ambient temperature on the Monthly QC and Maintenance Sheet.
5. Compare audit temperature to the T640x ambient temperature; if the measurements are off by more than + 2°C, troubleshoot and repeat.
6. If verification cannot meet tolerance, replace the temperature probe.

6.4.5 Total Flow (16.67 lpm) and Sample Flow (5.0 lpm) Verification

Flow verifications for total flow (16.7 lpm) and sample flow (5.0 lpm) can be conducted with the instrument operating normally so long as the data are "Off Scan." Although this section pertains to verifications, the information available in the flow calibration screen may also be useful for verifications. The flow calibration screens can be accessed at: >Calibration>Sample Flow Cal and >Calibration>Bypass Flow Cal. The flow calibrations procedures are detailed in **Section 6.5.2**.

The flow verifications and calibrations should be conducted in the following order:

1. Verify the total flow: 16.67 lpm.
2. Verify the sample flow: 5.00 lpm. If both the total and sample flow meet acceptable tolerances, the flow verifications and calibrations are complete.
3. If the sample flow is not acceptable, calibrate the sample flow and repeat verification of the total flow.
4. If the total flow is not acceptable and the sample flow is acceptable, calibrate the bypass flow.
5. Repeat verification of the total flow.

Verification of Total Flow (16.67 lpm). For the verification procedure, ensure data are "Off Scan."

1. Set up a NIST-traceable Flow Standard transfer device with the appropriate inlet for the flow to be calibrated.
2. Remove the inlet from Upper Inlet Tube.
3. Connect the Flow Standard to the top of the Upper Inlet Tube. Ensure the tubing connecting the inlet to the Flow Standard is not kinked.
4. With the T640x running, go to the main menu or Dashboard to review the total flow (i.e., 16.67 lpm).
5. Wait at least 1 min for the flow to restabilize.
6. Record the audit device flow and T640x total flow on the Monthly QC and Maintenance Sheet.

7. Compare the T640x total flow with the audit device flow and determine if the values differ by more than 5%, (e.g., beyond the range 15.87-17.54 lpm for the total flow if the sampler reads 16.67 lpm). Make any relevant notes on the Monthly QC and Maintenance Sheet.
8. Move on to verifying the sample flow (i.e., 5.0 lpm).

Verification of Sample Flow (5.0 lpm). For this procedure, ensure data are "Off Scan."

1. Disconnect the auxiliary flow line from the side of the ASC. Ensure the auxiliary flow line is not blocked and only pulling in ambient air.
2. Cap the Swagelok fitting on the side of the ASC.
3. Set up a NIST-traceable flow standard transfer device with the appropriate inlet for the flow to be calibrated. Ensure the audit device is appropriately sized for 5.0-lpm flow.
4. Remove the inlet from the Upper Inlet Tube.
5. Connect the Flow Standard to the top of the Upper Inlet Tube. Ensure the tubing connecting the inlet to the Flow Standard is not kinked.
6. With the T640x running, go to the Calibration>Sample Flow Cal menu. Alternatively, the sample flow can be viewed from the Dashboard.
7. Wait at least 1 min for the flow to restabilize.
8. Compare the "Measured Flow" on this screen with the Flow Standard (**Figure 15**) and determine if these values differ by more than 5% (e.g., beyond the range of 4.75-5.25 lpm for sample flow if the sampler reads 5.00 lpm).
9. If the sample flow meets the expected tolerance, the sample flow verification is complete. If the sample flow is outside of the acceptable tolerance, it is necessary to perform a sample flow calibration (Section 6.5.2).
10. Record actions and readings on the Monthly QC and Maintenance Sheet.
11. Disconnect the Swagelok cap from the ASC. Re-attach the bypass line, unless a bypass flow calibration is to be performed (descibed below).

Figure 15. Sample flow calibration screen.

Bypass flow verification and calibration (11.67 lpm), if necessary. A calibration of the bypass flow is only necessary if the total flow verification does not meet the acceptable tolerance and the sample flow has already been verified and/or calibrated. For this procedure, ensure data are "Off Scan."

1. Connect the NIST-traceable flow transfer standard device to the bypass line that was disconnected in the sample flow verification procedure outlined above. Ensure the fitting(s) connecting flow transfer standard and bypass line are secure and not leaking.
2. With the T640x running, go to the flow calibration menu: >Calibration>Bypass Flow Cal.
3. Wait a least 1 min for the flow to stabilize.
4. Compare the "Measured Flow" on this screen with the Flow Transfer Standard and determine whether the values differ by more than 5% (e.g., beyond the range of 11.12-12.29 lpm for bypass flow if sampler reads 11.67 lpm). However, values approaching the 5% tolerance level should also prompt a calibration since the bypass flow check is expected to be performed infrequently.
5. Record readings on the Monthly QC and Maintenance Sheet. If the bypass flow meets the expected tolerance, then proceed to Step 8. If sample flow is beyond the acceptable tolerance, or close to not meeting the tolerance, then proceed with Step 6 to perform a calibration of the bypass flow.
6. To calibrate the bypass flow, press the value button in the Actual Flow field, enter the value measured by the Flow Standard, and press the "Calibrate" button on this screen. The Bypass Measured Flow value should change to closely match the Actual Flow within a few seconds.

7. Record readings on the Monthly QC and Maintenance Sheet.
8. Re-attach the bypass line to the ASC.

6.4.6 PMT Verification

The Particle Sensor PMT verification uses SpanDust™, a monodisperse dust with a specific refractive index. All T640 instrument PMTs have a very specific response to this SpanDust, which allows for the sensor to be checked and adjusted in the field for drift caused by contamination of the optics. *This process is not a calibration of the optical sensor based on the mass of dust being used but simply a mechanism to check and adjust the PMT response to particles with a specific and known refractive index.*

Note: Although the PMT verification is a useful check to verify whether the performance of the monitor spectrometer is as expected, multiple checks of the PMT or individual verifications that lead to too must SpanDust™ entering the monitor optics can itself lead to poor performance of the spectrometer and/or RH sensor. Ensure that a minimum amount of SpanDust™ enters the sample tube during a verification and that repeats of verifications are kept to a minimum.

For a step-by-step demonstration of the PMT adjustment, use the QR code below to view a video by Teledyne API. Also available at: https://www.youtube.com/watch?v=pZYnXwYwtIs

For this procedure, ensure data are "Off Scan."

PMT Adjustment Video

1. Navigate to the PMT Adjust screen: >Home>Calibration>PMT Adjust.
2. Press the Start button on this screen to suspend normal data acquisition and start this adjustment process.
3. Remove the T640x sample inlet.
4. Prepare the SpanDust™ bottle by uncapping the "air intake" tubing on the cap of the bottle.
5. Place the tube from the SpanDust™ bottle into the top of the Upper Inlet Tube for the instrument.
6. Ensure that the silicone tube fits snugly inside the aluminum inlet tube; do not allow the bottle to hang. Doing so could dislodge the silicone tube from the inlet tube.
7. Gently tap the SpanDust™ bottle to barely agitate the contents just enough to allow the dust to be pulled into the sensor, and allow 30 sec for the Peak Channel reading in this screen to respond (Figure 16).
8. Record the maximum Peak Channel, PMT Setting, and Peak Channel Counts on the Monthly QC and Maintenance Sheet.

9. If the Peak Channel reading is acceptable (i.e., ± 0.5 of the SpanDust™ value stated on bottle), proceed to step 11.
10. If the Peak Channel is not acceptable, then retry one more time by pressing the Stop button, then the Start button on the T640x, then proceed with Step 7 above. If after two tries the Peak Channel is still not acceptable, move to the instrument calibration procedures described in Section 6.5.

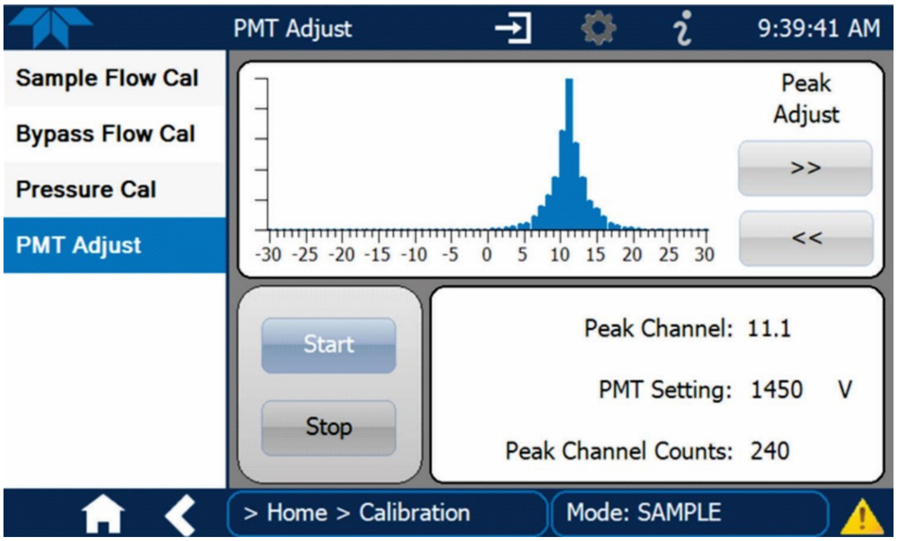


Figure 16. PMT adjust screen.

1. Re-attach the sample inlet and press the Stop button to stop the adjustment process and resume normal data acquisition.
2. Wait 10 min, review the data on the home screen, and then power the unit back "On Scan" in the data system.

6.5 Instrument Calibrations

There are three checks of the monitor that can be calibrated. These calibrations are performed after all verifications (see Section 6.4) are conducted. Calibrations only need to be performed for the checks that do not meet their expected performance criteria. The checks that can be calibrated are conducted in the following order, as necessary:

1. Pressure sensor calibration;
2. Flow sensor calibration and reverification; and
3. PMT calibration using SpanDust™.

6.5.1 Pressure Calibration

The pressure measurement of the T640x is for the ambient pressure at which the instrument is operated. No direct pneumatic connection to the instrument needs to be made to perform this calibration, and the data are not affected.

For this procedure, ensure data are "Off Scan."

1. With the Pressure Standard operating and measuring the ambient pressure in the same room as the T640x monitor, navigate to the Pressure Cal menu: >Calibration>Pressure Cal.
2. Compare the "Measured Pressure" on this screen with the Audit Pressure Standard (**Figure 17**).
3. If the two values differ by more than 10 mmHg, then press the value button in the "Actual Pressure" field, enter the value measured by the Pressure Standard and press "enter." Then press the "Calibrate" button on the screen.
4. Record pressure readings on the Monthly QC and Maintenance Sheet.

The Measured Pressure value should change to closely match the Actual Pressure within a few seconds.

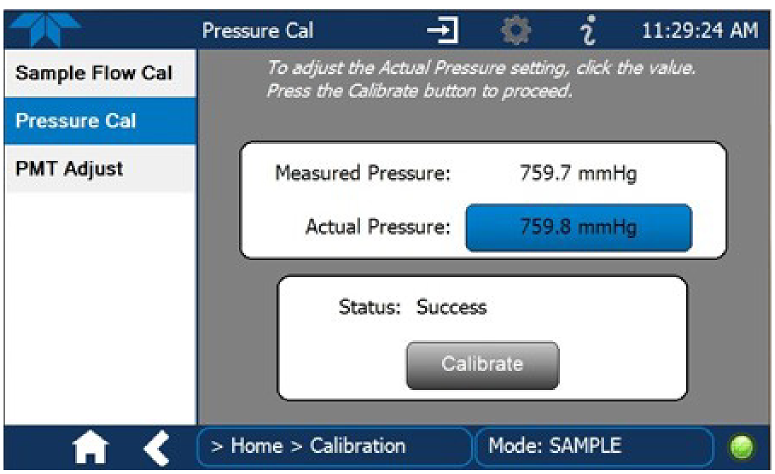


Figure 17. Pressure calibration screen. IMPORTANT: Perform this calibration prior to any flow calibration.

6.5.2 Sample Flow (5.00 lpm) and Bypass Flow (11.67 lpm) Calibrations

Flow calibrations are conducted on the sample flow (5.00 lpm) and the bypass flow (11.67 lpm) by going to the sample flow calibration menu at: >Calibration>Sample Flow Cal. Note: a calibration of total flow (16.67 lpm) is not available; instead, the sample and bypass flows are individually calibrated. Once a flow is calibrated, it should be reverified to be within a tolerance of + 2%. Total flow verification of a monitor is acceptable if within + 4% of the reading of an audit device.

Flow calibrations should be conducted after all verifications and a pressure calibration have been performed, as necessary. Conduct the flow calibrations and reverification of the flows in the following order:

1. Calibrate the sample flow (5.00 lpm);
2. Conduct sample flow (5.00 lpm) verification to ensure the monitor reading is within 2% of the audit device reading. Note: a 2% tolerance is to ensure that the flow sensor of the instrument is reading reasonably close to expected immediately following a flow calibration;
3. Calibrate bypass flow (11.67 lpm);
4. Conduct bypass flow verification to ensure the monitor reading is within 2% of the audit device reading;
5. Perform verification of total flow (16.67 lpm); see Section 6.4.5.

Calibration of Sample Flow (5.00 lpm). For this procedure, ensure data are "Off Scan."

1. Disconnect the auxiliary flow line from the side of the ASC. Ensure the auxiliary flow line is not blocked and only pulling in ambient air.
2. Cap the Swagelok fitting at the side of the ASC.
3. Set up the NIST-traceable flow standard transfer device with the appropriate inlet for the flow to be calibrated. Ensure the audit device is appropriately sized for 5.00-lpm flow.
4. Remove the inlet from the Upper Inlet Tube.
5. Connect the Flow Standard to the top of the Upper Inlet Tube. Ensure the tubing connecting the inlet to the Flow Standard is not kinked.
6. With the T640x running, go to the Calibration>Sample Flow Cal menu.
7. Wait at least 1 min for the flow to restabilize.
8. Compare the "Measured Flow" on this with to the Flow Standard (**Figure 18**) and determine whether these values differ by more than 5%, (e.g., beyond the range of 4.75-5.25 lpm for sample flow if the sampler reads 5.00 lpm).
9. Record XXX on the Monthly QC and Maintenance Sheet. If the sample flow meets the expected tolerance, then proceed to step 13 as the sample flow calibration is finished. If the sample flow is beyond the acceptable tolerance, continue with step 10 to perform a calibration of the sample flow.
10. If the sample flow is off by more than 5%, press the Start button (doing so disables the internal data logging) and then Actual Flow.

11. Enter the value measured by the Flow Standard and press "Enter" and then press the "Calibrate" button on this screen. The Measured Flow value should change to closely match the Actual Flow within a few seconds.
12. Record all flow values on the Monthly QC and Maintenance Sheet.
13. Continue reading the flow standard and ensure the standard is within 2% of the measured flow (i.e., 4.90-5.10 lpm). Record readings on the Monthly QC and Maintenance Sheet.
14. Disconnect the Swagelok cap from the ASC. Re-attach the bypass line unless a bypass flow calibration is to be performed; see below.
15. Press Stop on the sample flow calibration menu to end the sample flow calibration procedure and return to normal operation.

Figure 18. Sample flow calibration screen.

Bypass flow calibration (11.67 lpm), if necessary. A calibration of the bypass flow is only necessary if the total flow verification does not meet the acceptable tolerance and the sample flow has already been verified and/or calibrated. For this procedure, ensure data are "Off Scan."

1. Connect the NIST-traceable flow transfer standard device to the Bypass line that was disconnected in the sample flow verification procedure outlined above. Ensure the fitting(s) connecting flow transfer standard and bypass line are secure and not leaking.
2. With the T640x running, go to the flow calibration menu: >Calibration>Bypass Flow Cal.
3. Wait a least 1 min for the flow to stabilize.

4. Compare the "Measured Flow" on this screen with the Flow Transfer Standard (**Figure 19**) and determine whether these values differ by more than 5% (e.g., beyond the range of 11.12-12.29 lpm for bypass flow if sampler the reads 11.67 lpm). However, values approaching the 5% tolerance level should also prompt a calibration since the bypass flow check is expected to be performed infrequently.
5. Record flow values on the Monthly QC and Maintenance Sheet. If the bypass flow meets the expected tolerance, then proceed to Step 9. If sample flow is beyond the acceptable tolerance or close to not meeting the tolerance, then proceed with Step 6 to perform a calibration of the bypass flow.
6. If the bypass flow is off by more than 5%, press the Start button (doing so disables the internal data logging) and then Actual Flow.
7. Enter the bypass value measured by the Flow Standard and press Enter, then press the Calibrate button on this screen. The Measured Flow value should change to closely match the Actual Flow within a few seconds.
8. Record flow values on the Monthly QC and Maintenance Sheet.
9. Continue reading the flow standard and ensure the standard is within 2% of the measured flow (i.e., 11.47-11.93 lpm). Record flow values on the Monthly QC and Maintenance Sheet.
10. Re-attach the bypass line to the ASC.

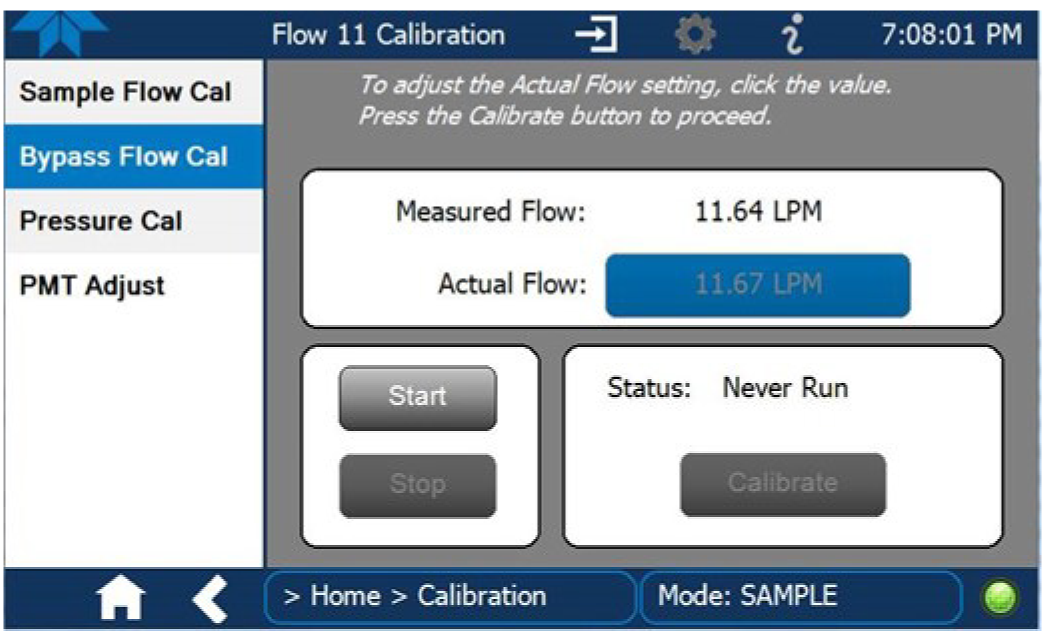


Figure 19. Bypass Flow calibration screen.

6.5.3 PMT Calibration

Once all verifications and any necessary calibrations to the pressure and flow systems are complete, an adjustment of the Particle Sensor PMT may be performed using SpanDust™. A calibration of the PMT is an adjustment in the field for drift caused by contamination of the optics. Note: Ensure that a minimum amount of SpanDust™ enters the sample tube during an adjustment of the PMT and that repeats of this calibration are kept to a minimum.

For a step-by-step demonstration of the PMT adjustment, use the QR code below to view a video by Teledyne API. Also available at: https://www.youtube.com/watch?v=pZYnXwYwtls

For this procedure, ensure data are "Off Scan."

PMT Adjustment Video

1. Navigate to the PMT Adjust screen: >Home>Calibration>PMT Adjust.
2. Press the Start button on this screen to suspend normal data acquisition and start this adjustment process.
3. Remove the T640x sample inlet.
4. Prepare the SpanDust™ bottle by uncapping the "air intake" tubing on the cap of the bottle.
5. Place the tube from the SpanDust™ bottle into the top of the Upper Inlet Tube of the instrument.
6. Ensure that the silicone tube fits snugly inside the aluminum inlet tube and do not allow the bottle to hang. Doing so could dislodge the silicone tube from the inlet tube.
7. Gently tap the SpanDust™ bottle to barely agitate the contents just enough to allow the dust to be pulled into the sensor; allow 30 sec for the Peak Channel reading in this screen to respond.
8. Record the maximum Peak Channel, PMT Setting, and Peak Channel Counts on the Monthly QC and Maintenance Sheet.
9. If the Peak Channel reading is acceptable (i.e., ± 0.5 of the SpanDust™ value stated on bottle), then proceed to step 13.
10. If the Peak Channel is not acceptable, then retry one more time by pressing the Stop button, then the Start button, and then proceed with step 7 above.
11. If after two tries the Peak Channel reading is not within ± 0.5 of the SpanDust™ value stated on bottle, then adjust the PMT Setting by pressing the Peak Adjust left (decrement) or right (increment) buttons to center the Peak voltage (Figure 20). Each press of the button corresponds to one volt.

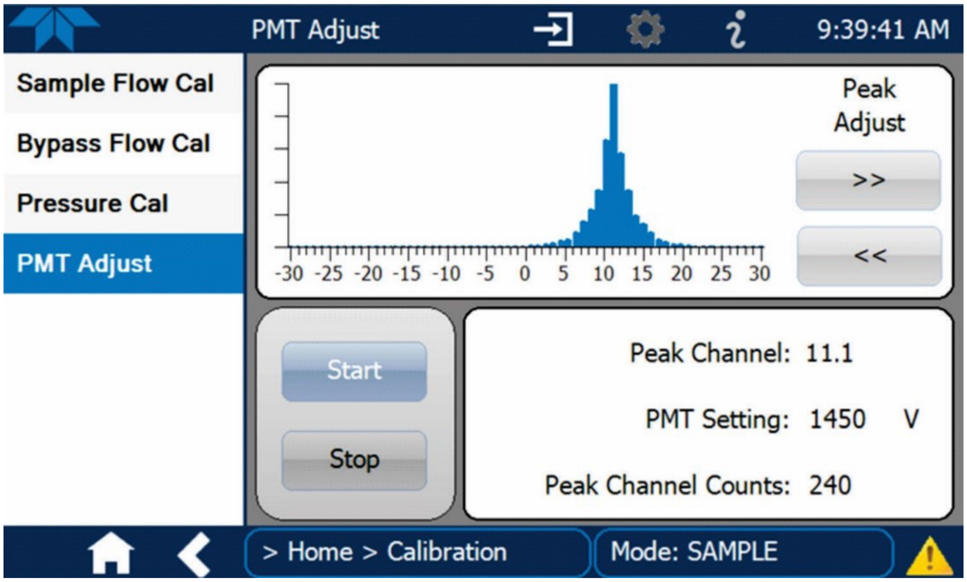


Figure 20. PMT adjust screen.

12. Allow 30 sec for the Peak Channel reading on this screen to respond. If the value is not ± 0.5 of the SpanDust™ value stated on bottle, repeat the process. This procedure can take several tries over a long period when conducted in a humid environment.
13. Once the Peak Channel reading is ± 0.5 of the SpanDust™ value stated on bottle, record readings on the Monthly QC and Maintenance Sheet.
14. Re-attach the sample inlet and press the Stop button to stop the adjustment process and resume normal data acquisition.
15. Wait 10 min, review the data on the home screen of the T640x, and then bring the unit back "On Scan" in the data system.

6.6 Troubleshooting and Service

This section provides guidance for resolving fault conditions and possible flow and calibration problems.

1. To review Alerts, select >Alerts.
2. Document any alerts, including date and time, on the Monthly QC and Maintenance Sheet.
3. To clear alerts, select the following: >Alerts>Select>Clear Selected. Then select the home button.
4. If alerts reappear, then there is something wrong that needs to be diagnosed.

6.6.1 Fault Diagnoses

The alerts log may be useful for diagnosing faults. **Table 3** lists some of the alerts that are triggered by faults, their likely causes, and possible solutions.

Table 3. Alerts and recommendations.

Message	Description	Possible Solution(s)
System Reset	Warning raised when the system is reset	Normal power cycle occurred? If not, check external power source.
Sample Flow High	The Sample Flow is greater than 5.25 lpm	Check pneumatic fittings. Re-calibrate flow.
Sample Flow Low	The Sample Flow is less than 4.75 lpm	Check pneumatics. Check for blockages. Re-calibrate flow.
Bypass Flow High	The Bypass Flow is greater than 12.25 lpm	Check pneumatic fittings. Re-calibrate flow.
Bypass Flow Low	The Bypass Flow is less than 11.08 lpm	Check pneumatics. Check for blockages. Re-calibrate flow.
Sample RH High	The Sample RH is above the set point	Check if the ASC is plugged in. Check whether the ASC control LED is illuminated on the control board. Check if water is in the sensor.
Check LED	If the LED temperature is equal to the box temperature, the LED may be OFF	Cycle power. Call Tech Support.
Check PMT	The PMT HV setting is out of range (800-2200)	Check sensor with SpanDust™. Clean the optical chamber. Call Tech Support.
Sample Flow Slope OOR	The Sample Flow Calibration Slope is Out of Range (OOR)	Check pneumatics for leaks. Rerun flow calibration. Call Tech Support.
BYPS Flow Slope OOR	The Bypass Flow Calibration Slope is Out of Range	Check pneumatics for leaks. Rerun flow calibration. Call Tech Support.

Message	Description	Possible Solution(s)
Check Int Pump	Check the internal pump if the PWM is > 80%	Check pneumatics for blockages. Check pneumatics for leaks. Check flow calibration. Replace pump.
Check Ext Pump	Check the external pump and/or bypass flow control valve if valve PID > 85%	Check pneumatics for blockages. Check pneumatics for leaks. Check external pump. Check flow calibration. External pump or bypass flow control valve may need replacing.
Sample Temp Warning	Sample Temperature Warning (>60)	Check the ASC (is it latched ON?) Ensure proper climate and ventilation for instrument.
Box Temp Warning	Box Temperature Warning (>60)	Ensure proper climate and ventilation for instrument.
AMB Press Slope OOR	Ambient Pressure Calibration Slope is Out of Range	Check calibration (make sure units match calibration device). Replace pressure sensor. Call Tech Support.

6.6.2 Flow Problems

If a flow auditing device indicates any problems with flow, check to ensure the following:

- All connections are seated tightly and evenly (no gaps);
- The inlet is not clogged or blocked;
- The pumps are running and are within their PWM range (i.e., 35% - 80%);
- The DFUs appear reasonably clean and have been changed within the last 12 months;
- The flow audit device is operating properly (e.g., the unit has been appropriately charged).

After making any adjustments, run a flow calibration and recheck the flow rate. If problems persist, contact Teledyne-API Technical Support for assistance.

7. Data Management and Records Management Parameters

7.1 Data Management

Data collected by the T640x at the monitoring site will be stored on a data acquisition system (DAS). The data can be remotely polled for upload into a centralized database. Ensure data backups are conducted on a regular basis.

The in situ DAS will be a commercially available computer-based unit capable of retrieving digital records from the station instruments via an Ethernet connection. It will store 1-minute averages from the instruments. The instrument will store approximately 1 yr of data internally, and the data can be retrieved at any time to fill in any missing data in the database due to transfer issues.

Table 4 lists the EPA's parameter, method, and unit codes for T640x and T640 data.

Table 4. Parameter, method, and unit codes.

Parameter Description	Parameter Code	Method Code for T640 at 5.00 lpm	Method Code for T640x at 16.67 lpm	Units	Unit Code
$PM_{2.5}$	88101	236	238	Micrograms/cubic meter (LC)	105
PM_{10} - LC	85101	236	239	Micrograms/cubic meter (LC)	105
$PM_{10-2.5}$ LC	86101	236	240	Micrograms/cubic meter (LC)	105
PM_{10} STP	81102	not available	239	Micrograms/cubic meter (25C)	001

7.2 Records Management

Field site visits will be stored in site log books documenting access to the monitoring sites and the key activities performed. Details on routine QC and maintenance will be recorded on the Monthly QC and Maintenance Sheet.

8. Quality Control/Quality Assurance

The instrument will be operated in accordance with the manufacturer's recommendation. The maintenance recommendations presented above, including the recommended verifications and adjustments, will be followed. Alerts (diagnostic codes) issued by the instrument will be reviewed and appropriate corrections will be initiated when indicated. The alerts will be retained as part of the instrument data. Daily review of instrument output is made to ensure operability. Data reasonableness will also be assessed to ensure instrument output is consistent with expectations for the instrument location, time of day, typical concentrations, and season.

9. Installation Instructions

9.1 Indoor/Outdoor Installation

This section presents the various connections for setup and information about preparing the instrument for operation. The T640x can be installed in an indoor or outdoor shelter with roof penetration or in an outdoor enclosure. **Section 9.2** provides step-by-step instructions for ASC connections and installation. If the instrument is being installed in a shelter with roof penetration, see **Section 9.6** for installation instructions. If the instrument is being installed in an outdoor enclosure installation, see **Section 9.7** for installation instructions.

Ensure that the rack installation provides proper ventilation clearance (minimum of 2.5 cm from the sides and top of the instrument and 10 cm from the back of the instrument) and inlet height (2 m above ground level).

9.2 Aerosol Sample Conditioner (ASC) Connections and Installation

The ASC requires an inlet nozzle and an adapter for installation. The black inlet nozzle to the optical sensor is specific to the instrument and not interchangeable with other T640x instruments. Note that the final assembly differs slightly between the T640x ASC and the T640 ASC.

1. Insert the black inlet nozzle through the center of the support collar into the top of the optical sensor, seating it tightly so that the nozzle's upper O-ring flange is flush with the upper surface of the sensor body (**Figure 21**).

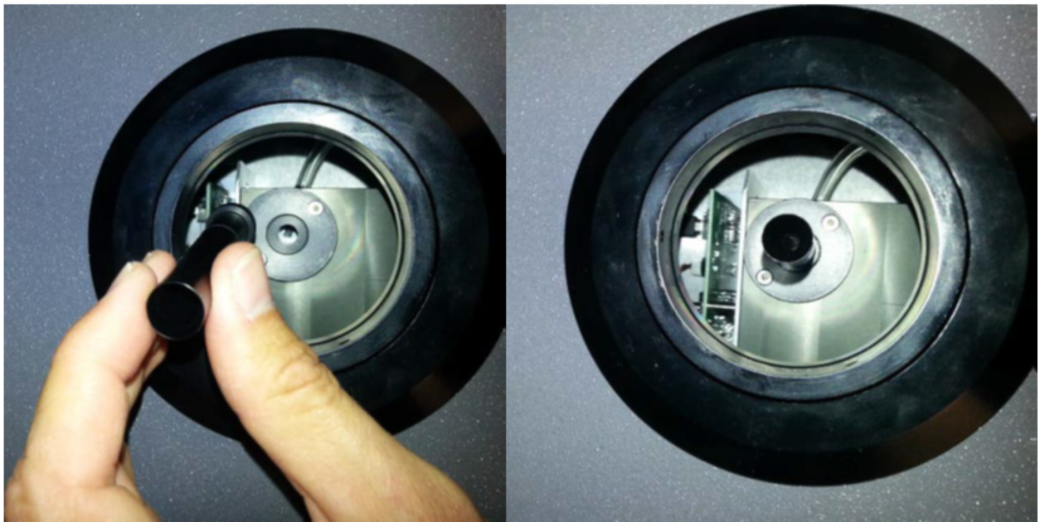


Figure 21. ASC Setup: inlet nozzle.

2. Slide the aluminum adapter over the black inlet nozzle, ensuring its base is flush with the top of the optical sensor (**Figure 22**).

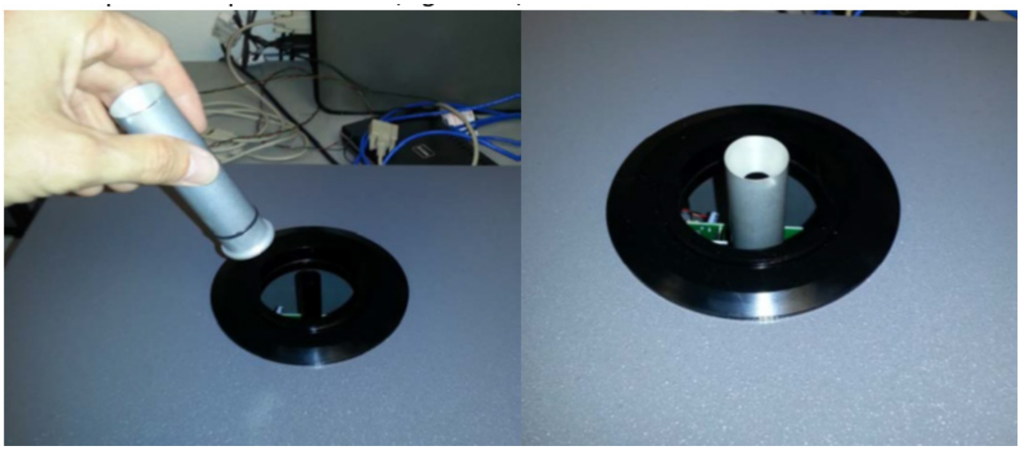


Figure 22. ASC setup: aluminum adapter.

3. Attach the water collector to the inlet (**Figure 23**).

Figure 23. Water collector attached to inlet.

4. Assemble the inlet and the ASC as shown in **Figure 24**, ensuring the parts fit snugly with no gaps. Note that if the instrument is to be installed in a shelter with roof penetration the inlet with the water collector should be left off for the time being.

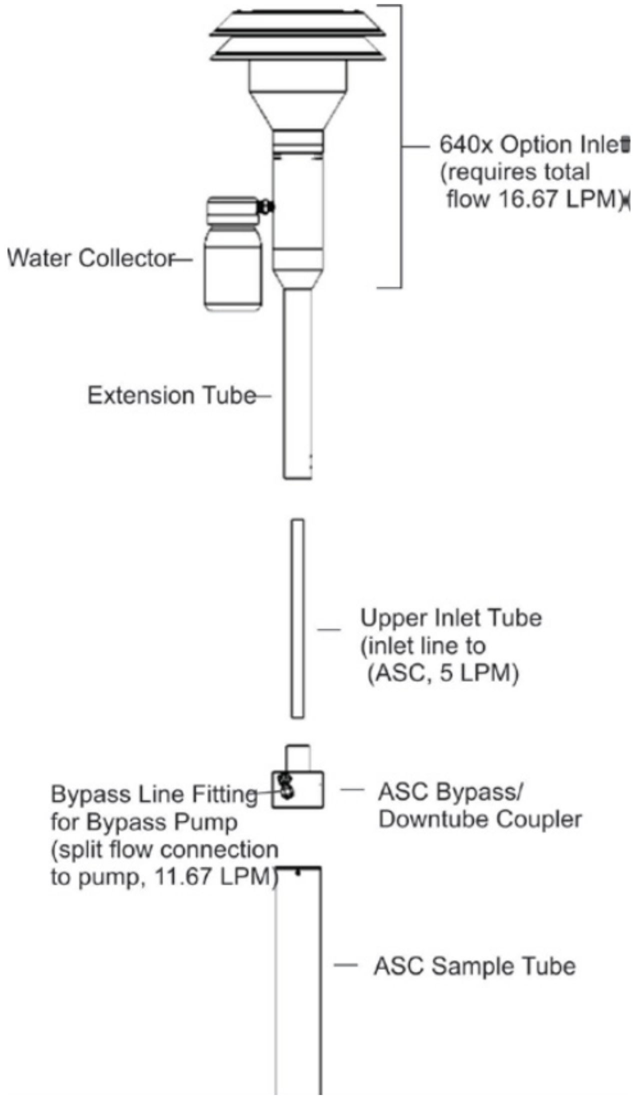


Figure 24. 640x inlet and ASC assembly.

5. Lower the ASC into the support collar, ensuring it fits straight with no gaps.
6. Plug the ASC wiring into the rear panel connector.

9.3 Temperature Probe Connection

1. Plug the ambient temperature probe connector into its respective rear panel electrical port (**Figure 25**).

Figure 25. Ambient temperature probe and ASC connections.

2. Route the probe outside and insert it into the solar shield, ensuring that the solar shield remains vertical (**Figure 26**).

Figure 26. Ambient temperature probe installed in the solar shield.

9.4 Power Connection

Adhering to any warning messages, insert the power cord between the instrument's AC power connector and a properly rated power outlet.

9.5 Communications Interface Connections

For network or Internet communication with the instrument, connect an Ethernet cable from the analyzer's rear panel Ethernet interface connector to an Ethernet port. The address settings default to automatic configuration by Dynamic Host Configuration Protocol (DHCP). Most users will want to configure the instrument with a static IP address; however, consult your network administrator to discuss other potential options. For firmware updates and data downloads, use a flash drive inserted into the front panel USB port. See Sections 3.2 and 3.1.7.3 of the T640x User Manual.

9.6 Shelter Installation with Roof Penetration

For rooftop installation instructions recommended by Teledyne API, see the video linked in the QR code below. Alternatively, you can view this video at: https://www.youtube.com/watch?v=8H5NmNgBg1M.

T640x Rooftop Installation Video

1. Determine the location where the T640x will operate in the shelter.
    a. The instrument should be in a location where the top of the ASC will be no fewer than about 60 cm from the top of the ceiling/roof line or,
    b. The instrument should be placed at a height within the shelter so that after the ASC and a 2.4-m extension sample line are installed, the inlet (on top of the 2.4-m extension sample line) is 2.0 m above the roof and equal in height with any other PM instrument inlets.
    c. Align all pieces before making any cuts in the roof.
    d. Ensure the monitor downtube is capped so that no debris enters the downtube during drilling and installation.
2. Drill a hole in the roof to accommodate the diameter of the 2.4-m extension sample line (5/8″ outside diameter).
3. Install the provided roof flange over the hole.
    a. Make sure to use good-quality roof sealant for the base of the roof flange to ensure weather tightness and to prevent any leaks.

4. Without locking it down, set up the sample line tripod so that its sample line hole aligns with the hole in the roof.
    a. The tripod should be set up at such a height to properly support the sample line with the inlet on top.
5. Without the inlet installed on the top of the ASC, line up the instrument so that the opening at the top of the ASC is in line with the sample line hole/roof flange on the shelter roof.
6. Install a slip coupler on top of the ASC.
7. Slide the 2.4-m sample line extension down through the tripod and the roof penetration until it meets the opening of the slip coupler.
    a. The sample line should be plumb to prevent any strain on the instrument and to prevent pneumatic leaks.
    b. The sample line should slide into the top of the slip coupler and bottom out when in completely. Ensure that the sample line is not pushing down on the connection inside the slip coupler such that the monitor can be moved to the side, as needed, for verifications and audits.
8. Lightly tighten the tripod cord grip and the roof flange cord grip around the sample line to hold it in place.
9. Test the slip coupler and ensure the monitor can be moved. Move back and re-connect the slip coupler.
10. At the top of the sample line (on the roof), place the provided inlet collar so that its top is roughly 7 cm from the top of the sample line. Doing so ensures proper clearance from the base of the inlet and prevents instrument flooding if the inlet were to ever get water inside of it.
11. Lock down the collar once it is determined to be at the proper spot roughly 7 cm from the top of the sample line.
12. Place the inlet on top of the sample line.
    a. Make sure the inlet is secure (i.e., that the collar holding it is not sliding).
    b. Proper installation should have the inlet 2 m above the roof.
13. Plug the ASC connector into the proper fitting on the rear panel of the T640x.
14. Connect the power cable and ambient temperature sensor at the back of the instrument.
15. Before sealing the cord grips, power up the instrument and make sure it is running properly.
16. Once the T640x instrument is determined to be installed and working properly, tighten the roof flange cord grip around the sample line.

17. Apply clear silicone caulk generously around the top end of where the cord grip rubber grommet meets the sample line to ensure a complete seal.
    a. Silicone caulk seals well and can easily be removed and reapplied if the instrument needs to be removed for servicing.
18. Additionally, tighten the tripod cord grip and lock down the feet of the tripod to fully secure the sample line.
19. Inspect the PM_{10} well to ensure it is clean.

9.7 Outdoor Enclosure Installation

1. Place the enclosure in the location where the instrument is to run.
2. Measure the distances and clearances for the location of the T640x monitor and inlet. The T640x instrument should be installed in the enclosure at a height where the inlet will be at least 2 m above ground (from ground level to the inlet height). Adjust the shelf as needed; however, do not actually locate the monitor on the shelf yet.
3. Slide the ASC up through the port of the enclosure by several centimeters above where the monitor will sit and tighten the collar over the ASC such that it is held in place. However, do not over-tighten it. The ASC must be installed from the inside of the enclosure due to the power connector on the ASC.
4. Locate the 640x monitor chassis on the shelf of the enclosure.
    a. Make sure the black inlet nozzle (Figure 21) and aluminum adapter (Figure 22) are installed on the optical sensor.
5. Once the T640x is in the enclosure and lined up with the opening on the top of the enclosure, carefully untighten the collar holding the ASC and slide it down gently until it inserts into the opening of the T640x.
    a. The ASC should go into the T640x level and be plumb. It is in completely when it i bottoms out onto the top of the optical sensor. This process can be checked by lowering the front panel of the T640x and making sure the base of the ASC is touching the top of the optical sensor flush.
6. Plug the ASC connector into the proper fitting on the rear panel of the T640x.
7. Connect the power cable and ambient temperature sensor at the back of the instrument.
8. Before sealing the collar, power up the instrument and make sure it is running properly.
9. Once the T640x instrument is determined to be installed and working properly, tighten the collar around the ASC.
10. Inspect the PM_{10} well to ensure it is clean.

11. Apply clear silicone caulk generously around the top end of where the collar rubber grommet meets the ASC to ensure a complete seal.
    a. Silicone caulk seals well and can easily be removed and reapplied if the instrument needs to be removed for servicing.

9.8 Pneumatics

Instrument pneumatics are shown in **Figures 27 and 28**.

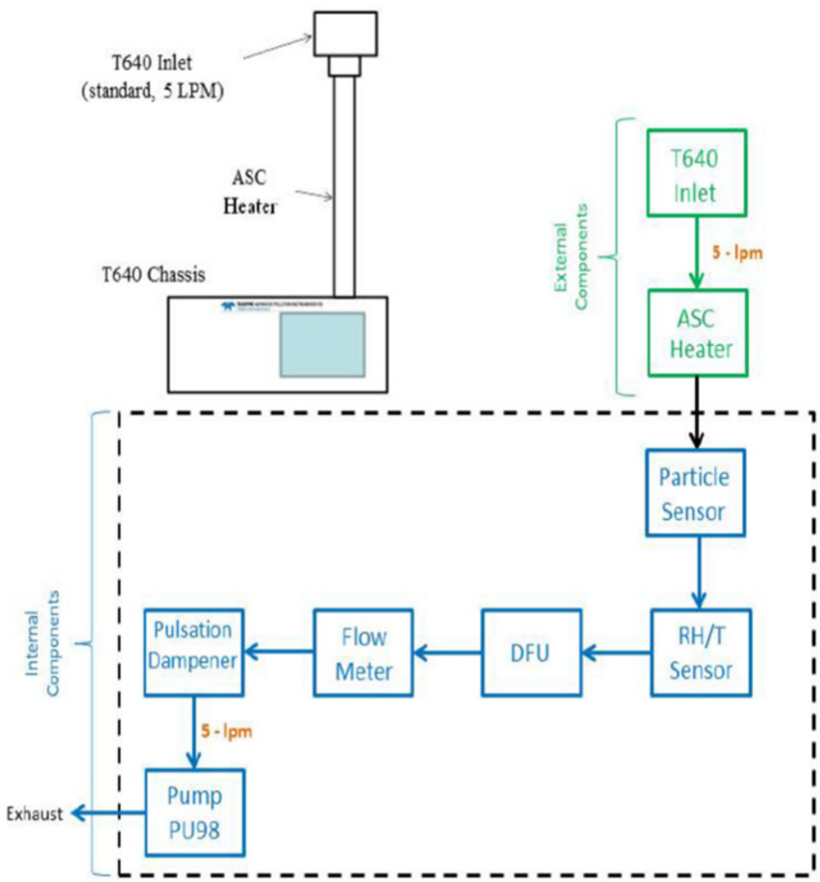


Figure 27. T640 pneumatics.

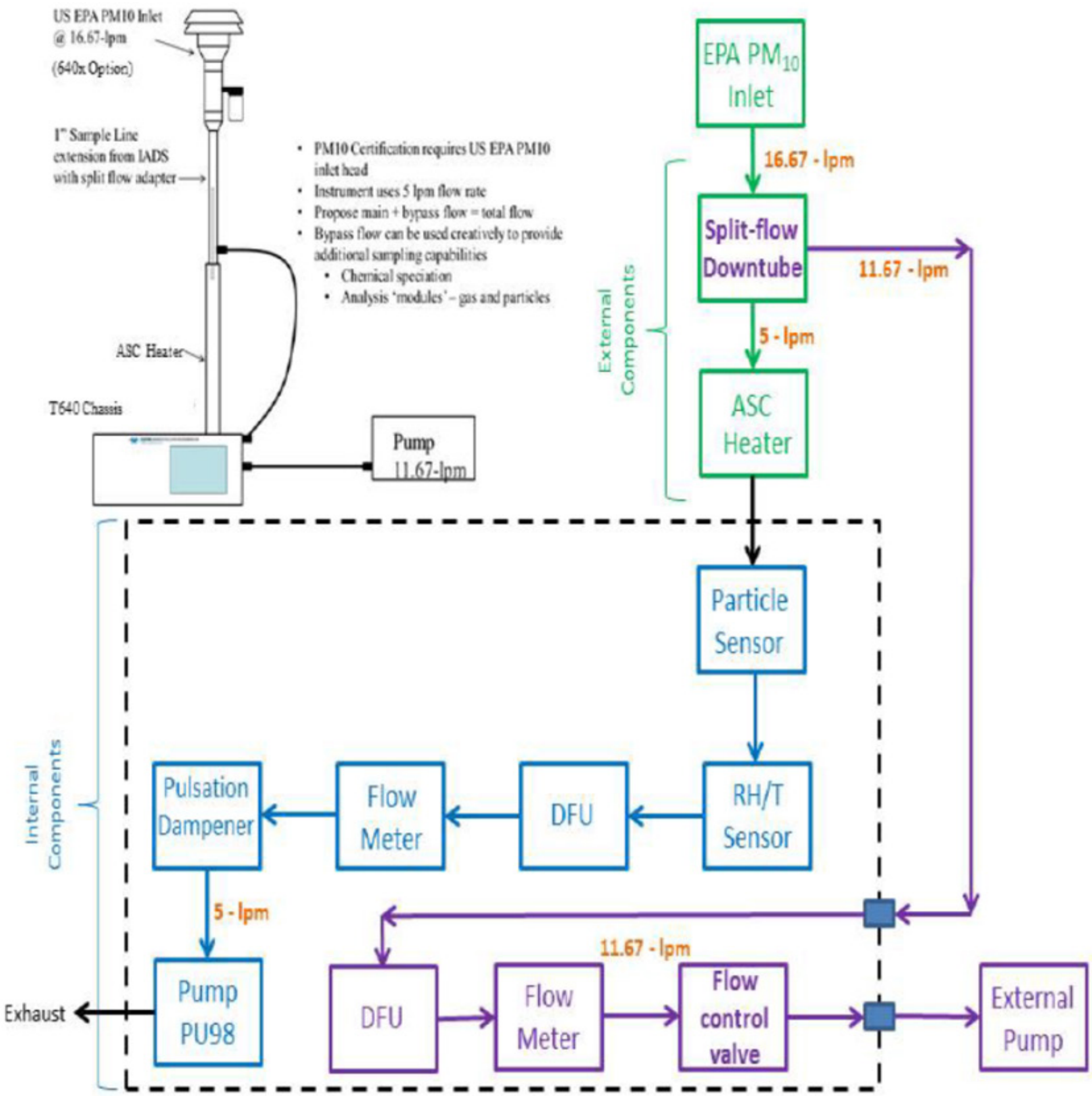


Figure 28. T640 with 640x option pneumatics.

9.9 Instrument Start-Up

With all hardware and electrical in place, power up the T640x. The monitor will take a few minutes to work through its start-up routine. Ensure the data system is not logging data at this point, except as necessary to ensure data transfer is appropriately bringing in information from the T640x. The following activities should be performed after the unit is brought on line. Note: references to the operational manual are provided, where applicable.

1. Check the firmware; upgrade firmware to the latest version, if necessary. (See Section 3.2 of the T640x User Manual).
2. Adjust the clock on the T640x to local standard time (LST). (See Section 3.1.12.2 of the T640x User Manual).
3. Select parameters to display on front panel home screen. (See Section 3.1.1 of the T640x User Manual).
    a. To select parameters, press the configuration button:
    b. Users can select whichever parameters are most important to them. Our strong recommendation is to include:
        i. Sample Flow (5.0 lpm)
        ii. Ambient Temp
        iii. Sample RH
4. Select parameters to include in the Dashboard. See the Monthly QC and Maintenance Sheet in **Section 10.0** below for recommended parameters to include. (See Section 3.1.9 of the T640 User Manual to configure the Dashboard).
5. We recommend using units of mmHg for pressure. To change pressure units to mmHg, go to Setup>Vars>Pressure Units>mmHg.
6. Conduct Instrument Verifications and Calibrations (Section 6.4).
7. Inspect the DFUs to ensure that they appear new.
8. Close the instrument front panel and inspect all connections.
9. Wait 10 min, which allows concentration data to be updated to ambient conditions.
10. Review concentration data on front panel display and ensure that all parameters appear reasonable compared with current conditions. Compare T640x data with other available data at the current site or a nearby site, if available.
11. Enable data recording to “On Scan.”
12. Document startup in the Field log book.

10. Monthly QC and Maintenance Sheet

		Order of Monthly Checks:
Station:		1. Document any alarms and then clear. 2. Record parameters as found in the Dashboard. 3. Take instrument "Off Scan" from data system. 4. Perform a Zero Test. 5. Clean the PM_{10} well. 6. Perform verifications of: a. Barometric Pressure (BP) b. Ambient Temperature (Ta) c. Total flow (16.67 lpm) d. Sample flow (5.00 lpm) e. SpanDust 7. Perform, if needed, calibrations of pressure, flow, and PMT. 8. Put the instrument back together. 9. Clear any remaining alarms. 10. Wait a minimum of 10 min to ensure PM concentrations are representative of ambient air. 11. Bring the instrument back on line to the data system.
Operator:		
Analyzer S/N:		
Date:		
Time monitor out of service (LST):		
Time monitor back in service (LST):		
Any alarms enabled? List alarm/date/time if applicable		

Parameters from Dashboard:

Amb P. (°C)		Amb T. (°C)		ASC Heater Duty	
Box T. (°C)		Current PMT HV		LED Temp. (°C)	
Package Version		PM_{10} Conc. (μg/m^3)		PM_{10} STP (μg/m^3)	
$PM_{2.5}$ Conc. (μg/m^3)		PMT Setting		Pump PWM (%)	
Sample Flow (lpm)		Sample RH (%)		Sample Temp. (°C)	
Sensor Firmware		Total Flow (lpm)		Valve PWM (%)	

QC Checks:

Audit Device:		**S/N:**		**Last Cert. Date:**	
	Verifications:		**Calibrations:**		
QC Check	**Audit Actual**	**T640x**	**Audit Actual**	**T640x**	**Tolerance**
Zero Test	NA		Re-zero if any issues found and corrected:		0.0 on each PM metric
BP					+ 10 mmHg
Ta					+ 2°C
Total Flow 16.67 lpm					+ 5% of T640 (e.g., 15.87-17.54 lpm)
Sample Flow 5.00 lpm					+ 5% of T640 (e.g., 4.75-5.25 lpm)
Bypass Flow 11.67 lpm (only as needed)					+ 5% of T640 (e.g., 11.12-12.29 lpm)
SpanDust™	Peak Ch. = PMT Setting = Peak Ch. Counts =				+ 0.5 value displayed on SpanDust™ bottle, (e.g., 11.1 or 11.3)

Additional Checks and Maintenance (less frequently than monthly):		***Date Completed***
Quarterly	1. Clean PM_{10} inlet (above the PM_{10} well)	
Every 6 Months	1. Clean Optical Chamber 2. Clean RH Sensor 3. Clean Ta Sensor	

Every 12 months or if valve or pump PWM value approaches 80%	1. New internal (5.00 lpm) DFU [inside front panel] 2. New external (11.67 lpm) DFU [at back of instrument] It is recommended to change both DFUs on the same day.	

Standard Operating Procedure for the SailBri Cooper Inc. Xact 625i

August 5, 2024

STI-8177

Contents

1. Scope and Application

This Standard Operating Procedure (SOP) document covers the use of the SailBri Cooper, Inc. (SCI) Xact 625i analyzer in a fenceline monitoring application. This document addresses routine maintenance activities including visual inspections, instrument checks, data management, quality assurance (QA) audit testing, and data validation. The maintenance forms are provided in **Section 8**.

2. Introduction and Overview

The SCI Xact 625i is a continuous ambient and fenceline multi-metals monitoring instrument that simultaneously measures up to 67 elements with atomic numbers ranging from 13 (i.e., aluminum; Al) to 92 (i.e., uranium; U). A schematic of the Xact instrument is shown in **Figure 1**. The instrument determines metal concentrations by measuring the volume of the air sampled during the sampling time and then measuring the mass of metals in the sample deposit. Metal concentrations are determined using nondestructive X-ray Fluorescence (XRF) from the particulate matter (PM) deposited on Teflon™ tape after the sampling is complete. The PM spot is then irradiated with X-rays from an X-ray tube. Upon irradiation, the various elements present in the PM will emit fluorescent light in the X-ray regime of the electromagnetic spectrum. The fluorescent X-ray light is then analyzed by a detector to determine the elemental composition based on the known fluorescent signatures of the target elements. Depending on the goals of the monitoring, the collection times can range from 5 minutes to longer (typically up to an hour). Concentrations are typically reported in nanograms per cubic meter (ng/m^3).

The purpose of field maintenance is to conduct field verification of the factory calibration of the Xact 625i and ensure that the instrument operates within its specifications.

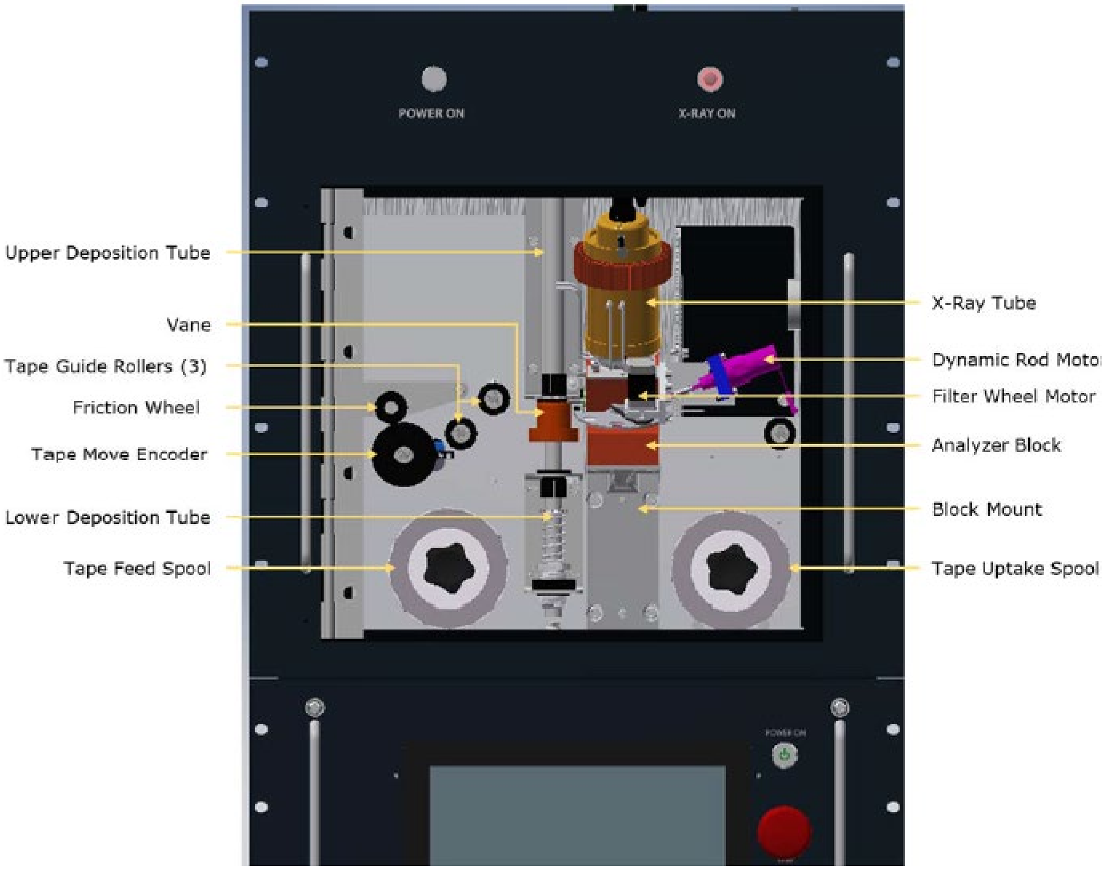


Figure 1. Schematic of the Xact 625i analyzer.

3. Definitions

Table 1. Definitions of terms and acronyms used in this document.

Term/Acronym	Definition
ADAPT	Automated Data Analysis & Plotting Toolset
ED-XRF	Energy Dispersive X-ray Fluorescence
Percent Match	The coefficient of determination multiplied by 100 (i.e., $R^2 \times 100$)
PM	Particulate Matter
PPE	Personal Protective Equipment
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SCI	SailBri Cooper, Inc. (i.e., the manufacturer of the Xact 625i)

Term/Acronym	Definition
SOP	Standard Operating Procedure
XRF	X-ray Fluorescence
XRS-FP	X-ray Spectrometry – fundamental parameter

4. Safe Work, Hazard Identification, and Precautions

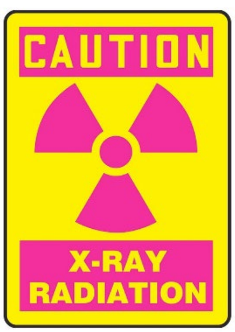
The following information is intended to provide guidance to ensuring a safe work environment.

Operator Qualifications

Operation of the Xact 625i does not require a technical background. However, operators must receive safety training, including specific training on the hazards of radiation prior to operating the instrument. Operators should undergo hands-on training provided either by SCI personnel, a distributor, or another Cooper Environmental Services (CES)-trained operator.

Work should conform to the manufacturer's guidance and job site health and safety practices.

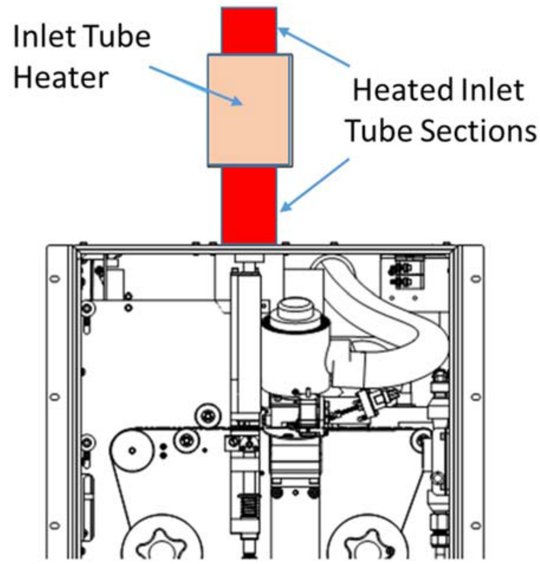
Hazard Warnings



WARNING – Any X-ray-producing equipment can be dangerous to both the operator and persons in the immediate vicinity, so safety precautions must be strictly observed. The Xact 625i is safe to use and is designed with multiple safeguards, including a removable Enable X-ray key and an emergency stop button, to prevent accidental radiation exposure. The X-ray source and detector are installed in a copper mounting block and enclosure to provide shielding from X-ray radiation. Xact 625i meets all radiation requirements for analytical X-ray equipment specified by the U.S. Food and Drug Administration (21CFR1020.40), Health Canada (CRC 1370), Health and Safety Executive (UK, ISBN 978 0 7176 1746 3), the International Atomic Energy Agency (Specific Safety Guide No. SSG-11), and the Conference of Radiation Control Program Directors (SSRCR Volume 1).

WARNING: *Temperature settings of heaters are capable of causing burn injuries. Do not touch the heaters when Xact 625i is in operation or when performing maintenance tasks immediately after sampling.*

The Xact 625i has one heater that could present a potential burn hazard. Allow sufficient cooling-down time after the instrument has stopped.



WARNING: *Voltages and currents used in electrical equipment can cause severe injury or death from electrocution. Avoid accidental contact with live circuit components.*

The Xact 625i is designed to draw up to 20 amps during normal operations. If electrical problems occur, contact an authorized distributor or SCI personnel. Do not attempt electrical repair.

Safe Operating Precautions

Do not energize the X-ray tube if the safety features of the instrument have been damaged or defeated.

Standard site Personal Protective Equipment (PPE) is appropriate. If gloves are required for work with Element Standards, nitrile or powderless latex should be used.

NOTICE

Please check off the following steps before conducting maintenance. Doing so reduces the chances of false notifications to the public and clients.

- ❐ Notify the client and project manager of maintenance tasks.
- ❐ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.
- ❐ Confirm that the data are invalidated on the public website before proceeding with maintenance.
- ❐ When maintenance is complete, check the public site for at least 15 min to ensure proper reporting (e.g., no missing data, no high values, etc.).
- ❐ Take the instrument out of maintenance mode.
- ❐ Notify the project manager and client when maintenance is complete.

5. Startup and Routine Operation

The Xact 625i starting sequence is as follows:

1. Ensure that the Xact 625i is properly installed and connected.
2. Ensure that the filter tape has been properly installed.
3. The main breaker on the back of the instrument labeled MAINS (above the power switch) should be in the ON position.
4. Flip the power switch on the back of the instrument to the ON position.
5. The power button on the front of the instrument will illuminate. This switch powers the computer and cooling fans.
6. When prompted by the Windows operating system, enter the appropriate login information. **IMPORTANT:** *Ensure that the X-ray key at the bottom right corner of Xact 625i is in the "X-ray On" position*
7. Click or tap the Xact Control icon on the instrument user interface desktop to launch the Xact Control program. Doing so will launch both the Control program and the XRS-FP program. **IMPORTANT:** *The XRS-FP program windows must remain open while the Xact Control program is running. Failure to do so can cause errors and result in the instrument functioning improperly or a system crash.*
8. If the Xact 625i has not been used within the last 24 hr, the X-ray tube must be warmed up. To warm up the X-ray tube, enter the password and navigate to the Maintenance page and click the "Warm Up" button. **IMPORTANT:** *If the Xact 625i's X-ray tube was not used within*

the last week, then tube seasoning and manual energy calibration must be performed prior to operating. Consult the Xact manual for these procedures.

9. To set the Sample Time for the Xact 625i, go to the Settings.
   a. Click “Enable Changes.”
   b. Select the desired Sample Time (i.e., 15, 30, 60, 120, 180, or 240 min).
   c. Click “Save.”
10. To set the Xact 625i to begin sampling, navigate to the home screen:
    a. Click “Status.”
    b. Click “Run.” The Status box will then turn green to indicate a successful start-up.

IMPORTANT: *When the Xact is in Run mode, the X-RAYS ON light is illuminated. The X-ray system can only function when the Xact is in Run mode and all interlocks (including the module door) are closed. X-ray analysis takes place after a sample deposit has been created. If the Xact has been started for the first time, the X-ray power will not come on until after the end of the first sample time period.*

6. Equipment and Supplies

1. Field notebook
2. All relevant PPE, hardware, and procedural guidance per SOP, Safety Plan, and Safe Work Permit/Job Safety Analysis
3. Local or remote network link device (as required)
4. Nitrile or powderless latex gloves
5. Adhesive tape for use during filter tape change
6. Leak Tester: Sample inlet ball valve included with the Xact 625i
7. A National Institute of Standards and Technology (NIST)-certified reference flow meter
8. Flexible test tubing
9. Xact 625i Calibration Guide (provided with the Xact 625i)
10. Element Standards and Standard Holder (provided with the Xact 625i)

7. Maintenance Activities

The following subsections of **Section 7** outline the routine performance indicator checks and maintenance activities to be carried out; the maintenance forms used to indicate when the checks are complete and document any corrective actions taken appear in **Section 8**. These activities are also expected, based upon the Quality Assurance Project Plan (QAPP), to be logged in a site logbook either in hard copy or electronic form; they can reference this SOP and associated forms. All QA criteria are documented in the QAPP.

The following Xact 625i maintenance activities and performance checks are recommended by the manufacturer and are discussed in the following subsections:

- Visually inspect the system
- Perform a Tape Change
- Examine the tubing, enclosure, and components for particle build-up, rust, or damage; replace parts as needed
- Perform a Leak Check
- Perform a Flow Check or Flow Calibration as needed
- Perform an XRF Calibration Check
- Perform a manual Energy Calibration
- Perform a QA Blank Check

7.1 Visual Inspections

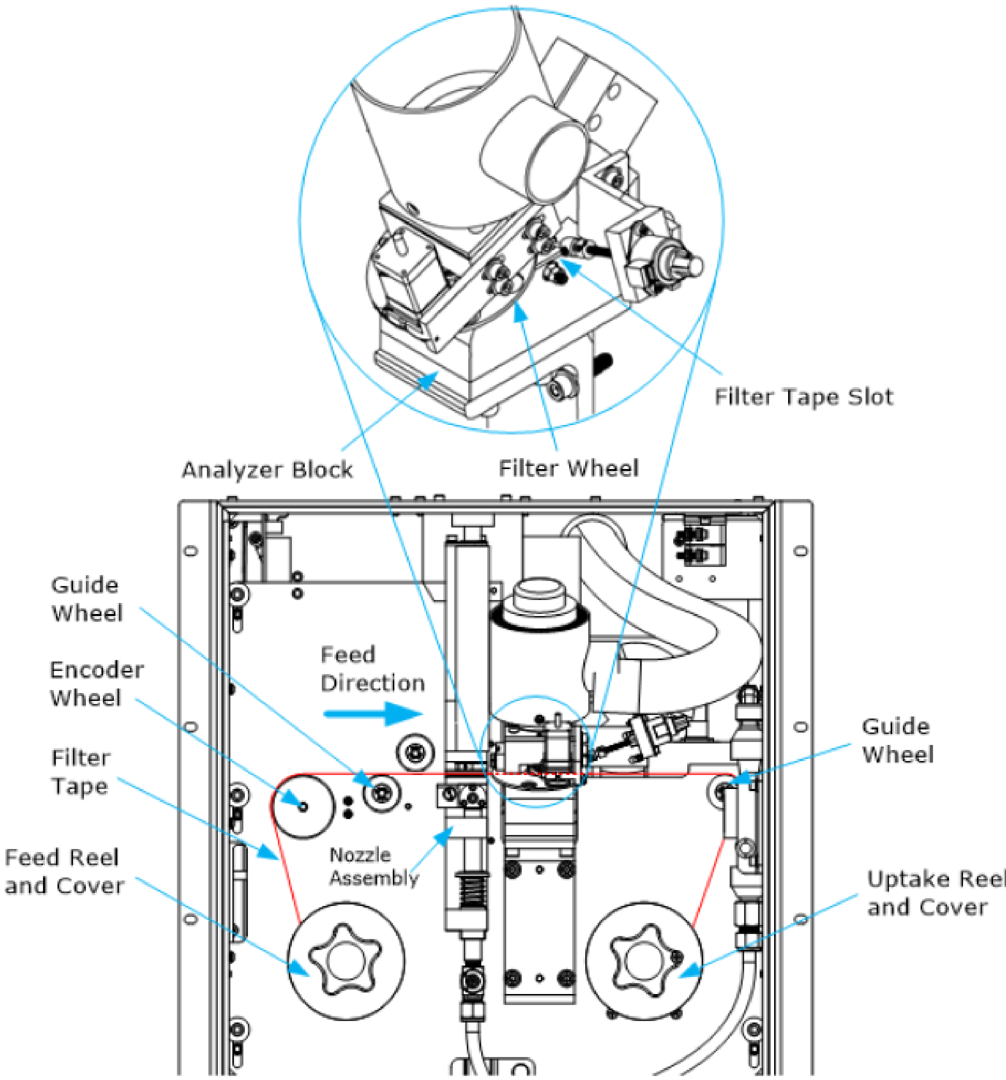
1. Ensure that the instrument is running and that the data look reasonable.
2. Clean and correct any obvious problems with the system (e.g., the presence of cobwebs, rodent nests, etc.).
3. Inspect all electrical cables for wear; replace as needed.
4. Indicate that these visual checks are complete on the form included at the end of this document.
5. Document any changes to the system in the course of these checks in the site logbook.

7.2 Tape Change

The tape change counter display will indicate when the filter tape needs to been replaced; overall, filter tape changes should occur monthly or according to the frequency of sample times listed in the following table. A filter tape change takes approximately 15 min to complete.

Sample Time (min)	Approximate Frequency of Tape
15	Once every 6 days
30	Once every 12 days
60	Once every 25 days
240	Once every 3 months

1. Before beginning tape change, ensure the Xact is in STOP mode by pressing the “STOP” button.
   a. Wait for the ‘X-ray Status’ message bar to indicate that X-ray tube is ramping down. The red X-ray light on the front door will turn off when ramp down is complete.
2. Remove the Feed and Uptake reel covers of the filter tape.



3. If there is tape remaining on the feed roll, cut the tape at the right side of the analyzer block. Wind the remaining tape on the uptake spool, and remove it before inserting a fresh roll.
4. Place the spool containing the clean tape on the feed reel.
5. Place an empty spool on the uptake reel to collect the used tape.
6. Place the filter tape from left to right along the filter wheel assembly over the feed reel, the encoder wheel, and the first guide wheel. Feed the tape through the nozzle assembly and through the tape slot under the filter wheel on the analyzer block. Then feed the tape over the second guide wheel and onto the uptake reel.

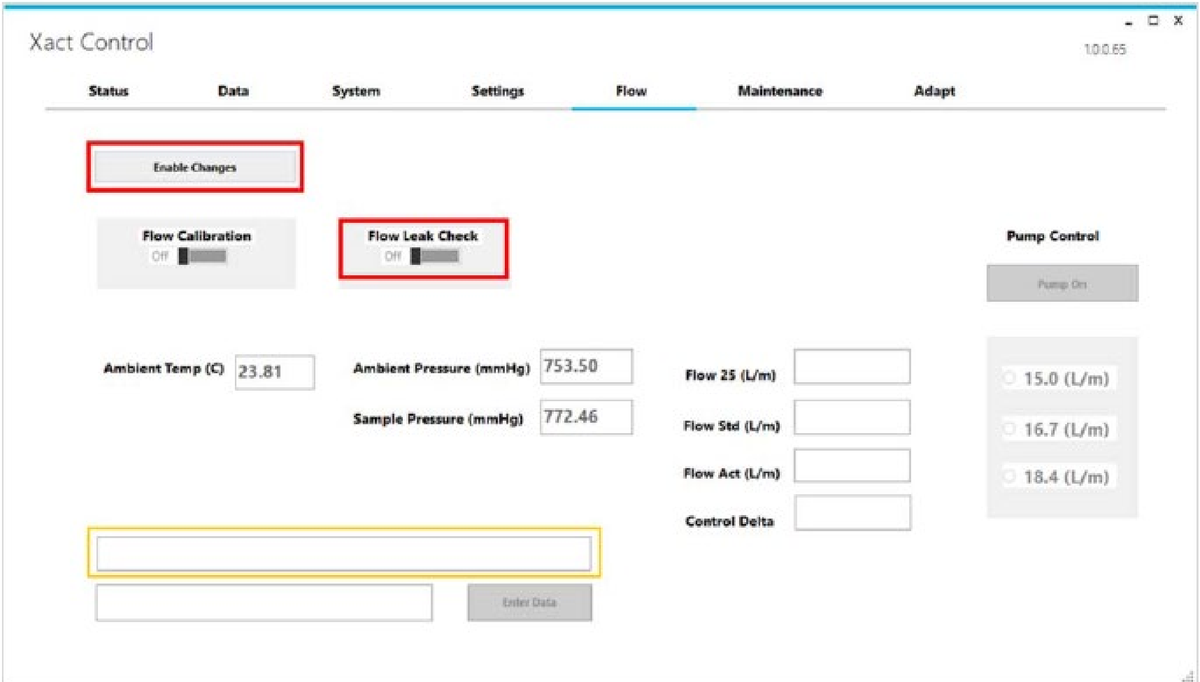
IMPORTANT: *Ensure that the tape is in the tape slot and not the filter wheel slot. Properly installed tape should be flat and not angled.*

7. Using adhesive tape, attach the filter tape to the uptake spool on the feed reel.
8. Replace the reel covers. Do not overtighten.
9. Close and lock the Xact 625i front door.
10. Navigate to the Maintenance page. In the "Tape Control" section, click on "Move Full" to manually move the tape. The status bar will indicate when the tape move is successful.
11. On the Maintenance page, in the "Tape Change" section, verify the settings for tape length (30 or 40 meters) and the low-tape-warning percent (typically 5%). If changes are made, save them by clicking the "Save Length and %" button.
12. Click the "Reset Tape Counter" button. Doing so will allow the software to estimate the amount of tape remaining.
13. Return to the home screen. Click on "Run" to set the Xact 625i to Run mode.

7.3 Leak Check

A sample inlet ball valve is needed for the leak test procedure

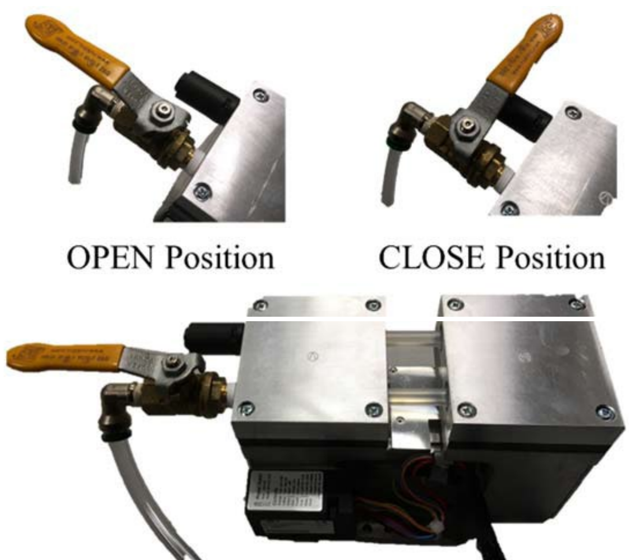
1. Ensure the filter tape is properly installed and the Xact 625i is in STOP mode.
2. Remove all PM inlets and install the leak tester over the PM inlet tube.
3. Open the "Flow" page tab.
    a. Click "Enable Changes"
    b. Turn on "Flow Leak Check"
4. Instructions will appear in the status window (i.e., the orange box in the figure on the following page).



Slowly close the ball valve so that the pump can create a vacuum:

a. The Sample Pressure reading will fall below 130 mmHg and the Xact Control will shut down the pump.

b. Close the Xact 625i's pump ball valve.



OPEN Position CLOSE Position

Xact 625i Pump

c. After 90 seconds, the status bar will display the following results:

Initial Sample Pressure (mmHg)

Final Sample Pressure (mmHg)

Elapsed Time (sec)

Leak Rate (mmHg/min)

Leak Check Result: PASS/FAIL

5. Record the values in the maintenance form.
6. Slowly open the ball valve to prevent damaging the flow sensor.
7. Open the Xact 625i's pump ball valve.
8. In the instrument control software, under the "Flow" tab, turn off "Flow Leak Check", Then select "Disable Changes"

IMPORTANT: *If the leak rate is less than 150 mmHg/min, the Xact 625i has passed the Leak Check. If the instrument fails the leak check, examine/reinstall the sample tubing and vanes and repeat the process. If the instrument continues to fail the test persistently, contact SCI personnel or an authorized distributor for further information.*

7.4 Flow Check

Before performing a Flow Check, ensure that the filter tape is properly installed, the nozzle is in the UP position, and that the instrument is in STOP mode.

1. Remove all PM inlets and install the Leak Tester over the PM inlet tube. The Leak Tester valve should be in the open position.
2. Connect the NIST traceable flow meter to the sample inlet ball valve using the flexible test tubing.
3. Navigate to the Flow page. Click the "Pump On" button; the status bar will prompt the user to select a flow rate.
4. Select a flow rate of 16.7 l/m and wait for the pump to adjust the sample flow rates; when the "Control Delta" box reads 0.000±0.004, the flow has stabilized. This process may take 15-20 seconds.
5. Note the "Flow Act (l/m)" value displayed and the reference flow rate from the flow meter in the maintenance form.
6. Repeat the steps above for flow rates of 15.0 LPM and 18.4 LPM.
7. Repeat the process two more times (for a total of three readings per flow rate).
8. Calculate and record the percentage difference between the flow rates on the maintenance

form and calculate the average of all the percentage differences.

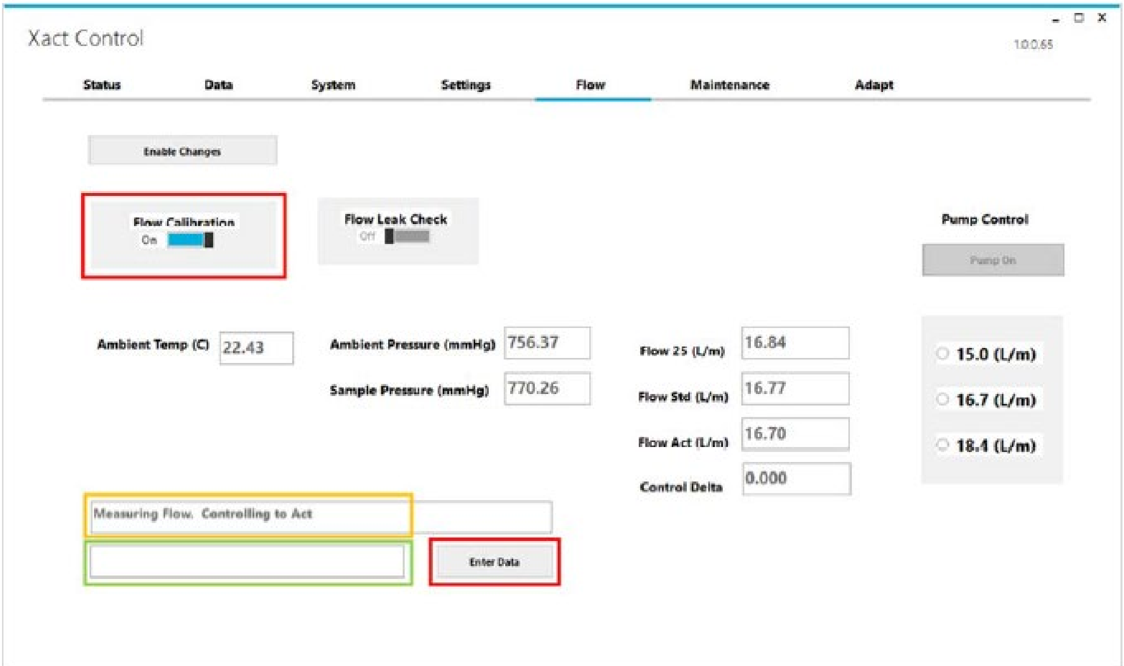
9. To complete the flow check, click on "Disable Changes."

If the Total Average percentage difference is less than 1% and the temperature and pressure are within 10% of the reference values, the Xact 625i has passed the Flow Check. If the Xact 625i fails the Flow Check, perform a Flow Calibration.

7.5 Flow Calibration

Follow these instructions to perform a Flow Calibration:

1. Remove all PM inlets and install the ball valve over the PM inlet tube.
2. Connect the flow meter to the sample inlet ball valve using the flexible test tubing.
    a. Allow the flow meter sufficient time to stabilize (roughly 60 sec).
3. Navigate to the Flow page and click on "Enable Changes" and turn the "Flow Calibration" toggle switch ON. Follow the instructions that appear in the status window (i.e., the orange box in the figure on the following page) to manually enter values in the input window (i.e., the green box in the figure on the following page).
    a. When prompted, input the reference ambient temperature from the flow meter and click on "Enter Data."
    b. When prompted, input the reference ambient pressure from the flow meter and click on "Enter Data."
    c. The pump will adjust the sample flow rates to each of the three predefined calibration flow rates (i.e., 15.0, 16.7, and 18.4 l/m). Wait for the flow to stabilize (i.e., wait for the "Control Delta" box to read 0.000±0.004; this process may take 15-20 sec). When prompted, input the reference flow rate from the flow meter and click on "Enter Data."
4. The Xact Control program will automatically calibrate the Xact 625i's flow system.



7.6 XRF Calibration Check

This procedure should only be performed with Element Standards marked with A for analyte. At least five recommended standards should be used: two each for the EC1 and EC2 energy conditions and one for the EC3 energy condition. The user can perform the check with additional standards.

Prior to starting the XRF Calibration Check, ensure that the instrument is in STOP mode.

Make sure the instrument underwent Xact 625i Daily Automated QA Checks within the last 24 hr.

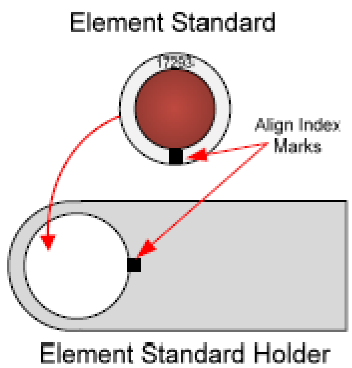
To manually perform the QA Check:

1. Navigate to the Maintenance page.
2. In the “XRF Check” section, select “Ecal.”
3. Click on “Run Acquisition.” The status bar will display operational messages.
4. Wait for the X-rays to ramp down. This process can take roughly 3-10 min.

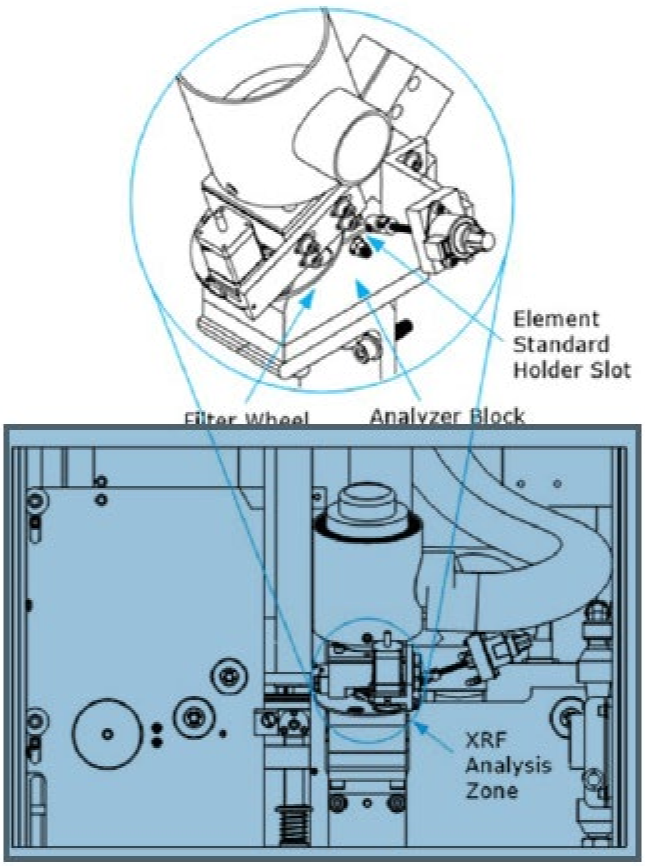
CAUTION: *Always handle Element Standards by their plastic ring edge. Store them in their individual containers when not in use. Nitrile gloves or powderless latex gloves are recommended during this procedure, although they are not mandatory.*

5. Remove the filter tape from the analysis block.

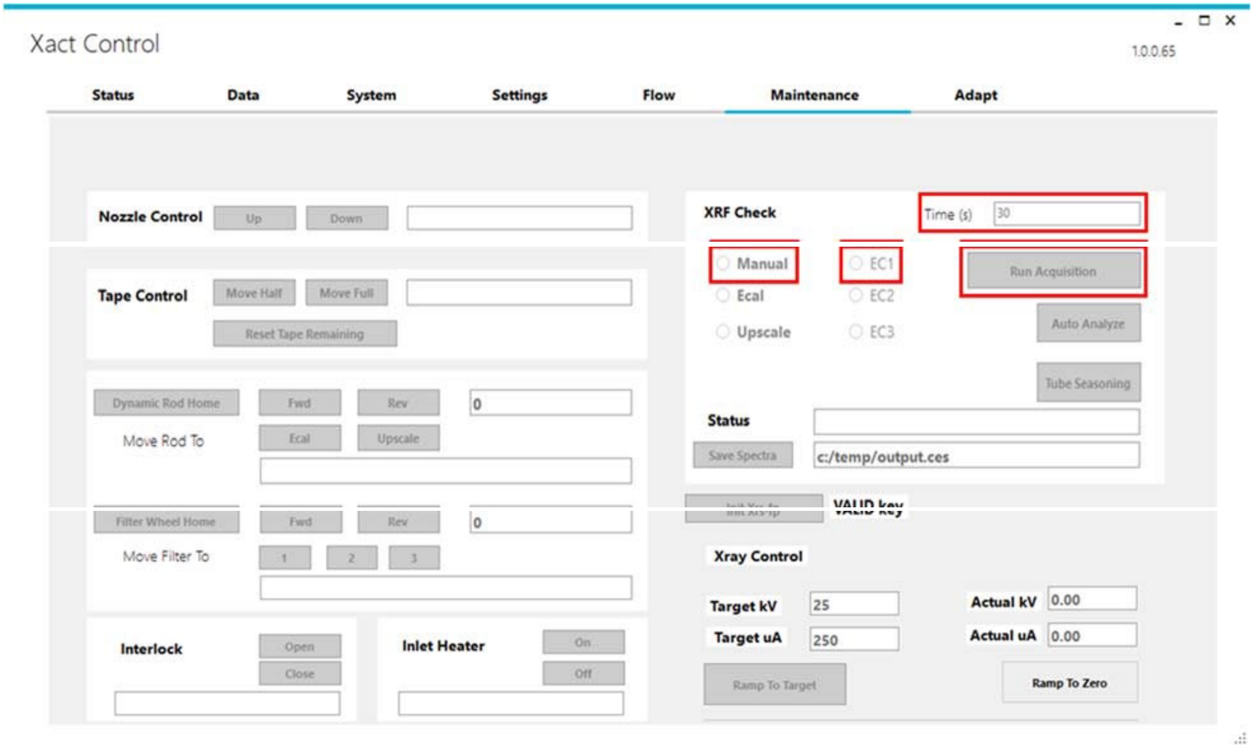
6. Place the first Element Standard into the Element Standard holder; the Standard should be oriented with the plastic ring up. Align the index mark on the Element Standard with the index mark on the Element Standard holder. The Element Standards are very fragile! Extreme care should be taken not to damage or contaminate the deposit.



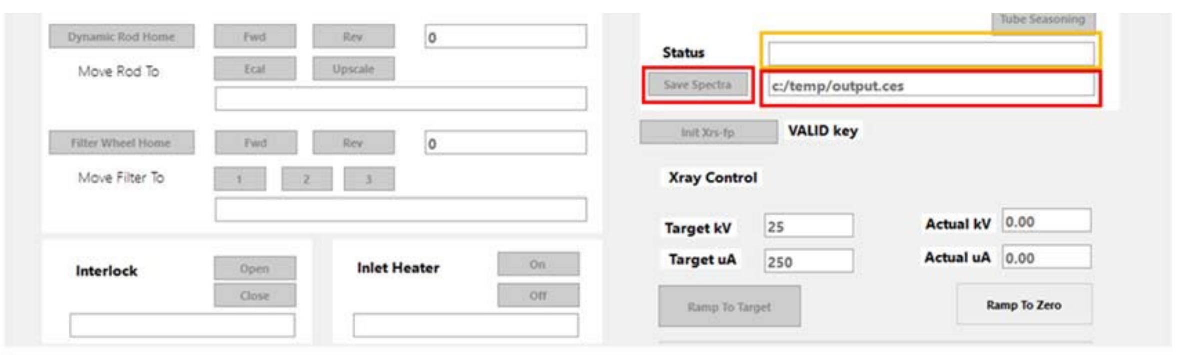
7. Insert the Element Standard holder in the slot under the filter wheel (on the right side of the analyzer block) in the analysis zone. The Element Standard holder takes the place of the filter tape in the analysis block. Be sure to push the Element Standard holder as far into the analysis zone as possible.



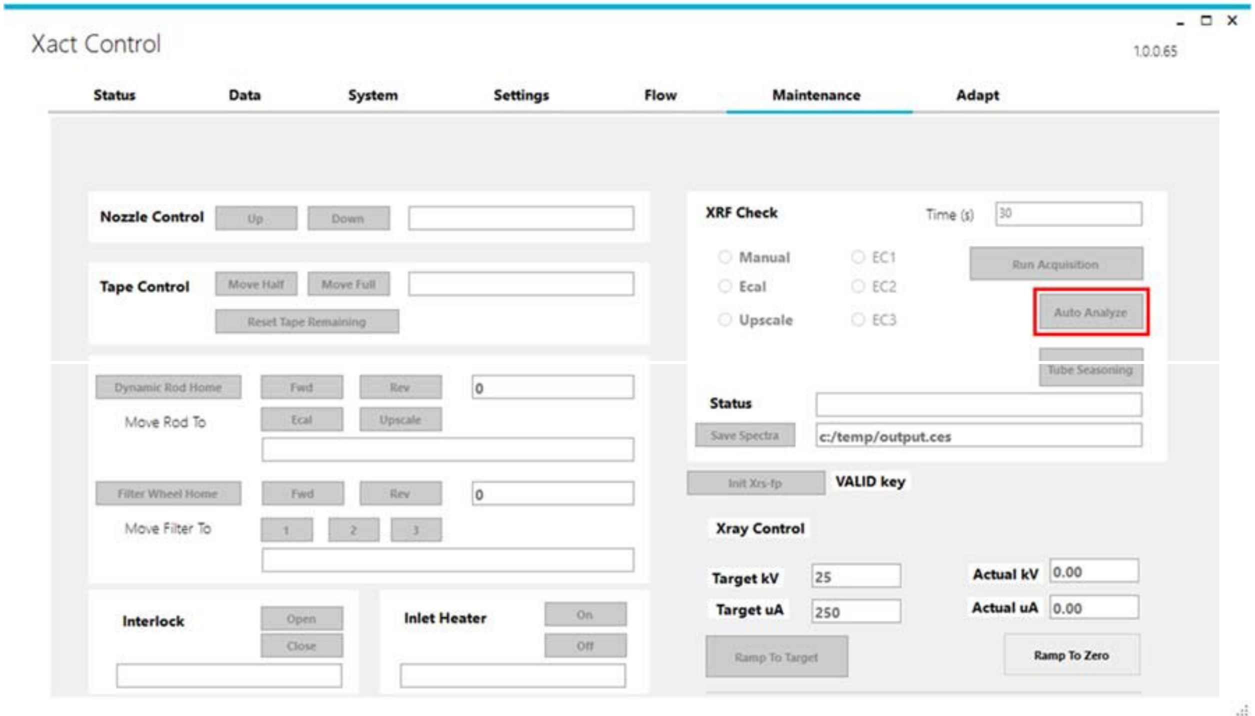
8. Close and lock the front door of Xact 625i.
9. Navigate to Maintenance page within 'XRF Check' section.
    a. Select "Manual" and "EC1" for Ca Element Standard.
    b. Enter the acquisition time from the Calibration guide into the time text box.
    c. Click "Run Acquisition" To initiate acquisition.



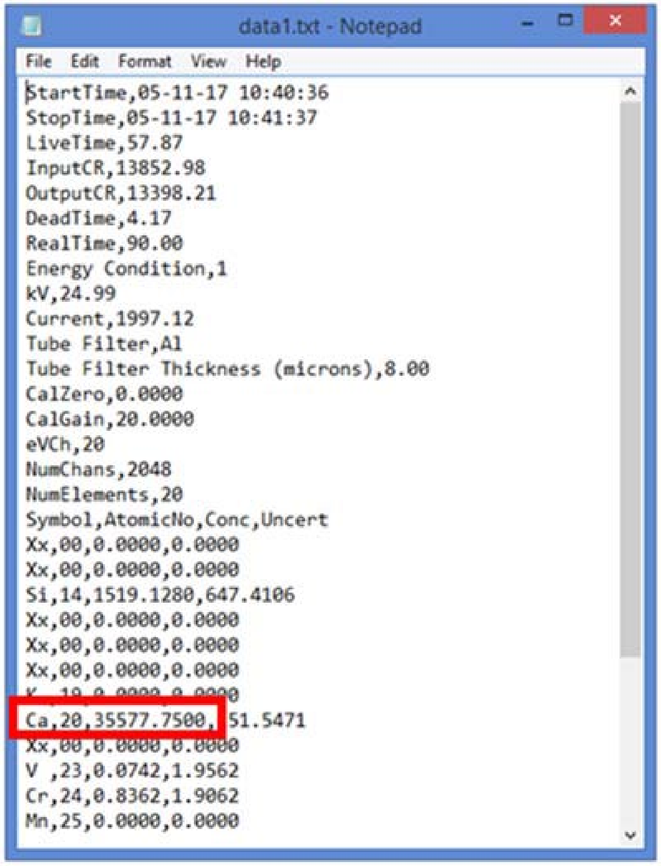
10. After acquisition is complete, the 'Status' window of 'XRF Check' section will prompt you to save the spectra. Enter the folder path, save the file with .ces extension (example: C:/temp/20_Ca_12345_XRF_Check.ces), and click "Save Spectra."



11. Wait until the status indicates that the X-rays have started to ramp down, then click "Auto Analyze".



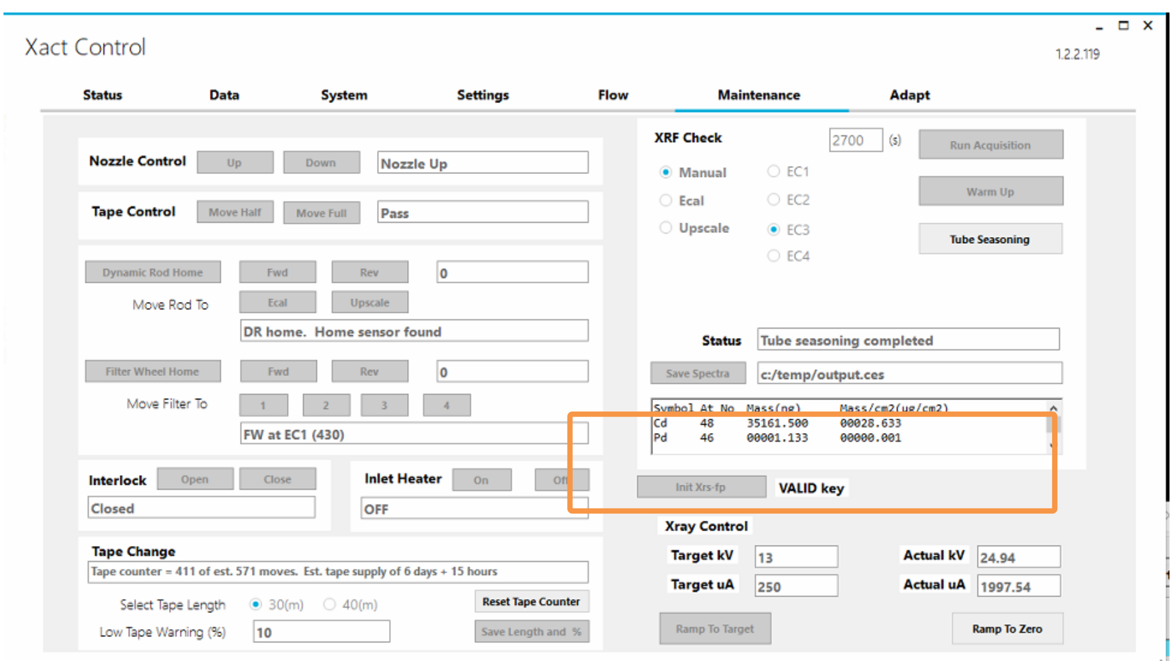
12. Navigate to C:/process_data/data1.txt to obtain the reported mass. For example, Ca reported mass in the figure below is 35577.75 ng. Ca Element Standard acquired in EC1 energy condition will be saved in data1.txt. Data for EC2 and EC3 will be saved in data2.txt and data3.txt respectively.


data1.txt - Notepad

File Edit Format View Help

```
StartTime,05-11-17 10:40:36
StopTime,05-11-17 10:41:37
LiveTime,57.87
InputCR,13852.98
OutputCR,13398.21
DeadTime,4.17
RealTime,90.00
Energy Condition,1
kV,24.99
Current,1997.12
Tube Filter,Al
Tube Filter Thickness (microns),8.00
CalZero,0.0000
CalGain,20.0000
eVCh,20
NumChans,2048
NumElements,20
Symbol,AtomicNo,Conc,Uncert
Xx,00,0.0000,0.0000
Xx,00,0.0000,0.0000
Si,14,1519.1280,647.4106
Xx,00,0.0000,0.0000
Xx,00,0.0000,0.0000
Xx,00,0.0000,0.0000
K ,19,0.0000,0.0000
Ca,20,35577.7500,51.5471
Xx,00,0.0000,0.0000
V ,23,0.0742,1.9562
Cr,24,0.8362,1.9062
Mn,25,0.0000,0.0000
```

Reported mass will also be populated under "Save Spectra" (orange box below).



13. Record this value in the 'Reported Mass (ng)' column into the maintenance form.
14. Copy the value from 'Mass (ng)' column for Ca from 'Calibration Guide' (example given in **Table 3** in **Section 8**. BE SURE TO USE THE GUIDE SPECIFIC TO THE STANDARDS YOU ARE USING) into the 'Mass (ng)' column into the maintenance form.
15. Repeat the process for the remaining Element Standards on the maintenance form.
16. Calculate and record the percentage difference between corresponding mass (ng) values. If percentage difference is within ±10%, the XRF Calibration Check is successful. If Xact 625i fails the XRF Calibration Check, contact a SCI personnel or an authorized distributor.

7.7 Xact Recalibration

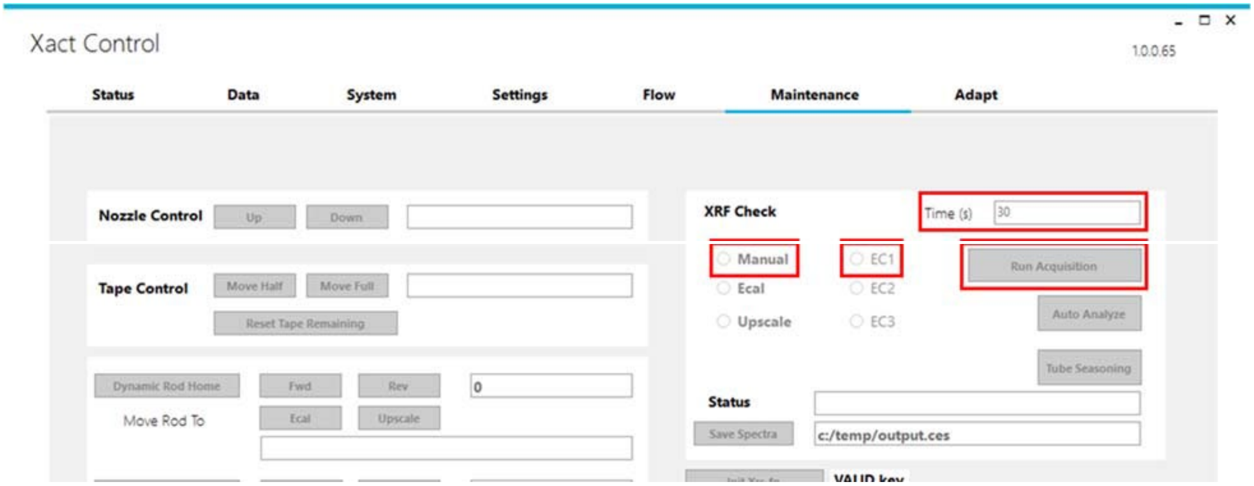
Xact Recalibration is performed when a new X-ray tube is installed or if the user wants to change Xact 625i settings for monitoring to focus on a group of elements different from those the instrument was calibrated for at the factory. Since Xact 625i is a precisely calibrated instrument for user requested elements of interest, the entire instrument must be recalibrated to monitor different elements. Such Xact Recalibration must only be performed by SCI personnel or an authorized distributor.

7.8 Blank QA

To perform a QA Blank Check, ensure that a clean tape is properly installed and that the instrument is in Stop mode.

Navigate to the Maintenance page.

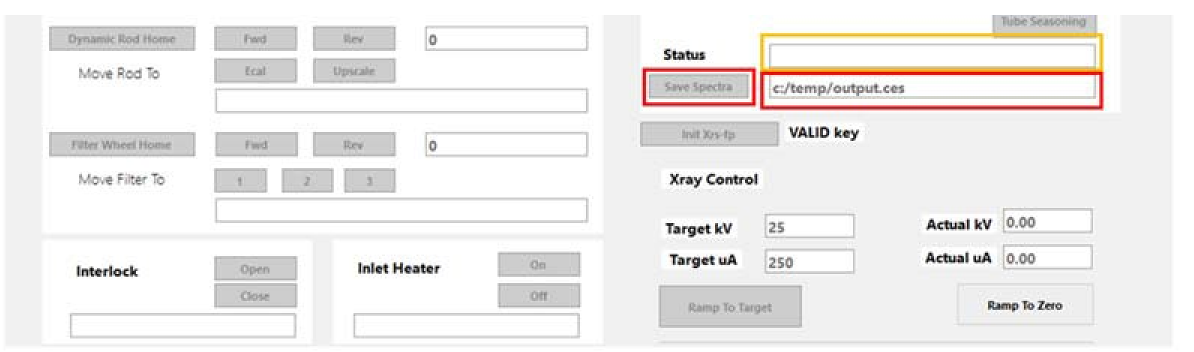
1. Within 'XRF Check' section:
    a. Select "Manual" and "EC1"
    b. Enter the acquisition time for EC1 in seconds (Refer to table below)
    c. Click "Run Acquisition"



Recommended acquisition time breakdown for each energy condition based on Xact 625i sample time are provided in the table below.

Sample Time (minutes)	Acquisition Time (seconds)		
	EC1 (20%)	EC2 (40%)	EC3 (40%)
15	180	360	360
30	360	720	720
60	720	1440	1440
120	1440	2880	2880
180	2160	4320	4320
240	2880	5760	5760

2. After acquisition is complete, the status window of 'XRF Check' section (orange box in figure below) will notify when the spectra is ready to be saved. Enter the folder path, save the file with .ces extension (example: c:/temp/EC1_Blank.ces), and click "Save Spectra."



3. Wait until the status window indicates that X-rays have ramped down, then click “Auto Analyze.”
4. The resulting EC1 elemental masses for Blank can be viewed in the process data file located at C:\process_data\data1.txt.
5. Repeat the process for EC2 and EC3 based on the times in the acquisition time table.
6. Routinely monitor the QA Blank values to capture any systematic deviations with time.

8. Maintenance Forms

Instrument:______________________________

Technician:________________________

Date:______________________________

Instructions: complete checks described below and enter data or initial next to each one once complete. Make note of any corrective action.

- ❒ Notify the client and project manager of maintenance tasks.
- ❒ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.
- ❒ Confirm that the data are invalidated on the public website before proceeding with maintenance.
- ❒ When maintenance is complete check the public site <u>for at least 15 min</u> to ensure proper reporting (no missing data, no high values, etc.).
- ❒ Take out of maintenance mode
- ❒ Notify the project manager and client when maintenance is complete.

Upon completion sign and date:________________________________

Table 2. Maintenance activities and performance indicator checks for the Xact 625i.

Activity / Check	Completed (Y/N)
Visually inspect the system	
QA Upscale Tracking	
Tape Change	
Leak Check	
Flow Check	
XRF Calibration Check	
Flow Calibration	
Blank Check	
Xact Recalibration	

Xact 625i Leak Check Form

Instrument:______________________________

Technician:______________________________

Date:___________________________________

Parameter	Observed	Acceptance Criteria
Initial Sample Pressure (mmHg)		
Final Sample Pressure (mmHg)		
Elapsed Time (sec)		
Leak Rate (mmHg/min)		

Acceptance criteria for each test are defined by the QAPP.

Xact 625i Flow Check

Instrument:___________________________

Technician:____________________________

Date:_________________________________

	Flow Rate (LPM)	Xact	Reference
Trial 1	16.7		
	15.0		
	18.4		
Trial 2	16.7		
	15.0		
	18.4		
Trial 3	16.7		
	15.0		
	18.4		

Flow Rate (LPM)	Average	%Difference
15.0		
16.7		
18.4		

Xact 625i XRF Calibration Check Form

Instrument:______________________________

Technician:______________________________

Date:____________________________________

2x EC1, 2x EC2, and 1x EC3 are required

Element	Atomic Number	Standard Compound	Standard ID	Energy Condition	Acq. Time (sec)	Mass (ng)	Reported Mass (ng)	% Diff
Ca	20	CaF_2		1	120			
Mn	25	MnF_2		1	60			
Se	34	Se		2	70			
Pb	82	Pb		2	70			
Cd	48	CdSe		3	2700			

Optional

Element	Atomic Number	Standard Compound	Standard ID	Energy Condition	Acq. Time (sec)	Mass (ng)	Reported Mass (ng)	% Diff
Al	13	Al		1	4400			
Fe	26	Fe		2	70			
Pd	46	Pd		3	900			
Ag	47	Ag		3	1200			
Sn	50	Sn		3	1800			

Table 3. Example calibration guide that comes with the thin-film standards. Be sure to use the guide that corresponds with your standards

Xact™ 625i Calibration Guide													
Element of Interest	Atomic Number	Compound on Micromatter Standard	Standard ID	Meas. Conc. μg/cm²	Mass ng	Condition 1	Purpose 1	Acq. Time (Sec)	Condition 2	Purpose 2	Acq. Time (Sec)	Condition 3	Purpose 3	Acq. Time (Sec)
Al	13	Al	41826	46.04	56538	x	I	4400						
Si	14	SiO2	41827	47.03	57755	x	A	2700						
P	15	GaP	41828	16.20	19897	x	I	2700						
S	16	InSx	41829	10.95	13445	x	I	2700						
K	19	KCl	41830	25.5	31318	x	A	360						
Ca	20	CaF2	41831	21.7	26663	x	A	180						
Ti	22	Ti	41833	41.2	50546	X	I	63						
V	23	V	41834	44.7	54915	X	A	63						
Cr	24	Cr	41835	46.4	[illegible]	X	A	63						
Mn	25	Mn	41836	47.6	[illegible]	X	A	63	X	I	65			
Fe	26	Fe	41837	47.4	58209	X	I	63	X	A	65			
Co	27	Co	41838	46.9	[illegible]	X	I	63	X	A	65			
Ni	28	Ni	41839	[illegible]	55593				X	A	[illegible]			
Cu	29	Cu	[illegible]	[illegible]	56923				X	A	65			
Zn	30	ZnTe	[illegible]	15.1	18565				X	A	180			
Ga	31	GaP	[illegible]	28.9	35504				X	A	65			
Ge	32	Ge	[illegible]	47.0	57665				X		65			
As	33	GaAs	[illegible]	32.5	39871				X	A	65			
Se	34	Se	[illegible]	49.3	60483				X	A	65			
Br	35	CsBr	41845	20.3	24935				X	I	65			
Nb	41	[illegible]	41852	42.6	52325				[illegible]	A	65			
Pd	46	[illegible]	41854	53.9	66130							X	A	1400
Ag	47	[illegible]	41855	50.2	61699							X	A	1200
Cd	48	CdS	41856	29.4	36120							X	A	2700
In	49	[illegible]	41857	48.9	60066							X	I	1800
Sn	50	Sn	41858	54.2	66558	X	I	65				X	A	1800
Sb	51	Sb	41859	43.1	52891	X	I	65				X	A	1800
Te	52	Te	41860	47.5	58348	X	I	65				X	I	2700
I	53	PbI	41846	29.8	36584	X	I	65						
Cs	55	CsBr	41845	33.8	41563	X	I	65						
Ba	56	BaF3	41861	37.2	45730	X	A	65						
Pt	78	Pt	41867	50.1	61523				X	I	65			
Au	79	Au	41868	48.3	59290				X	A	65			
Hg	80	AgHg	36587	9.5	11655				X	A	65			
Tl	81	TlCl	41869	35.9	44091				X	A	65			
Pb	82	Pb	41870	42.3	51942				X	A	65			
Bi	83	Bi	41871	50.5	61956				X	I	65			
As	33	PSR							X	I	65			

Xact 625i Minimum Detection Limits

Table 4. Xact 625i minimum detection limits.

Element	Atomic Number	Detection Limits* (ng/m³) at Sample Times					
		15 mins	30 mins	60 mins	120 mins	180 mins	240 mins
Al	13	840	290	100	35	19	12
Si	14	150	51	17.8	6.3	3.4	2.2
P	15	44	15	5.2	1.8	0.99	0.64
S	16	26	9.1	3.16	1.1	0.6	0.39
Cl	17	15	5	1.73	0.61	0.33	0.21
K	19	9.8	3.4	1.17	0.41	0.22	0.14

Element	Atomic Number	Detection Limits* (ng/m^3) at Sample Times					
		15 mins	30 mins	60 mins	120 mins	180 mins	240 mins
Ca	20	2.5	0.86	0.3	0.1	0.057	0.037
Ti	22	1.3	0.46	0.16	0.056	0.03	0.02
V	23	1	0.34	0.12	0.042	0.023	0.015
Cr	24	0.97	0.33	0.12	0.041	0.022	0.014
Mn	25	1.2	0.41	0.14	0.05	0.027	0.018
Fe	26	1.4	0.49	0.17	0.061	0.033	0.021
Co	27	1.1	0.39	0.14	0.049	0.026	0.017
Ni	28	0.78	0.27	0.1	0.034	0.018	0.012
Cu	29	0.65	0.23	0.079	0.028	0.015	0.01
Zn	30	0.55	0.19	0.067	0.023	0.013	0.008
As	33	0.52	0.18	0.063	0.022	0.012	0.008
Se	34	0.66	0.23	0.081	0.029	0.016	0.01
Br	35	0.85	0.3	0.1	0.037	0.02	0.013
Ag	47	16	5.5	1.9	0.68	0.37	0.24
Cd	48	21	7.2	2.5	0.89	0.48	0.31
In	49	26	8.9	3.1	1.1	0.6	0.39
Sn	50	33	12	4.1	1.4	0.78	0.51
Sb	51	42	15	5.2	1.8	0.99	0.64
Ba	56	3.3	1.1	0.39	0.14	0.074	0.048
Hg	80	0.99	0.35	0.12	0.043	0.023	0.015
Tl	81	0.95	0.33	0.12	0.041	0.022	0.014
Pb	82	1	0.36	0.13	0.045	0.024	0.016
Bi	83	1.1	0.37	0.13	0.046	0.025	0.016

*Interference-free one sigma detection limits for a 0.707 $inch^2$ spot sample size at a 68% confidence level (C1σ) per U.S. EPA IO-3.3 and Currie, 1968.

References: (1) U.S. EPA Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, June 1999: Method IO-3.3. (2) Currie, L. A., "Detection and Quantification in X-Ray Fluorescence Spectrometry" in T. G. Dzubay, X-ray Fluorescence Analysis of Environmental Samples, Ann Arbor Science, 1977; and L. A. Currie, Analytical Chemistry, 40, p586, March 1968.

Standard Operating Procedure for Campbell Visibility Sensor (CS 120A)

February 13, 2024

STI-7540

Contents

1. Scope and Applicability

This standard operating procedure (SOP) provides instructions for servicing the Campbell visibility sensors used in fenceline monitoring applications. The procedures here cover routine maintenance and calibration of the Campbell CS120A visibility sensor.

2. Routine Service and Maintenance

Routine service tasks are designed to maintain the visibility sensor in good working condition. This is intended to lower the frequency of non-routine maintenance. The routine service tasks are described below. The site should be serviced once every four weeks. If no problems are encountered, the site visit will take less than one hour.

When maintenance is complete, the maintenance forms in Section 6 should be saved in the maintenance folder for the project located on Sonoma Technology's shared drive. Data will be flagged in a manner consistent with the QAPP if there are issues that cannot be immediately corrected. In the case of extended down time, the sensor should be replaced with a working sensor.

2.1 Maintenance Checklist

Table 1 depicts the maintenance activities that must be performed during each site visit to ensure all instruments are performing correctly.

Table 1. Routine quarterly maintenance checklist.

Action
Visually inspect the system, including all cables. Ensure they are not fraying.
Inspect optics on detector and clean if necessary.
Check calibration. An acceptable % accuracy is less than 25%

[a] Lowering the meteorological tower is not necessary for routine site maintenance visits. Do not attempt to lower the tower with fewer than two people.

After physically inspecting the meteorological sensors, the technician should take note of the current visibility reading from the instrument and confirm that it matches current atmospheric conditions. Visibility data from the National Weather Service can be used to aid in this task.

2.2 Securing the Shelter

Turn off the computer's display monitor, and record your completion time in the Site Log form. Turn off the shelter lights and lock the shelter.

3. Calibration and Standard Operating Procedures for Meteorological Sensors

Annual audits will be conducted on meteorological instrumentation. The meteorological instrumentation calibrations will be conducted with reference to the recommendations in the EPA's *Quality Assurance Handbook for Air Pollution Measurement Systems (QA Handbook), Volumes I, II, and IV* (U.S. Environmental Protection Agency, 2017b, 1994, 2008) and in accordance with the *Technical Assistance Document for the National Air Toxics Trends Stations Program, Revision 3* (U.S. Environmental Protection Agency, 2016a) and the *Technical Assistance Document for Sampling and Analysis of Ozone Precursors for the Photochemical Assessment Monitoring Stations Program*, Revision 2 (Battelle, 2018).

As part of the calibration process, each instrument will first be tested to determine whether it is operating within the prescribed operational limits and whether non-routine maintenance or adjustments are required. Based on an instrument's response to the initial performance test with respect to the minimum acceptable performance criteria (see data quality objectives in the QAPP), the instrument will then be repaired, calibrated, or in rare cases, replaced. A standard form will be used to document the performance of each sensor before and after any adjustments. A digital copy of this document is to be kept on the STI servers. Notes on what was performed are also to be recorded in the station logbook. The performance criteria for the visibility sensor is that the measured extinction coefficient must be within 25% of the reference value.

3.1 Visibility Sensor Testing and Calibration

3.1.1 Materials Needed

- Microfiber cloth
- Calibration bungs
- Calibration disk
- Micro-USB to USB-A cable

3.1.2 Startup Checklist

Verify that the following actions are completed when starting up the Campbell Visibility Sensor:

_____ Verify that serial connections to the datalogger are correct (sensor TX to logger RX, sensor RX to logger TX, and sensor ground to any ground terminal on the logger).

_____ Check datalogger to see if data is coming from the sensor.

_____ Check the data to make sure it makes sense (visibility value is a reasonable number and the correct values are being recorded to the right parameters).

_____ Make sure the lenses are clean and clear of obstructions (spider webs, etc.).

_____ Use a microfiber cloth (you can use a blower first). Do not use abrasive cleaners; use isopropyl alcohol only if needed.

3.1.3 System Verification Procedure

The following tests will be performed as a verification of analyzer operation.

Testing and Calibration Prep

The sensor can be checked and adjusted using the optional sensor high-grade calibration kit Part Number 28678 from Campbell Scientific. The calibration must be performed using the onboard menu system. To access this menu via LoggerNet's terminal emulation program, see procedure in Section 4.

The test should ideally be performed under the following conditions:

- Ambient temperature between 0ºC and 50ºC.
- The local visibility is approximately 10,000 meters or more.

To perform the verification test, follow these steps:

1. Select Menu Item 4 on the main terminal screen. Once you have selected Menu Item 4, the following is an example of what should appear on the screen.

```
CS120A INFORMATION - MENU 4
 ID 0
 S/N 1234
 OS version: 007646v12
                                   Alarm   Value
- Last visibility reading:          -       65m
- Overall system status:            0       No faults
- Emitter dirty window alarm:       0       0%
- Emitter internal temperature:     0       27.4
- Detector dirty window alarm:      0       -4%
- Detector internal temperature:    0       23.2
- Detector DC light saturation:     0       -
```

```
- Hood heater temperature:          0       16.9
- CS120A Calibrator Serial No:       -       1192
- CS120A Calibrator EXCO:            -       48.4
- Calibration value factory offset: -       0.025
- Calibration value factory scale:  -       0.02630
- Calibration value cal offset:     -       0.090
- Calibration value cal scale:      -       0.02814
- Signature fault:                  0       -
- Flash write errors:               0       0
- Flash read errors:                0       0
- Supply voltage:                   <7.0V  12.0V
- Aux supply voltages:              +5V=4.9 -5V=-5.1 +6V=6.0
(8) Get debug
(9) Refresh
(0) Return to main menu
```

2. Make note of the extinction coefficient on the sensor calibrator. Once suitable local visibility conditions have been verified, place the sensor calibrator into the volume by fastening it to the central mounting point.

3. Allow 5-10 minutes for the measurements to stabilize.

4. Record the As Found system parameters, that can be found in Menu 4.

5. Enter 9 as needed to continue to refresh the data to see the last visibility reading.

6. Once the last visibility reading is consistent, take note of the new reading.

7. The conversion of the visibility reading to the extinction coefficient for comparison is 3000 divided by the last reading.

8. Calculate the percent error between this new value and the extinction coefficient. The percent error should be equal to or less than the %Error specified in the QAPP.

9. If the precent error is greater than specified in the QAPP, attempt cleaning the lenses. If the percent error is still greater than the value specified in the QAPP, proceed with calibration.

3.1.4 System Calibration Procedure

1. To perform the calibration, select Menu Item 3 on the main terminal screen. Once you have selected Menu Item 3, the following screen should appear.

```
CS125 CALIBRATION - MENU 3
ID 0
S/N 1006
(1) Perform calibration
(2) Restore the factory calibration
```

```
(3) Perform dirty windows zero offset calibration
(4) Restore dirty windows factory calibration

(9) Refresh
(0) Return to main menu
```

2. Select **Option 1** to start the calibration.

3. Confirm that a calibration is to be performed. Please note that once "**Yes**" is entered, exiting the program is not possible until the test is complete. However, power cycling the unit at this point will have no adverse effect on the sensor.

4. Once the test has started, the program will ask for the sensor calibrator serial number and coefficient with a confirmation at each step giving the opportunity to correct typing mistakes.

```
Starting calibration.
Input the sensor calibrator serial number ->E2002
Is E2002 correct? (Y/N)?
Input the sensor calibrator constant ->28.8
Is 28.8 correct? (Y/N)?
```

5. Start the dark level calibration by placing one calibration bung into each hood, and then pressing any key.

   Once calibrator information has been entered, the sensor will hold until the foam bungs are placed into the sensor hoods. The bungs are designed to block all light from the outside from reaching inside the head. Place one bung into each hood. If either of the bungs is damaged or appears to have any gaps around the edge, contact Campbell Scientific.

```
Starting dark level calibration.
This test will take approximately two minutes
```

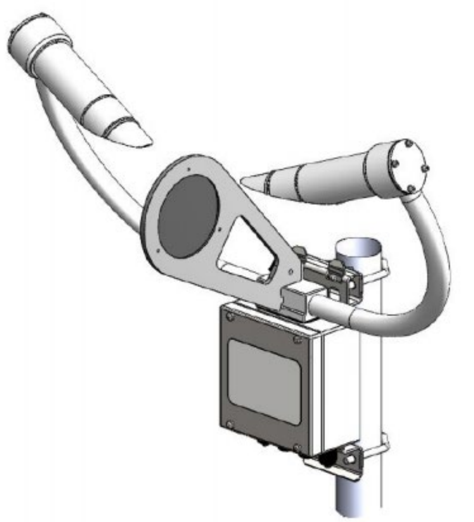
   This part of the test will take approximately two minutes. Every ten seconds, a dot should appear indicating that the test is progressing as normal.

```
Dark level test complete. Please remove the bungs.
Now place the sensor calibrator into the sampling
volume.
Press any key once this is done.
```

6. Remove the bungs once the sensor instructs for this to be done.

Light Level Calibration

7. Place the sensor calibrator into the volume by fastening it to the central mounting point. Press any key.



```
Starting light level calibration.
This test will take approximately two minutes.
```

This part of the test will take approximately two minutes. Every ten seconds, a dot should appear indicating that the test is progressing as normal.

```
Calibration is now complete.
Saving user settings
Press any key to exit.
```

Once the second stage of the test has been completed, the new calibration constants will be saved automatically. Exit the menu by pressing any key. All calibration constants, including both the user and the factory setting, can be viewed from Menu Item 4 from the main menu once the test is completed.

8. Document the new user calibration constant and the factory setting each time a calibration is done.

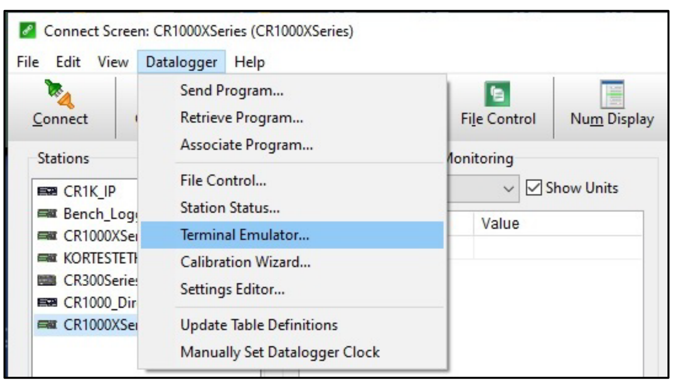
9. REMEMBER to remove the calibration disk once finished.

4. Campbell Terminal Emulator Connection Procedure

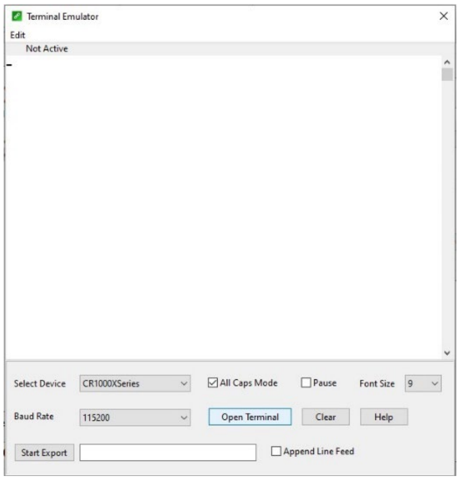
The following is a procedure to access the real-time visibility sensor data with a Campbell Scientific Data Logger through LoggerNet Terminal Emulator.

1. Connect a laptop to the Campbell Scientific Data Logger with a USB cable, RS232 cable, or via ethernet cable and IP address.
2. From the LoggerNet application, open the “Connect Screen” through “Main” and “Connect” options.

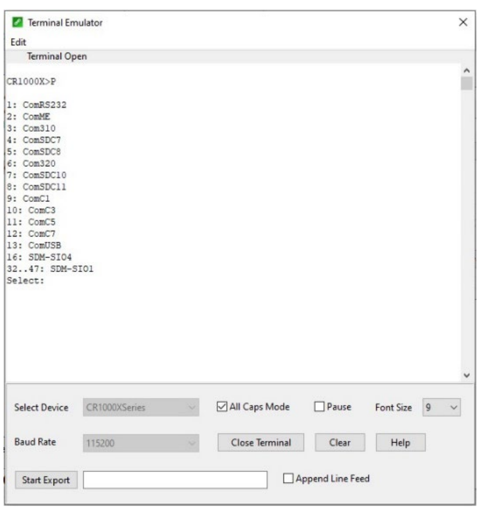
3. Select the “Datalogger” tab at the top right of the “Connect Screen.” Then select “Terminal Emulator…” from the drop down menu.



4. A blank window will display, but the terminal emulator is not open yet. To open connection to the terminal emulator, select "Open Terminal" at the bottom of the Terminal Emulator window.



5. When the terminal is open, the button that previously said, "Open Terminal," will change to "Close Terminal." Press enter until "CR1000X>_" appears in the terminal.
6. Type the capital letter "P" to display comport options.



7. Look at the lowest terminal bar on the data logger and identify which terminal port has a blue wire to the left of a white wire. The terminal port that the blue wire is connected to corresponds to the comport that needs to be selected. For example the "C1" terminal port corresponds to the option "9: comC1." Type the list number after "Select:_" that corresponds to the correct comport and press enter.
8. If the correct comport is selected "opening [comport number]; press ESC ESC ESC ESC to close" will display and sometimes will be followed by an array of numbers. Now type "open 0" and press enter. Note, often the curser or the text will not be visible during this step. Also,

frequently, the first attempt will not work. Allow time for the command to process. Typically, additional rows of array numbers will display after failed attempts are finished processing. Continue to enter "open 0" until the following setup menu displays.

```
WELCOME TO THE CAMPBELL SCIENTIFIC LTD CS120A SETUP MENU
 ID 0
 S/N 1234
 (1) Message output menu
 (2) User alarm menu
 (3) Calibrate CS120A
 (4) System information
 (5) Communications setup
 (6) System Configuration
 (9) Exit and save
 (0) Exit and don't save
  ->
```

9. Enter "4" for "System information" and the real time data from the visibility sensor will display.
10. Enter "9" as needed to continue to display the most current data.
11. To exit the terminal emulator session, enter zero to exit the information menu and return to the main menu.
12. Enter zero again to exit and not save.
13. Press Esc four times to close.
14. Select "Close Terminal" to close the terminal
15. Close the terminal emulator window.
16. LoggerNet can be closed and the laptop can be disconnected from the logger.
17. Note: opening the terminal emulator will halt data transfer from the data logger. To re-establish data transfer, reset the data logger by disconnecting the power source, wait 10 seconds, and plug the power source back into the data logger.
18. Confirm data flow has been re-established.

5. References

U.S. Environmental Protection Agency (1994) Quality assurance handbook for air pollution measurement systems, Volume I: a field guide to environmental quality assurance. Report prepared by the U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA/600/R-94/038a. Available at **https://www3.epa.gov/ttn/amtic/qalist.html**.

U.S. Environmental Protection Agency (2008a) Quality assurance handbook for air pollution measurement systems, Volume II: ambient air quality monitoring program. Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-08-003, December. Available at **http://www.epa.gov/ttn/amtic/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf**.

U.S. Environmental Protection Agency (2008b) Quality assurance handbook for air pollution measurement systems, Volume IV: meteorological measurements version 2.0 (final). Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-08-002, March. Available at **https://www3.epa.gov/ttn/amtic/qalist.html**.

U.S. Environmental Protection Agency (2016) Technical assistance document for the National Air Toxics Trends Stations Program, Revision 3. Prepared for the Office of Air Quality Planning and Standards, Research Triangle Park, NC, by Battelle, Columbus, OH, October. Available at **https://www3.epa.gov/ttnamti1/files/ambient/airtox/NATTS%20TAD%20Revision%203_FINAL%20October%202016.pdf**.

U.S. Environmental Protection Agency (2017) Quality assurance handbook for air pollution measurement systems, Volume II: ambient air quality monitoring program. Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-17-001, January. Available at **https://www3.epa.gov/ttnamti1/qalist.html**.

6. Campbell Visibility Sensor Audit Record Example

Visibility
As Found

Site Name:	Field Site Name	**Date:**	January 1, 2024
Site Latitude:	12.345678 N	**Technician:**	Tech Name
Site Longitude:	-123.456789 W	**Reference Make:**	Campbell Scientific
Sensor Make:	Campbell Scientific	**Reference Model:**	CS125
Sensor Model:	CS120A	**Reference Serial No:**	E21192
Sensor Serial No:	E1234	**Reference Cal Date:**	N/A

	Reference	**Site Sensor**	**Error (%)**	**PASS/FAIL**
Extinction Coefficient (km^{-1})	48.4	50.0	3.3	PASS
Visibility (m)		60.0000		

Overall system status:	No faults	Calibration value factory offset:	-0.041
Emitter dirty window alarm:	-1%	Calibration value factory scale:	0.02619
Emitter internal temperature:	30.8	Calibration value cal offset:	0.064
Detector dirty window alarm:	0%	Calibration value cal scale:	0.029
Detector internal temperature:	25.7		
Hood heater temperature:	20.9		

Notes:

Sensor found to be within specification.
Will clean sensor lenses with alcohol wipes, lint-less lens tissue, and a blast of compressed air.

Visibility
As Left

	Reference	Site Sensor	Error (%)	PASS/FAIL
Extinction Coefficient (km^{-1})	48.4	52.6	8.7	PASS
Visibility (mi)		57.0000		

Overall system status:	No faults
Emitter dirty window alarm:	-1%
Emitter internal temperature:	31.2
Detector dirty window alarm:	-1%
Detector internal temperature:	26.1
Hood heater temperature:	21.2

Calibration value factory offset:	-0.041
Calibration value factory scale:	0.02619
Calibration value cal offset:	0.064
Calibration value cal scale:	0.029

Notes:

Sensor left within specification

Sonoma Technology

Standard Operating Procedure for Data Verification and Validation

August 27, 2024

STI-8222

Contents

1. Scope and Application

This standard operating procedure (SOP) describes the verification and validation of fenceline monitoring data, including daily checks and quarterly analyses. Additional information is provided in the corresponding fenceline air monitoring plan (FAMP) and Section D.2 of the quality assurance project plan (QAPP).

2. Introduction and Overview

At all fenceline monitoring sites, a Data Acquisition System (DAS), or data logger, performs basic quality control (QC), averages data to 5-min resolution, and aggregates data into a desired file format. Data are then transmitted from each sampling site to a cloud-based file storage service via cellular modem, where they are stored and available for retrieval as needed. Data from the cloud are ingested into Sonoma Technology's Insight© data management system (DMS), where a robust automated QC (AutoQC) logic assigns data flags in real time based on instrument diagnostics and local meteorological measurements. Data are stored within the DMS and any changes to data are recorded via chain-of-custody logs. These preliminary data are displayed on the public website within 10–15 minutes of collection.

Data are reviewed daily by air quality data analysts to assess system operations, confirm the automated data flagging is correct, and ensure any corrections to data flagging are propagated to the public website immediately. Extended analyses are performed every calendar quarter and reviewed by the project Quality Assurance (QA) Manager. Figure 1 illustrates the general data flow and QC schematic.

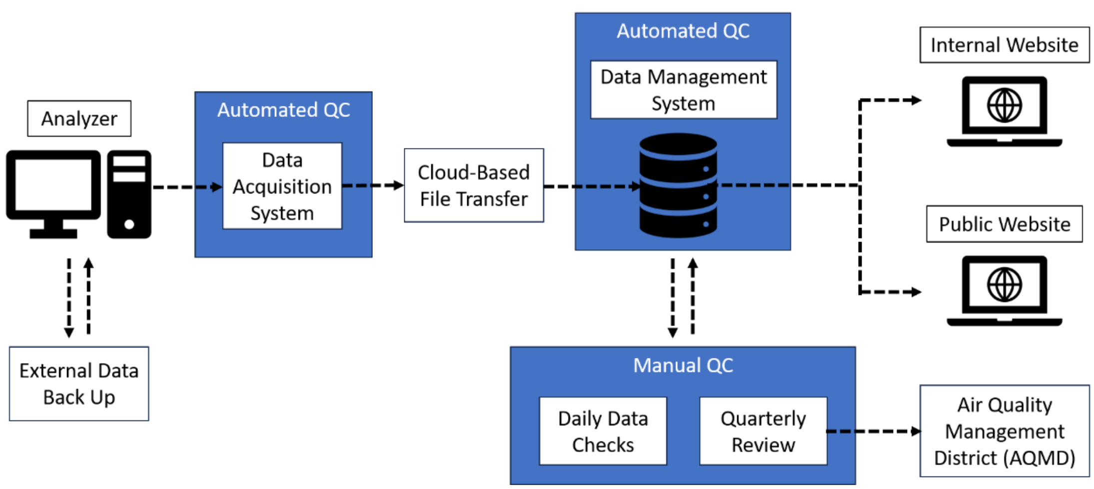


Figure 1. Data flow and QC schematic.

3. Definitions

Data verification is a process of comparing how the data were gathered to the procedures established by the project QAPP and SOPs. It is a data review technique that evaluates the conformance of data collection practices to established methods, procedures, or specifications. Data verification consists of checking that SOPs were followed and QC activities were performed.[1]

Data validation is a process of confirming that reported values meet the quality objectives of the project. It is a data review technique that examines whether the particular requirements for a specific, intended use are fulfilled. Data validation examines whether acceptance criteria outlined in the QAPP were achieved.[1]

Acceptance criteria are the defined performance criteria for the project that data must meet to be considered acceptable for reporting. Additional information regarding acceptance criteria is provided in Section A.7 of the QAPP.

Data flags are assigned to each data point based on instrument diagnostics and local meteorological measurements. Within the Sonoma Technology Insight DMS, data flags are composed of QC and operational (OP) codes. Additional information regarding data flags is provided in Section D.2 of the QAPP.

The **minimum detection limit (MDL)** is the lowest concentration of each parameter that can be measured by each analyzer at each sampling path. Additional information regarding MDLs is provided in Section B.2 of the QAPP.

Spectral data refers to the individual absorbance spectra collected at each open-path monitoring site. The analytic software evaluates raw spectral data in real time to report concentration data, and can be reviewed if data validation efforts identify potential issues that require investigation. Additional information regarding spectral data is provided in Section B.10 of the QAPP.

A **spectral match parameter** is used to identify parameters of interest and potential interferences present with open-path sampling. Spectral subtraction is used in cases with overlapping absorbance features, and the subtraction technique is proprietary to the instrument manufacturer. Additional information regarding spectral match parameters is provided in Section B.2 of the QAPP.

4. Safe Work, Hazard Identification, and Training for Data Review

Data verification and validation is performed remotely in an office environment away from field sampling sites. Common office hazards include slips and trips, sprains and strains, poor workstation ergonomics, indoor air-quality problems, insufficient or excessive lighting, noise, and electrical

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[1] EPA Quality Assurance Handbook Vol II, https://www.epa.gov/sites/default/files/2020-10/documents/final_handbook_document_1_17.pdf.

hazards. These hazards are identified and mitigated through safety walkthroughs, formal reporting of unsafe conditions, and regular training sessions on correcting safety hazards.

Training for data review is conducted by senior staff with at least one year of experience with refinery fenceline monitoring systems, as well as analyzer manufacturers. Project personnel are provided copies of the QAPP and SOPs, and receive updated versions when available. Initial training is provided prior to personnel performing work, and refresher trainings are conducted on an annual basis. The QA Manager will identify specific training requirements for all project personnel and will determine when trainees are qualified to work independently. Training records will be maintained by the Field Staff Manager.

5. Data Review and Quality Control

Data for the fenceline monitoring network appears on both public and internal websites (Figure 1). The internal website allows for detailed QC and flagging of the data, which are checked daily and finalized quarterly as outlined in Section D.2 of the QAPP. The following text describes how to perform daily and quarterly data verification and validation.

5.1 Daily Checks

Data are manually reviewed on a daily basis by qualified analysts. An internal, non-public field operations website (Sonoma Technology's Insight DMS) is used for customized data queries and visualizations, and the public-facing website is reviewed to ensure the real-time display is current and accurate. Instrument performance issues or data gaps are escalated to the field operations team, and the Project Manager determines the appropriate actions to resolve issues in a timely manner.

Data analysts are qualified to perform daily checks after a training period of at least two weeks. Training includes education on monitoring rules and requirements, instrumentation, automated QC processing, expected concentration ranges, diagnostic thresholds, and internal procedures to escalate a data issue. Trainees shadow an experienced data analyst during daily checks for a week, and are then overseen by an experienced analyst while they perform their first week of data checks.

This daily data review allows the analyst to visualize fenceline concentrations and instrument diagnostics, thereby identifying potential instrument performance issues and confirming the current operational status of the network. Instances of missing or invalid data, instrument signal strength below defined thresholds, repeated (stuck) data values, rapid changes (spikes or dips) in data values, or negative concentrations are recorded in a spreadsheet that tracks observations across a calendar quarter. This form provides a template for data analysts to check relevant parameters against acceptance criteria and commonly expected values for routine reference. Daily data check spreadsheets from past quarters are maintained in an archive with other project documentation.

The following procedure details the daily data check for an individual monitoring network:

1. Log in to the Sonoma Technology Insight DMS with the facility-specific credentials for the check being performed. Credentials are stored in a secure password management software.
2. Navigate to the Dashboard, which contains configurable widgets showing time series plots of relevant parameters.
3. Record any periods of **missing data** and verify that (1) missing data alerts were sent and (2) resolution is being pursued by the field operations team. If this cannot be verified, escalate the finding to the Project Manager.
4. Review any **detection events** and confirm the validity determination made by the after-hours on-call team through review of instrument diagnostic parameters and spectral validation (see Section 5.3 of this SOP).
5. Review recent **visibility measurements** and note any periods with visibility <2.5 miles on the spreadsheet.
    a. Periods with visibility <2.5 miles may impact performance of open-path analyzers and often correlate with observations of invalid data at multiple sampling paths.
6. Check that **meteorological instrumentation** is functional and that measured values are within reason (e.g. directional measurements are between 0–360 degrees, speeds generally match local weather conditions). Record any instances of missing or abnormal meteorological measurements in the daily observation spreadsheet and escalate to the field operations team.
7. Compare the current **open-path analyzer diagnostic parameters** to the acceptance criteria (see Section A.7 of the QAPP) to assess operational status of the monitoring network.
    a. Periods with diagnostic parameters (e.g. signal strength) outside of acceptance criteria will result in invalid data and may result from open-path analyzer misalignment. Record these periods in the spreadsheet and escalate to the field operations team for necessary site visits.
8. Because data flagging for each compound is determined by the analyzer diagnostic parameters, review one **representative compound concentration time series** for each analyzer at each sampling site, and note the following information:
    a. Any periods of missing or invalid data.
    b. Any periods of data flagged for additional review (i.e. automated checks for range, rate-of-change, and sticking).
    c. For periods where data were flagged as invalid due to environmental conditions, confirm that (1) analyzer diagnostic parameters are outside of acceptance criteria, and (2) visibility is <2.5 miles.
    d. Any QC and OP codes that are inconsistent with the expected values, based on analyzer diagnostic parameters.

   e. Instances of apparent baseline drift.
   f. Reported concentrations (valid data) not within the expected range for each compound.
      i. Verify that concentration patterns are reasonable with respect to the time of day, season, and current meteorological conditions, and whether they correlate across multiple sampling sites.
      ii. Verify that concentrations are within the limits of what can be measured by the instrument.

9. Perform any edits to QC and OP codes to reflect the findings of the daily data check. Additional information regarding propagation of these changes to the public website is provided in Section D.3 of the QAPP.
   a. Changes to **concentration values** are extremely infrequent and should only be made if a problem with the analytical concentration determination or the averaging scheme is discovered. Changes to QC and OP codes are often sufficient to correctly reflect data quality.
   b. Changes to **QC and OP codes** are infrequent, and are only made if a clear reason to do so is discovered.
      i. For example, invalidate data if a violation of the acceptance criteria that was not captured by AutoQC logic is discovered.
      ii. Similarly, validate data that was flagged for additional review if it meets acceptance criteria.
   c. All edits to data and data quality flags are captured by chain-of-custody logs within the DMS.
10. Verify detection events with elevated concentrations (>5–10 times the MDL) by performing spectral validation according to Section 5.3 of this SOP.
11. Navigate to the public website for the facility, review the 5-min time series plot for each individual compound, and verify that:
   a. Data displayed on the public site matches the data viewed in the non-public data review website (Sonoma Technology's Insight DMS). Note any discrepancies in the spreadsheet and escalate to the Project Manager.
   b. Periods of missing or invalid data are correctly reflected on the public website.
   c. Detection events are correctly reflected on the public website.
12. Report any observed anomalies to the field operations team and Project Manager, and update the daily data check spreadsheet in the project documentation archive. Additional information regarding project documentation is provided in Section A.9 of the QAPP.

Typical observations for select diagnostic parameters and compounds monitored under Rule 1180 are shown in Table 1. The full list of measured compounds is provided in Section A.5 of the QAPP.

Table 1. Typical observations for select compounds monitored under South Coast AQMD Rule 1180.

Parameter	Observational Notes
Visibility	The maximum value measured by the sensor is 30 miles. Values <10 miles may affect instrument performance, and values <2.5 miles may result in invalid data due to environmental conditions if analyzer diagnostics are also not within acceptance criteria.
Integration Time (UV-DOAS)	This parameter is commonly between 20–250 ms for most sampling sites. Values stuck at 300 ms should be recorded and escalated to the field operations team. A pattern of elevated integration time and low signal strength can indicate poor instrument alignment. This parameter should be anticorrelated with visibility during fog events.
Signal Strength (UV-DOAS)	This parameter is commonly >70%. A pattern of low signal strength can indicate poor instrument alignment.
Signal Strength (FTIR)	This parameter is commonly >2%. A pattern of low signal strength can indicate poor instrument alignment.
Winds	Wind speeds are typically 1-20 mph, and wind direction should generally follow expected patterns due to local terrain (e.g., sea and land breezes along the coast).
Benzene	This parameter is typically below the detection limit of the instrument.
Toluene	This parameter is typically below the detection limit of the instrument.
Ethylbenzene	This parameter is typically below the detection limit of the instrument.
o-Xylene	This parameter is typically below the detection limit of the instrument.
m-Xylene	This parameter is typically below the detection limit of the instrument.
p-Xylene	This parameter is typically below the detection limit of the instrument.
SO_2	This parameter is typically below the detection limit of the instrument, but ambient background concentration are detected occasionally.
H_2S	This parameter is typically below the detection limit of the instrument.

5.2 Quarterly Validation

Quarterly validation is performed after each calendar quarter to ensure quality and in accordance with Rule 1180 requirements. The 5-min resolution data for all relevant parameters are exported from the Sonoma Technology Insight DMS and imported into an R analysis workbook. Here, analysts perform additional analyses, visualizations, and assessments to verify AutoQC, confirm determinations made during daily data checks, and perform completeness calculations (see Section A.7 of the QAPP).

Data analysts are qualified to perform quarterly analysis after a training period of at least three months. Training includes the daily data check steps outlined in Section 5.1, experience conducting daily data checks for a period of three months, and shadowing an experienced data analyst during at least one complete quarterly analysis process. The trainee's work is reviewed by the experienced analyst while they perform their first round of quarterly analysis, and they are released for independent work during their second round.

The following procedure details the quarterly analysis process for an individual monitoring network:

1. Log in to the Sonoma Technology Insight DMS with the facility-specific credentials for the check being performed. Credentials are stored in a secure password management software.
2. Navigate to the Data Export page, where configurable export queries can be programmed and executed. Export all relevant parameters collected during the quarter as ".csv" files.
3. Import these exported data files into an R workspace using the most recent quarterly analysis script(s), maintained in the Sonoma Technology Bitbucket code repository.
4. Execute the quarterly analysis script(s), which performs the following tasks:
    a. Assign data flags using the same AutoQC logic as real-time data flagging (see Sections B.10 and D.2 of the QAPP).
    b. Flag negative outliers as invalid, using "–3 x MDL" as the threshold for comparison.
    c. Generate a series of output tables, figures, and ".csv" files for additional review.
5. Review the quarterly data set in detail. Note that findings pertaining to missing or invalid data are usually identified and corrected during the quarter, meaning the quarterly analysis process is commonly a redundant check on previously identified issues and resolutions. Any new findings identified during quarterly analysis must be escalated to the Project Manager for investigation, and proposed resolutions must be approved by the QA Manager.
    a. If >5% of diagnostic parameters (signal strength, spectral match) are missing, escalate the finding to the Project Manager for additional investigation.
    b. If >25% of missing or invalid data is associated with one analyzer or sampling site, escalate the finding to the Project Manager for additional investigation.

c. If concentration data were collected but coincident diagnostic information was missing or outside of the expected range, AutoQC determinations are manually inspected to ensure accurate data flagging.

    i. If visibility data is missing during a period of invalid concentration data, manual data review confirms that concentration data **are not** flagged as "invalid due to environmental conditions." In the absence of visibility data to confirm low-visibility conditions, data count against completeness (see Section A.7 of the QAPP).

    ii. If instrument diagnostic parameters are missing but concentration data are reported, a malfunction of the analyzer software has occurred and data are flagged as invalid.

    iii. If spectral match parameters are reported outside of the expected range (e.g. <0 or >100 for percent match), a malfunction of the data acquisition script has occurred and data are flagged as invalid.

d. Review periods where visibility data is <2.5 miles, ensuring that **only** concentration data with diagnostic parameters outside of acceptance criteria are flagged as "invalid due to environmental conditions" and are not counted against completeness.

e. Review periods of invalid or missing data lasting longer than two hours and escalate findings to the Project Manager. Create null records in the place of missing data according to Section C.2 of the QAPP.

f. Review periods of planned and unplanned maintenance and compare them to field logbooks and maintenance records. Ensure that routine maintenance was performed as scheduled, logs reflect a sufficient level of detail, and all bump tests results are within acceptance criteria.

    i. Any failed bump tests should have been followed by additional maintenance and retesting as outlined in the individual instrument SOPs.

    ii. Maintenance logs may explain data anomalies and justify adjustments to QC and OP Codes, following discussion with the Project Manager.

g. If applicable, review any questionable data for which investigation was not performed and QC and OP codes were not adjusted during the daily data checks. Adjust QC and OP codes according to Section D.2 of the QAPP and escalate the finding(s) to the Project Manager.

h. Review any and all changes to QC and OP codes, including their justification, with the Project Manager.

6. Assess the data reasonableness through statistical analyses, review of exceptional conditions off-refinery, and comparisons to outside data.

a. For all sampling sites and parameters, calculate the monthly and quarterly 5-min concentration mean, standard deviation, and minimum and maximum values. Non-detections are assigned a value of "0 ppb" for statistical analysis.

i. Compare observations to previous quarters and typical observations (Table 1) and escalate any anomalies to the Project Manager.

ii. Confirm that known detection events observed during the quarter are correctly reflected in the calculated monthly and quarterly maxima.

iii. Verify that the calculated monthly and quarterly minima are > "–3 x MDL," and escalate the finding of any negative outliers to the Project Manager.

b. In the event of anomalous data, review exceptional conditions off-refinery in conjunction with meteorological data to assess potential impacts to fenceline measurements.

c. In the event of anomalous data, retrieve available outside data sources for comparison according to Section B.9 of the QAPP.

7. Review any detection events and periods where reported concentrations are >5–10 times the MDL, according to Section 5.3 of this SOP.

8. For all sites and compounds, calculate data completeness according to Section A.7 of the QAPP.

   a. Review the resulting completeness tables and compare against logbooks and maintenance logs.

   b. Escalate findings of data completeness <95% to the Project Manager for additional investigation.

9. For all sites and compounds, manually calculate the rolling hourly average data from quality-controlled 5-min data, following the same logic used in real-time by the public website.

   a. Investigate the cause of any discrepancies between hourly values reported on the website and hourly values calculated during quarterly analysis, and escalate findings to the Project Manager.

5.3 Spectral Validation

Measurements made in real time by open-path analyzers can be replicated with manufacturer-provided data processing software. This enables analysts to visualize and confirm each real-time analytic determination made by the analyzer during daily and quarterly analysis, to ensure data accuracy and quality.

The following procedure details the spectral validation process:

1. Retrieve the relevant (raw) data files from the analyzer of interest, which correspond to the event requiring spectral validation.
    a. This consists of:
        i. The daily data summary file corresponding to the day of interest.
        ii. Individual absorbance spectra (including applicable background spectra) corresponding to the time period of interest.
        iii. Instrument libraries from the analyzer of interest.
        iv. The analytic software configuration file from the analyzer of interest.
2. Open the manufacturer-provided data processing software and adjust the analysis parameters to match the configuration file retrieved from the analyzer of interest.
3. Where applicable, load the instrument libraries and verify that the available compounds match the expected values for the monitoring network.
4. Examine the daily data summary file from the date and time period of interest to determine which individual absorbance spectra are of interest, and (where applicable) which dynamic background was loaded for each absorbance spectrum.
5. Load the applicable background and absorbance spectra. The software will automatically duplicate the analysis, according to the configuration parameters (see Step 2 above), and generate a differential absorbance spectrum overlaid with the applicable instrument library.
6. Select the compound of interest and visually inspect the plot, confirming the curve fitting to the library reference spectrum, and associated spectral match determination relative to the programmed analysis regions.
7. Report any discrepancies or incorrect peak fits to the Project Manager for additional investigation.

5.4 Quality Assurance Management

Following the completion of quarterly analysis, an independent review of post-QC quarterly data sets is completed by the QA Analyst. This independent review is conducted on a representative sub-set of data using similar methods to those described in Section 5.2 of this SOP. Data are reviewed without input from the data analyst who prepared the post-QC quarterly data set.

Findings of the independent review are compared to those of the quarterly analysis in a joint meeting between the Data Analyst, QA Analyst, and QA Manager. The QA Manager conducts an informal interview process to ensure that quarterly analysis was conducted according to the QAPP, and that field documentation reflects the procedures outlined by the QAPP. New findings or deviations are reported to the Project Manager by the QA Manager for additional investigation, and any necessary resolutions must be approved by the QA Manager before quarterly data are submitted (see Section C.2 of the QAPP).

6. Public Website Display

Data is displayed on the public website according to the data flags (QC and OP codes) for each record. Data flags are assigned by the AutoQC logic and further evaluated according to Section D.2 of the QAPP. Display behavior is the same for both 5-min data and rolling hourly average data.

Valid detections (e.g. QC=0, OP=0) are shown on the website (**Figure 2**). Concentrations are reported as recorded by the analyzer, with numeric values shown in the time series detail panel (left), the map detail panel (middle), and the map marker (right). For valid detections with concentrations below the MDL (e.g. QC=0, OP=17), numeric values are shown but data are flagged as "Below Detection" (BD). For hourly data only, the outer ring of the map marker visualizes the concentration relative to an hourly threshold, with green indicating values below the threshold and orange indicating values above the threshold.

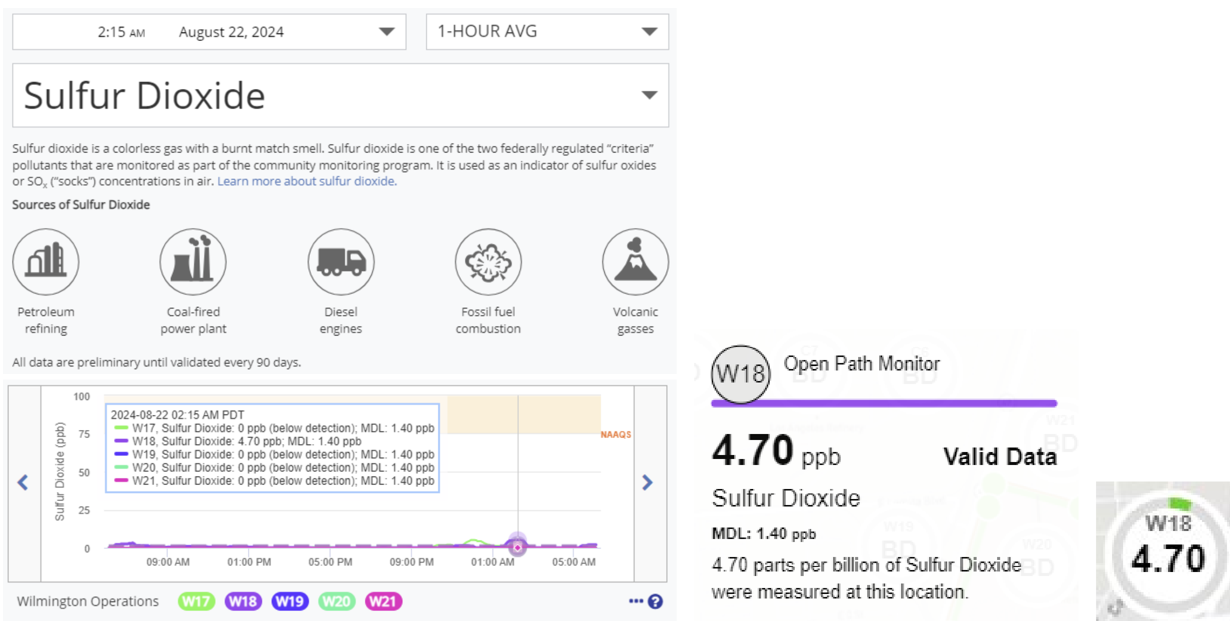

Figure 2: Example of valid detections as displayed on the public website.

Valid non-detections (e.g. QC=0, OP=74) are shown on the website (**Figure 3**). Concentrations are reported as "0 ppb" on the time series detail panel (left) according to Section D.2 of the QAPP. On the map detail panel (middle) and map marker (right), valid non-detections are flagged as "BD."

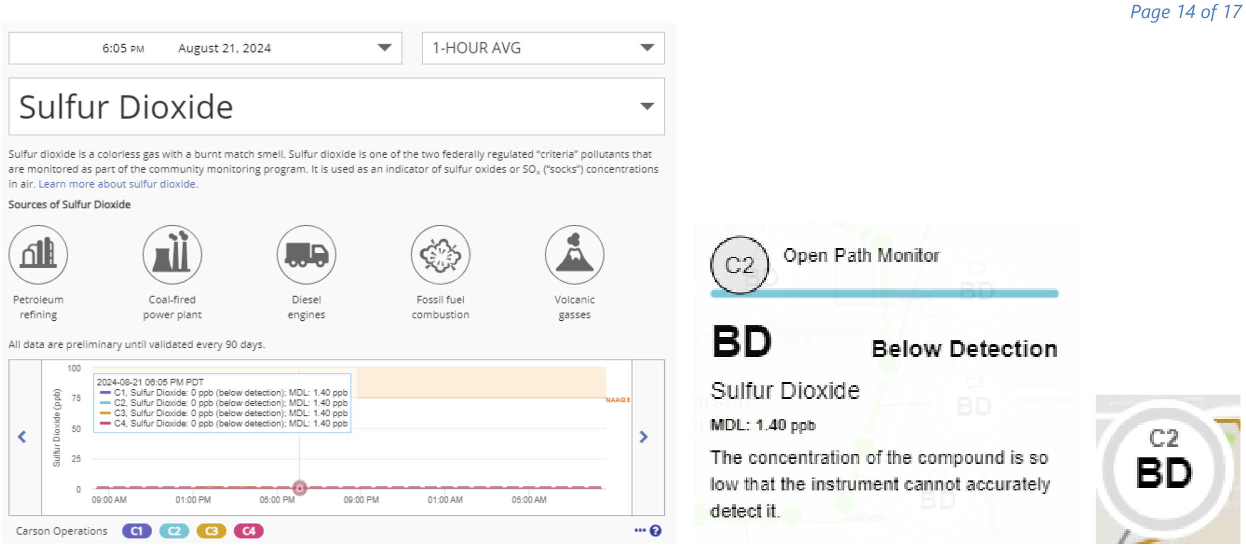

Figure 3: Example of valid non-detections as displayed on the public website.

Questionable data (e.g. QC=5) are shown on the website (Figure 4). Concentration values are reported on the time series detail panel (left), either as recorded (e.g. OP=72) or as "0 ppb" (e.g. OP=76), depending on whether or not they correspond to detection events. The map detail panel (middle) and map marker (right) may or may not display values (depending on the specific cause of the questionable data) and indicate that further review is needed. This additional review is completed according to Section D.2 of the QAPP.

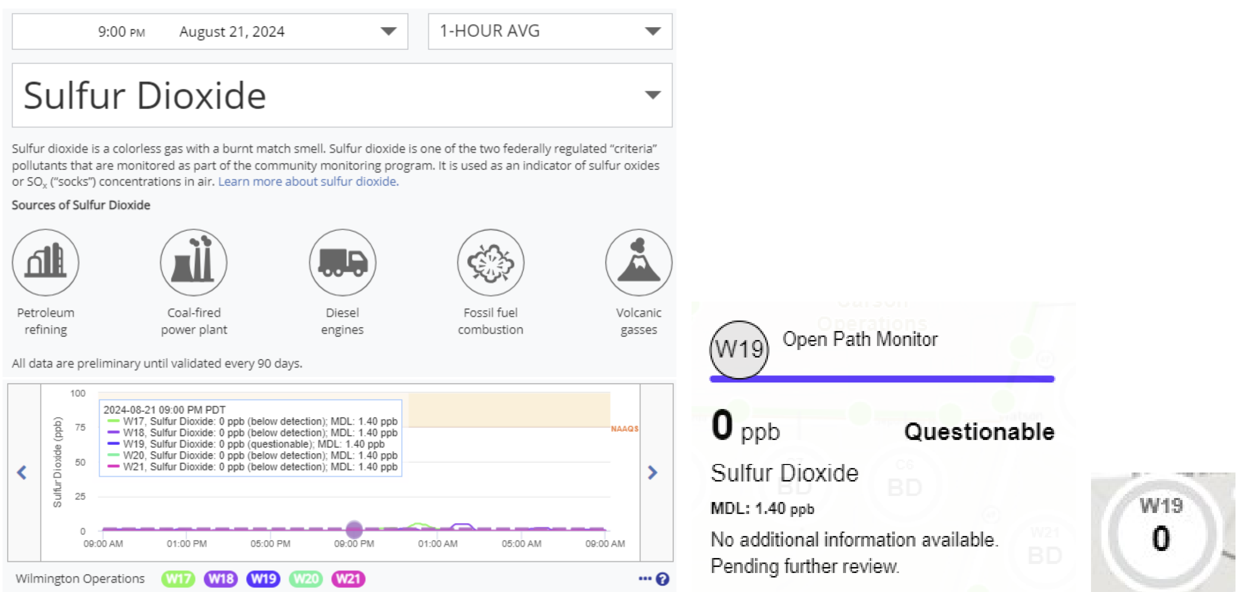

Figure 4: Example of questionable data as displayed on the public website.

Invalid data (e.g. QC=9) are not shown on the website (Figure 5). Concentration values are not reported on the time series detail panel (left), the map detail panel (middle), or the map marker (right) because the data do not meet acceptance criteria.

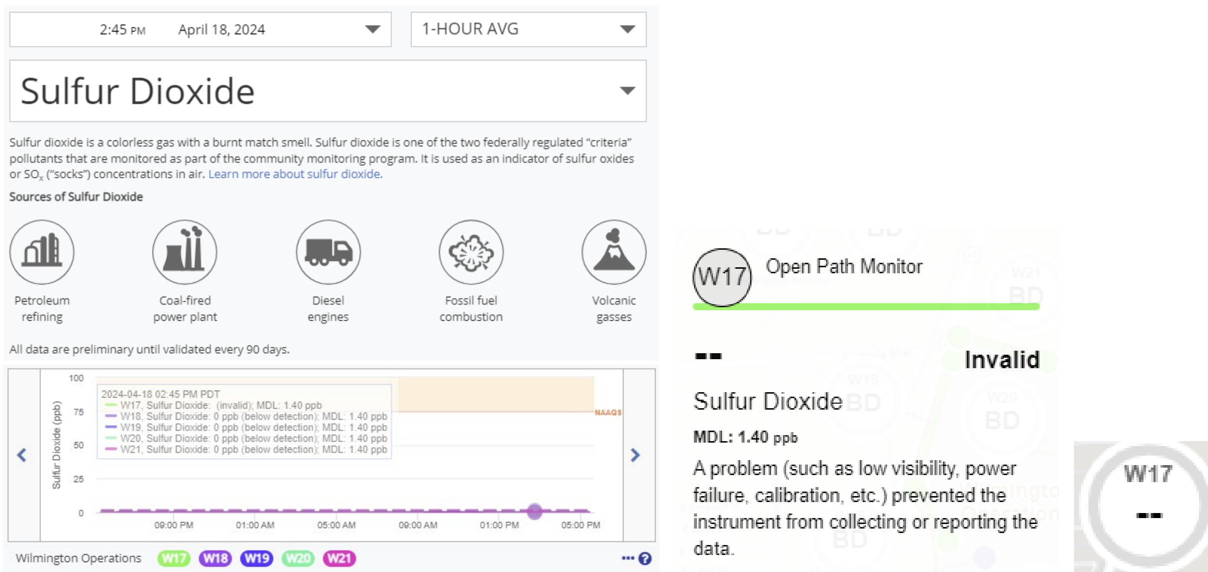

Figure 5: Example of invalid data as displayed on the public website.

Missing data (e.g. QC=8) are not shown on the website (Figure 6). Concentration values are not reported on the time series detail panel (left), the map detail panel (middle), or the map marker (right) because data were not collected. Missing data results in internal alerts to the project team (see Section B.6 of the QAPP).

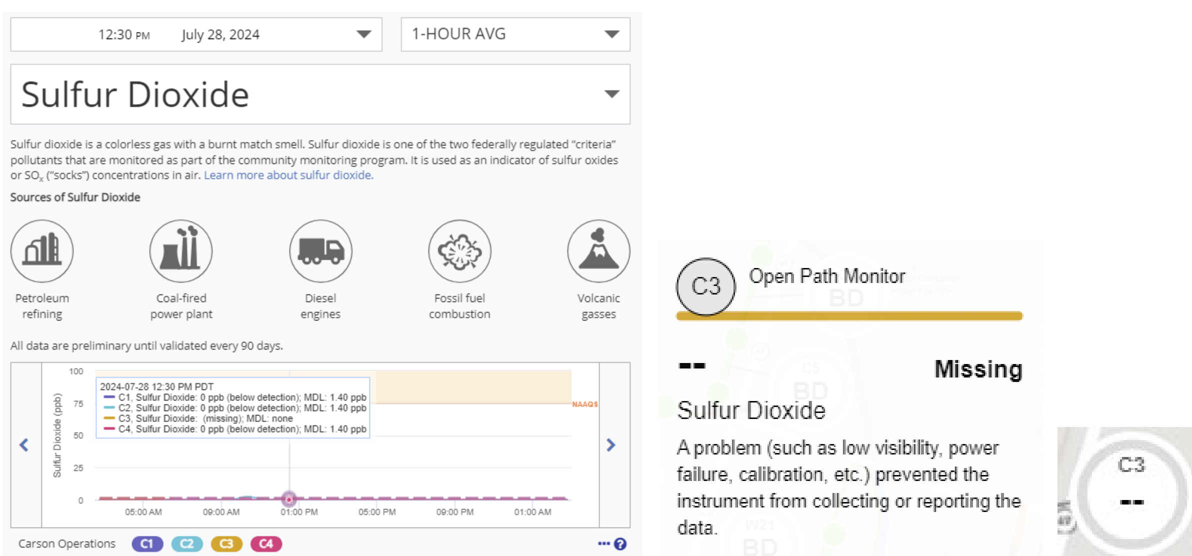

Figure 6: Example of missing data as displayed on the public website.

7. Daily Data Check Spreadsheet

Complete the checks described below and record observations in the space provided. Note any corrective action or issues that were escalated to the field operations team or Project Manager. Additional information regarding acceptance criteria is provided in Section A.7 of the QAPP.

Data Analyst: ________________________ Date and Time: ____________________________

Parameter	Reference	Observations
Internal Website Review (5-min data)		
UV-DOAS		
Integration Time	Confirm that values <300 ms	
Signal Intensity	Confirm that values >75%	
Representative Parameter (e.g., benzene)	Record any instances of invalid data	
	Record any instances of missing data	
	Record maximum concentration	
FTIR		
Signal Intensity	Confirm that values >2%	
Representative Parameter (e.g., Total VOCs)	Record any instances of invalid data	
	Record any instances of missing data	
	Record maximum concentration	
Met		
Visibility	Confirm that values >2.5 mi	
Wind Direction	Confirm that values are reasonable (0-360 degrees)	
Wind Speed	Confirm that values are within typical values for this site	
Point Monitors		
Black Carbon	Record any instances of invalid data	
	Record any instances of missing data	
	Record maximum concentration	
Hydrogen Sulfide	Record any instances of invalid data	
	Record any instances of missing data	
	Record maximum concentration	
Public Website Review (5-min data)		
UV-DOAS	Record any instances of invalid data	
	Record any instances of missing data	
	Record any benzene detection events	
	Record any toluene detection events	
	Record any ethylbenzene detection events	
	Record any o-xylene detection events	
	Record any m-xylene detection events	
	Record any p-xylene detection events	
	Record any NO_2 detection events	
	Record any SO_2 detection events	

FTIR	Record any instances of invalid data	
	Record any instances of missing data	
	Record any hydrogen cyanide detection events	
	Record any 1,3-butadiene detection events	
	Record any ammonia detection events	
	Record any acrolein detection events	
	Record any formaldehyde detection events	
	Record any acetaldehyde detection events	
	Record any carbonyl sulfide detection events	
	Record any styrene detection events	
	Record any total VOCs detection events	
Point Monitors	Record any instances of invalid data	
	Record any instances of missing data	
	Record any black carbon detection events	
	Record any hydrogen sulfide detection events	
All Compounds	Record any instances of missing data	