Quality Assurance Project Plan

Prepared by

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Prepared for

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A. Project Management

A.1 Title Page

Quality Assurance Project Plan
Fenceline Monitoring for the Phillips 66 Los Angeles Refinery in Wilmington, California

The attached Quality Assurance Project Plan (QAPP) is hereby recommended for approval and commits the Phillips 66 Los Angeles Refinery – Wilmington Operations (P66 Wilmington Refinery) to follow the elements described within.

A.2 Table of Contents

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Review and Revision History

Revision Number	Date	Responsible Party	Description of Change
1	October 8, 2019	P66	Initial Submission to South Coast AQMD
2	October 11, 2019	P66	Revised Submission to South Coast AQMD
3	August 5, 2024	P66	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 annually 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 P66 in Wilmington, 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
Environmental Services Department	Phillips 66 Wilmington	Refinery Contact(s)
Public Relations Department	Phillips 66 Wilmington	Field Communication Advisor(s)
Wayne Nastri	South Coast AQMD	Executive Officer
Andrea Polidori, PhD	South Coast AQMD	Assistant Deputy Executive Officer, Monitoring and Analysis Division
Olga Pikelnaya, PhD	South Coast AQMD	Rule 1180 Program Manager
Hilary Hafner	Sonoma Technology	Quality Assurance Officer
All Project Personnel	Sonoma Technology	Various

Personnel included in 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 and equipment, data management and quality control (QC) procedures, and public reporting via automated notifications and a publicly accessible website.

Refinery staff work with a designated contractor to achieve the goals of the fenceline monitoring network. An organization chart (**Figure 1**) and various project roles are detailed below. Project contact information is provided in **Table 1**.

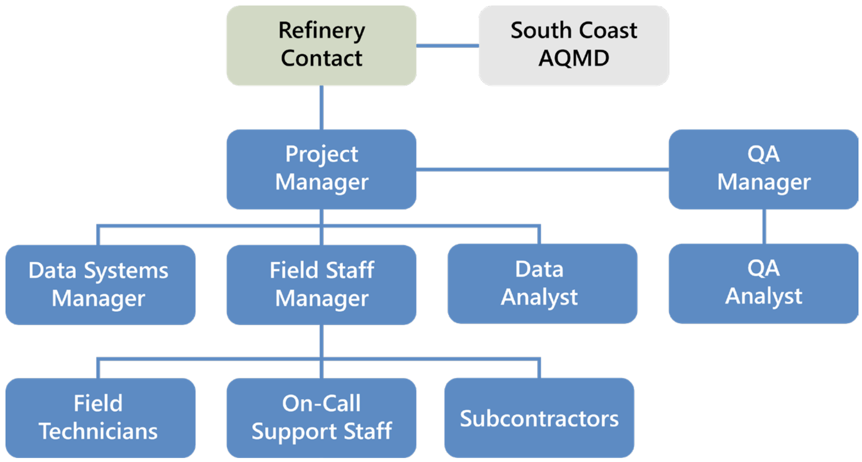


Figure 1. Organization chart for the refinery's fenceline monitoring project.

Refinery Contact. The Refinery Contact is responsible for project 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 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 to ensure that the QAPP and SOPs are followed, and oversee corrective action plans when needed.

Quality Assurance Manager. The Quality Assurance Manager (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 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. Field Technicians are responsible for the successful operation of instrumentation and equipment, providing 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. 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 Field Staff Manager and adhere to all project requirements.

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
24-Hour Community Awareness	P66 Wilmington Refinery	Field Communication Advisor(s)	larpaac@p66.com 310-543-7431 (English and Spanish)
Hilary Hafner	Sonoma Technology	QA Manager	hilary@sonomatech.com 707-665-9900

A.5 Problem Definition and Background

The P66 Los Angeles Refinery conducts air quality monitoring at its refinery in Wilmington, CA, 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], particulate matter less than 10 and 2.5 microns in

[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

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, nickel), and other compounds (hydrogen sulfide [H_2S], carbonyl sulfide, ammonia, black carbon [BC], hydrogen cyanide, hydrogen fluoride). Facility-specific exemptions and justifications for monitoring are detailed in the FAMP.

The P66 Wilmington Refinery includes an optical tent monitoring system that provides open-path monitoring using UV-DOAS instruments along four fenceline paths. This system was installed as part of the Multiple Air Toxics Exposure Study V (MATES), which was conducted by South Coast AQMD in 2018-2019 to collect information on air toxics and their associated health risks throughout the South Coast Air Basin through long-term monitoring. The optical tent at the Wilmington Refinery was authorized by the South Coast AQMD Governing Board as an advanced monitoring project, and it was adopted as part of the fenceline air monitoring system after the MATES V study ended.

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 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 Standards (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 and Section B of this document.

Table 2. Rule 1180 notification thresholds.

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

[a] The minimum detection limit (MDL) is greater than the notification threshold for this compound, so notifications are not sent, as described in the FAMP.

A.6 Project Description

The P66 Wilmington Refinery currently conducts fenceline monitoring of criteria air pollutants (SO_2, NO_2), volatile organic compounds (total VOCs, formaldehyde, acetaldehyde, acrolein, 1,3-butadiene, styrene, BTEX), metals (cadmium, manganese, and nickel) and other compounds (H_2S, carbonyl sulfide, ammonia, BC, hydrogen cyanide). Naphthalene, $PM_{2.5}$, PM_{10}, and metals will be monitored following the January 5, 2024, amendment of Rule 1180, as described in the FAMP. The Wilmington Refinery is exempt from monitoring hydrogen fluoride and PAHs.

Sampling sites were selected in consideration of nearby local receptors (e.g., schools and 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, and final quarterly data sets will be (1) made available for public download and (2) made available to be transmitted electronically to the South Coast AQMD Executive Officer. Additional details are provided in the FAMP and Section B of this document.

Additional details about the fenceline monitoring project are provided in the FAMP.

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:

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 facility's 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 serve as a basis of comparison.
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, 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 the 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 ($\mu g/m^3$), 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. Quantitative metrics for calculating completeness are detailed further within this section.

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	≥10%
FTIR		
Bump Test (Accuracy and Precision)	Quarterly (and after major service)	±25%
Amplitude Ratio (Analogous to Spectral Match)	Continuous	≥0.9
Zero Path Difference (ZPD) Peak to Peak Voltage (Analogous to Signal Intensity)	Continuous	≥0.1
ZPD Position	Continuous	256–257
H_2S Point Monitor		
Span Test (Accuracy and Precision)	Biweekly (and after major service)	±15%
Zero Test	Biweekly (and after major service)	±2 ppb
Multipoint Calibration	Quarterly (and after major service)	±2 ppb (zero) ±15% (each nonzero test conc.)
Aethalometer		
Flow Check	Monthly	±10%
Neutral Density Check	Quarterly	±10%
PM Analyzer		
Flow Check	Monthly	±5%
Span Dust Check	Quarterly	±0.5 channel tolerance
Meteorological Sensors		
Wind Speed (accuracy)	Semiannual	±0.25 m/s (below 5 m/s) ±5% (above 5 m/s)
Wind Direction (accuracy)	Semiannual	±5 degrees
Temperature (accuracy)	Semiannual	±0.5 degrees C
Relative Humidity (accuracy)	Semiannual	±7%
Visibility Sensor		
Extinction Coefficient (accuracy)	Annually	±25%

Completeness

Data completeness is assessed by reviewing the data 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 this quarter.

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

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

- Missing = Possible – Captured

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

- % Missing = (Missing / Possible) * 100

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

- Expected = Possible – Invalid-Weather – Planned Maintenance

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

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

- % Invalid = (Invalid / Possible) * 100

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

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

- % Suspect = (Suspect / Possible) * 100

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

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

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

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

Optical Tent System

Data generated by the optical tent system is quality controlled externally and included in routine reporting via the public website and notification system, and quarterly reports.

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 available. Initial training is provided prior to personnel 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 will 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 1–9).

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 quality 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 Project Manager creates a DOTS entry for each upcoming deliverable, and then the project 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 by P66 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. Once installed, visibility sensors will 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.

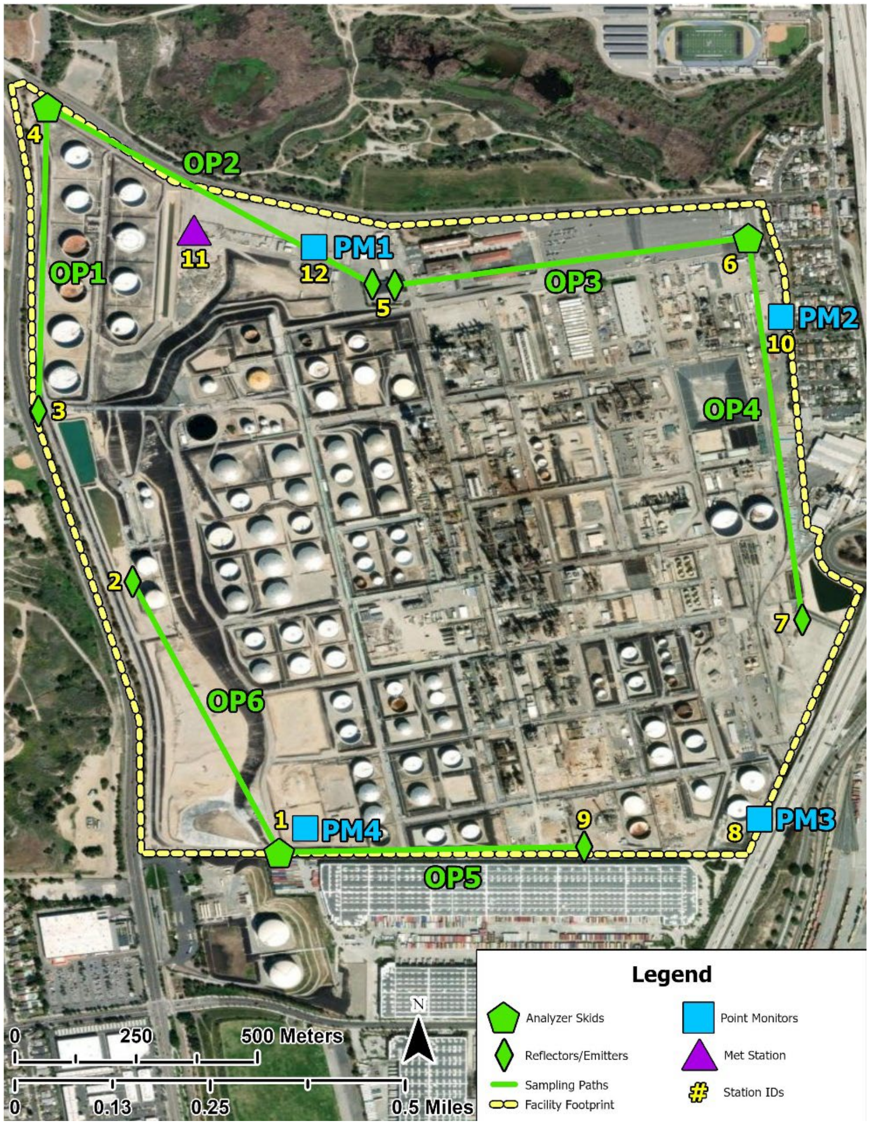


Figure 2. Sampling locations for the P66 Wilmington Refinery fenceline monitoring system.

B.2 Sampling Methods

BTEX, SO_2, and naphthalene are measured by bistatic UV-DOAS (source and detector on opposite ends of the sampling path) 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. This is measured by the analyzer, which then compares regions of a sample absorbance spectra to the same regions of a reference absorbance spectra.

Total VOCs (measured as a sum of hexane and 1,3-butadiene), formaldehyde, acetaldehyde, acrolein, 1,3-butadiene, styrene, carbonyl sulfide, ammonia, hydrogen cyanide, and NO_2 are measured by monostatic FTIR, which operates similarly to the UV-DOAS. A combination of industry standard and proprietary methods are used to mitigate interference from water vapor and interference gases.

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 due to 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.[3]

BTEX and naphthalene are measured along four fenceline paths by monostatic UV-DOAS via the optical tent system.

H_2S concentrations are measured through UV-induced fluorescence, whereby H_2S is converted to SO_2, exposed to UV light, and the resulting emitted photon is measured in real time. 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.

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.

[3] 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.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 manufacturers, 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 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		✓	

Activity	Monthly	Quarterly	Annually
Clean detector optics			✓
Document signal levels to establish a baseline for light source replacement frequency			✓
Verify system settings			✓

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

Activity	Monthly	Quarterly	Annually	Biannually
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)	✓			
Perform bump test		✓		
Clean retroreflectors		✓		
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 the light source			✓	
Replace cryocooler				✓

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
Perform Zero and Span (Z/S) check	✓		
Review and verify test functions	✓		
Inspect sample lines	✓		
Change inlet particulate filter	✓		
Perform flow check		✓	
Perform multi-point check		✓	

Activity	Monthly	Quarterly	Annually
Replace SO_2 scrubber material and sintered filters			✓
Check for H_2S->SO_2 converter efficiency (CE), replace or service the converter if CE < 96%			✓
Replace the critical flow orifice assembly			✓
Perform a pump check and rebuild if needed			✓
Perform leak check			✓
Perform UV lamp adjustment			✓
Perform photomultiplier tube (PMT) sensor hardware calibration			✓
Calibrate offset and slope			✓

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	✓		
Inlet flow check	✓		
Clean size selective inlet	✓		
Clean cyclone	✓		
Verify date and time	✓		
Calibrate flow	✓		
Inspect tape roll and replace as needed		✓	
Inspect optical chamber and clean as necessary		✓	
Calibrate tape sensor		✓	
Clean air test		✓	
Stability test		✓	
Neutral density filter test			✓
Grease optical chamber sliders			✓
Inlet leakage test			✓
Change bypass cartridge filter			✓

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 9).

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			✓

Semiannual maintenance activities for the meteorological sensors are summarized in Table 10 and additional details are provided in the SOP (Attachment 6). Calibrations are conducted according to EPA recommendations.[4,5,6]

Table 10. Semiannual 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.

[4] U.S. Environmental Protection Agency (1994) Quality assurance handbook for air pollution measurement systems, Volume I: a field guide to environmental quality assurance. EPA/600/R-94/038a. Available at https://www3.epa.gov/ttn/amtic/qalist.html.
[5] U.S. Environmental Protection Agency (2017) Quality assurance handbook for air pollution measurement systems, Volume II: ambient air quality monitoring program. EPA-454/B-17-001, January. Available at https://www3.epa.gov/ttnamti1/qalist.html.
[6] U.S. Environmental Protection Agency (2008) Quality assurance handbook for air pollution measurement systems, Volume IV: meteorological measurements version 2.0 (final). EPA-454/B-08-002, March. Available at https://www3.epa.gov/ttn/amtic/qalist.html.

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) 24 hours a day, 7 days a week. 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 cause of 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. 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

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 in the instrument SOPs (Attachments 1–9).

A new and improved bump test procedure using NIST-traceable reference gas and flow through test cells is currently under development. 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 benzene and ammonia are typically on the order of 1–20 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/fan 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, and then 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 other 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 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 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).

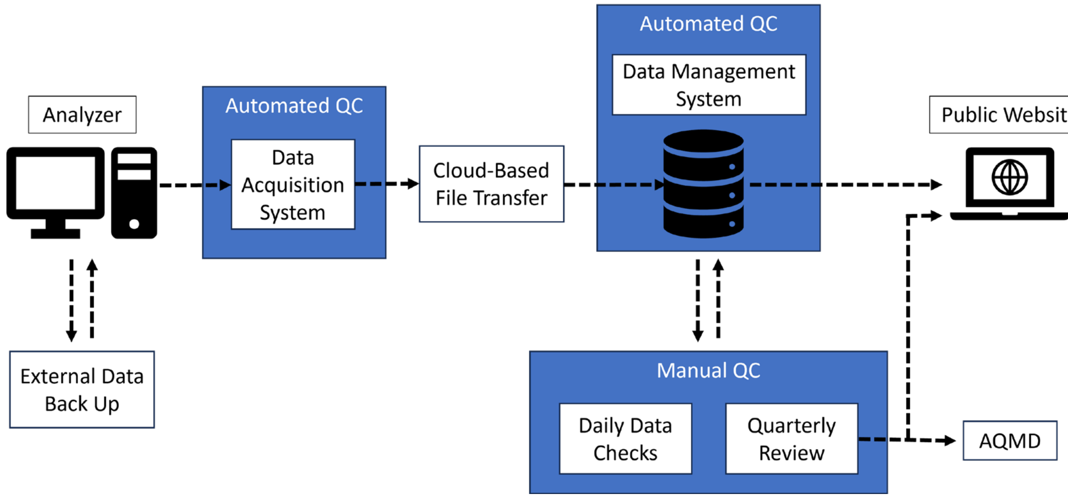


Figure 3. Data flow and QC schematic.

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 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 qualified 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 (usually 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 and operational [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.

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.

Data Accessibility

The most recent 5 calendar years of electronic historical data collected by the fenceline monitoring system will be made available within 60 calendar days after the conclusion of each quarter for public download in an easily downloadable, accessible, and interpretable electronic format that is approved by the South Coast AQMD Executive Officer.

Upon request, the most recent 5 calendar years of electronic historical data collected by the fenceline monitoring system will be available to be transmitted electronically to the South Coast AQMD Executive Officer within 60 calendar days after the conclusion of each quarter in a format that is approved by the Executive Officer.

D. Data Validation and Usability

D.1 Data Review, Verification, and Validation

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 usually consists of checking that SOPs were followed and QC activities were performed.[7]

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.[7]

To produce defensible, high quality environmental information for its intended use, data shall:

- Meet regulatory requirements
  - Monitor in accordance with the FAMP
  - Achieve the acceptance criteria outlined in the QAPP
  - Follow the procedures outlined in the relevant 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.

[7] 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 operations assessment and ensures that automated data flagging is correct. Data Analysts may adjust the QC and 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 and 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 is 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 the 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 the data require additional review but are likely accurate. Other causes of suspect/questionable data include concentrations out of 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 concentration to the defined instrument MDL. Additional information regarding how data is 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 the 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	3,900	1,300	
Ethylbenzene	3,900	1,300	
Total Xylene	15,000	5,000	
SO_2	225	75	
Naphthalene	225	75	
Total VOCs	2,190	730	
Formaldehyde	132	44	
Acetaldehyde	780	260	
Acrolein	90	30	

Compound	Range (ppb)	Rate-of-Change (ppb)	Sticking
1,3-Butadiene	891	297	
Styrene	15,000	5,000	
Carbonyl Sulfide	810	270	
Ammonia	13,521	4,507	
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. The Data Analyst 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, the Data Analyst investigates 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 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 and 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.

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 and 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 another data analyst. 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 review and reporting and will be made available for electronic transmission to the South Coast AQMD Executive Officer and also made available 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 and OP codes is shown in Table 15. Additional details regarding QC and OP codes are provided in Table 12.

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 on the website, 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 a 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 UV-DOAS
- **Attachment 2**: Standard Operating Procedure for the Kassay RAM 2000 Open-Path FTIR
- **Attachment 3**: Standard Operating Procedure for the Teledyne T101 H_2S Point Monitor
- **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 Meteorological Instruments
- **Attachment 7**: Standard Operating Procedure for Belfort Model 6400 Visibility Sensor
- **Attachment 8**: Standard Operating Procedure for Data Verification and Validation
- **Attachment 9**: Standard Operating Procedure for the SaliBri Cooper Inc. Xact 625i

Sonoma Technology

Standard Operating Procedure for the UV-DOAS

August 5, 2024

STI-8196

Contents

1. Scope and Application

This SOP covers the use of the open-path (OP) ultraviolet differential absorption spectrometer (UV-DOAS) analyzer at the Phillips 66 Los Angeles Refinery – Carson and Wilmington operations (P66 Carson Refinery and P66 Wilmington Refinery) fenceline monitoring systems. This document addresses routine maintenance activities including visual inspections, instrument checks, data management, and quality assurance (QA) audit testing. The maintenance forms are provided in Section 7.

2. Introduction and Overview

The OP UV-DOAS analyzers at the P66 Carson and Wilmington Refineries (P66 OP UV-DOAS) consist of Argos Scientific hardware with Cerex Monitoring Solutions (CMS) analytic software. The P66 OP-UV-DOAS analyzer is capable of detecting benzene, toluene, ethylbenzene, xylenes (BTEX), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and a number of other gases in the ultraviolet (UV) region of the electromagnetic spectrum. The P66 OP UV-DOAS analyzer is installed in a bistatic configuration, with an emitter at one end of the monitoring path and a receiver at the opposite end.

The emitter is equipped with a xenon UV source and collimation optics that projects the light beam to the receiver, and is mounted on a Quickset motorized positioner device that can be controlled remotely to align the emitter to the receiver. The receiver is equipped with steering optics, a spectrometer, and a manual pan and tilt mechanism for aligning the receiver to the emitter. The working range of the spectrometer includes wavelengths between approximately 200 and 315 nm.

This document addresses the routine operations and maintenance procedures for the P66 OP UV-DOAS analyzer, and is intended to guide field technicians in ensuring and verifying that equipment is performing to expectations. Proper field maintenance ensures the instrument is operated within specification. The QA Test process challenges the instrument using a target gas contained within a sealed cell attached to a linear actuator within the receiver. During the QA Test the linear actuator is used to insert the cell into the beam path. The resulting concentration measurements are evaluated for analyzer performance. Precision is calculated according to the QAPP.

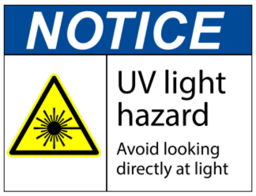
3. Safe Work, Hazard Identification, and Precautions

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

Operator Qualifications

The P66 OP UV-DOAS analyzers should only be installed, operated, and serviced by personnel who have been trained in the operation of the system components and are familiar with the potential hazards associated with the deployment site, installation infrastructure, instrument access methods, and the handling of gas delivery and testing equipment. Work should conform to the manufacturer guidance and site health and safety practices.

The P66 OP UV-DOAS analyzer is 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. P66 Opp UV-DOAS analyzers contain an UV 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 P66 OP UV-DOAS analyzer. 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, powder-free 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 (FTT) 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 (no missing data, no high values, etc.).
- ❒ Take equipment out of maintenance mode.
- ❒ Notify the project manager and client when maintenance is complete.

4. Routine Operations

To set the P66 OP UV-DOAS analyzer to acquire data for normal operations, the instrument CMS must be operating and the instrument must be aligned.

Alignment Procedure

The P66 OP UV-DOAS analyzer system requires alignment of both the emitter and receiver components. In most instances, proper alignment can be achieved by only adjusting the position of the emitter. The receiver component generally only requires alignment after having been physically bumped or exposed to a seismic event. Always verify proper alignment of the emitter through direct observation before adjusting the receiver component.

1. Log Activity in the site logbook and/or an electronic notebook.
2. Log into FTT, place the analyzer in planned maintenance mode, and disable missing data alerts.
3. Start the PTCR-96 software on the analyzer computer. This software allows remote adjustment of the emitter.
4. Connect PTCR-96 to the Auto-positioner by pressing **Start** within PTCR-96. The software will attempt to communicate with the auto-positioner. *Multiple attempts may be required to successfully connect to the auto-positioner.*
    a. Upon successful connection, all tabs in the PTCR-96 graphical user interface (GUI) will become available.
    b. Note the current coordinates by saving them as a preset or writing them down.
    c. If PTCR-96 fails to connect to the auto-positioner:
        i. Open CPR Manager software (Desktop Icon) to confirm there is a network connection to the MOOG positioner. Exit PTCR-96 and try again. *Repeat as necessary.*
        ii. Rebooting the computer may be required to regain network connection to the MOOG positioner.
5. Open the CMS Align Window. In CMS, press **Stop > UV Tab > Align**. Observe the intensity reported in the lower left corner (see the red box in **Figure 1**) of the Align window while adjusting alignment.

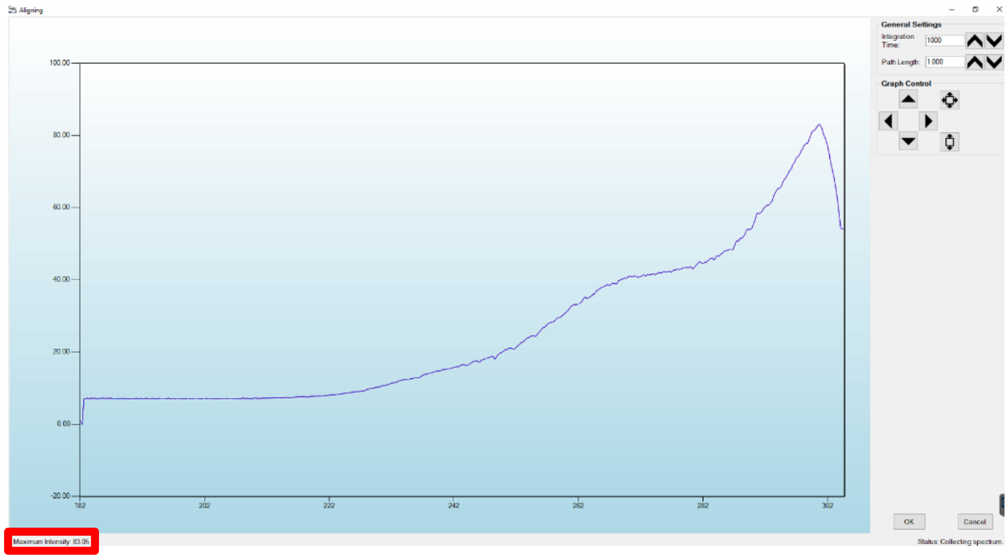


Figure 1. Screenshot of CMS in **Align** mode

6. In PTCR-96 (Figure 2) press the **Presets** Tab. Select the first preset 0 and click **Save Current Position As Preset**. Select preset 1 and click **Save Current Position As Preset**. With preset 1 selected, modify the Pan or Tilt coordinates to adjust the position, clicking **Save Coordinates As Preset** after each adjustment and double clicking **preset 1** to move the MOOG positioner to those coordinates. Leave the positioner at the coordinates resulting in the highest maximum signal as observed in the Align window and click **Save Current Position As Preset** to save those coordinates to preset 0.

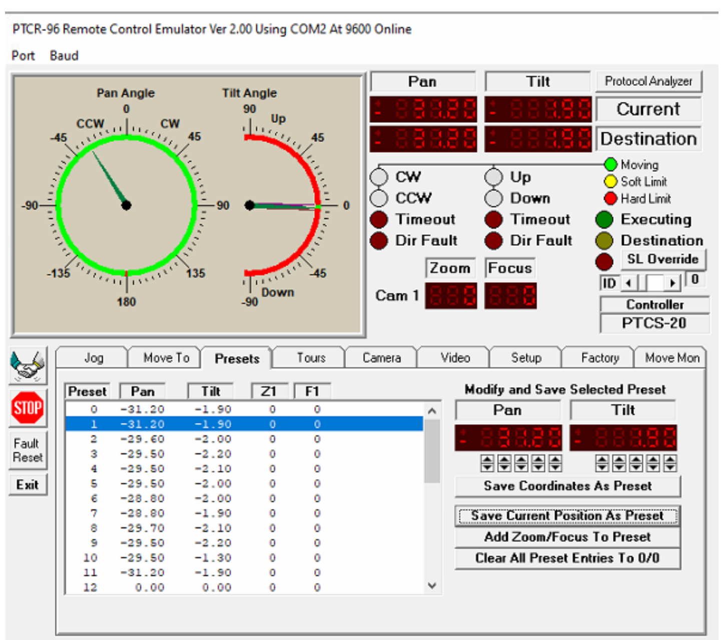


Figure 2. PTCR-96 software.

a. If the system saturates (identified when the top of the intensity curve is not visible due to being maxed out), reduce the integration time value in the Align window to a value resulting in a maximum intensity of approximately 50% (do not set integration time to less than 8 msec). Repeat testing coordinates to maximize intensity. For some paths, it may be necessary to repeat this process several times if xenon UV sources are new.

b. If the auto-positioner stops responding to coordinates, change the following commands:

   i. Press the **Fault Reset** button and try again. You may observe that a timeout indicator is lit.

   ii. Press the **SL Override** button and try again.

   iii. Restart PTCR-96 and try again.

7. If it is not possible to achieve signal intensity greater than 20% at 1,000 msec integration time, notify the project manager.

8. Dismiss the Align window and press **Yes** if prompted to save any changes on exit.

9. When normal data flow has resumed, place the analyzer in normal operation mode and enable missing data alerts in FTT.

   Note: If you need to change any setting back to the original configuration, click **File** > **Save** > **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.

   Example CMS settings are shown below.

- <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: OFF
    - Single Data Folder: OFF

        - Primary Summary File Logging: ON
            - C:\Users\CMS-USER\Documents\Cerex\Data
        - Secondary Summary File Logging: OFF
        - 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
        - Zero Readings on Negative Concentrations: OFF
        - Display BDL: OFF
        - Quick Analysis MDL Wave length Range: 276-280 (range does not matter)
        - Temperature/Pressure Concentration: OFF
    - Filters
        - Absorbance Savitzky-Golay: ON
            - Derivative Order: 0
            - Polynomial Order: 1
            - Wavenumber Range: 200-307
            - Window Size: 3
        - Baseline Correction Savitzky-Golay: OFF

- <u>Instruments</u>
    - UV
        - Operation
            - UV: ON
            - Acquisition Time (s): 60 (this is the "averaging time" of the instrument)
            - Integration Time (msec): Self adjusting if auto integration is turned on. This is the amount of time that the instrument will collect light.
            - Path Length (m): 1 (2 for monostatic, 1 for bistatic)
            - Trigger Mode: Normal

        - Auto Routine
            - Auto Integration: **ON** (the software will determine integration time)
            - Intervals (s): 60
            - Wavenumber Range: 295-300 (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: 80-92 (this is the target intensity range for the autointegration routine)
            - Maximum Integration: 1,000
            - Auto Background: **ON**
            - Interval (Acquisitions): 5
            - Wavenumber Range: 295-300
        - Verification
            - Verification: **OFF** (this inactivates all inputs)
- <u>Controller</u>
    - General
        - Serial Port: n/a
        - Sensor Refresh Interval (s): 15
    - Sensors
        - Do not Touch Anything
    - Alarms
        - Do not Touch Anything
- <u>Email</u>
    - General
        - Data Recipient: Blank
        - Email Sender: Blank
        - Email Periods (s): 60 (time does not matter as we do not use this setting)
        - Send Data: **OFF**
    - SMTP
        - Server: smtp.gmail.com
        - Port: 587
        - Username: Blank
        - Password: Blank
        - Timeout (s): 100
        - SSL Authentication: ON
- <u>Auxiliary Coms</u>
    - Modbus
        - Modbus: **ON**
        - System Type: Ethernet
        - TCP Port: 502

- Unit ID: 2
- 16-bit unsigned int to: OFF

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

5. 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 P66 OP UV-DOAS analyzers – especially lens paper
4. All relevant PPE, hardware, and procedural guidance per the 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 analyzer (as required)
7. P66 OP UV-DOAS analyzer
8. Isopropyl alcohol (≥80%)
9. Distilled water
10. Pressurized sprayers
11. UV-source bulb
12. Powder-free nitrile or latex gloves

6. Maintenance Activities

The following section outline the routine performance indicator checks and maintenance activities to be carried out for each analyzer. Maintenance forms used to indicate when the checks are completed and document any corrective actions taken are in Section 7. These activities are also expected, based upon the project plan, to be logged in a site logbook in hard copy or electronic form, and can reference this SOP and associated forms.

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

- Visually inspect the system.
- Inspect optics on detector and retroreflector and clean if necessary.
- Confirm the alignment to verify there has not been significant physical movement. Note: this is automatically monitored as well.
- Download data from the detector hard drive and delete old files to free up space, if needed. Ensure data are backed up on two external drives before deleting.
- Ensure there are no obstructions between the detector and the retroreflector (such as equipment, vegetation, vehicles).
- Change out the xenon UV source.
- 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.

6.1 Visual Inspections

1. Ensure 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 and 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.
6. Power up the instrument, make sure CMS software has started, and realign the instrument.

6.2 Light Level Check

For good visibility conditions, signal strength is normally >20% and integration time is normally between 300 and 1,000 ms. Signal intensity <17% indicates realignment may be necessary. Signal intensity <10% results in invalid data and warrants immediate corrective action.

Check and record signal strength at 250 nm. Minimum signal intensity at 250 nm should be greater than 5%.

6.3 System Settings

Check the system settings against those documented in Section 4. If any settings do not match, provide any explanation for the changes. If you change any settings, document how the settings were changed in a site logbook. Note all instrument settings are saved daily by the analyzer.

6.4 Data Management

6.4.1 Archiving and Deleting Older Data

Note: Data older than twelve months should be deleted from the instrument (frequency as described in the QAPP) to prevent the instrument from filling its internal hard drive.

Raw instrument data are stored on the analyzer computer. Data consist 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 computer 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.

Details on the proper procedure for deleting data files from the instrument are as follows.

1. Confirm the data files have been successfully written to two external hard drives.
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: 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 auxiliary (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 period have been transferred over completely to the two external hard drives.
6. Once you have confirmed that those files have transferred over to the external hard drives,

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

delete those exact complete data summary and simple data summary files from the instrument data folders on the analyzer computer.

7. For each individual day of single beam folders, ensure the amount of single beam files are the same on the internal hard drive of the instrument and the two external hard drives.
8. If all 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 available on the instrument's internal drive. If removal of the files does not result in enough disk space (based on previous data transfers), the disk drive may need to be reindexed (Section 6.4.2).

6.4.2 Rebuilding the Instruments Indexing Preferences

If deleting data from the instrument does not seem to increase free instrument disk space, 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 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 instrument's 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 indexing has been completed.

6.5 Cleaning Optics

Cleaning external windows on the receiver and emitter is an important part of the maintenance plan. Caution should be taken as there are electrical fan heaters that are used to keep moisture and particulates from collecting on the retroreflectors.

If light levels are low or visual inspection reveals soiled optics, cleaning can improve light throughput. In general, if the optic is not dirty, do not 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. Power the component off as compressed canned air is flammable. Use compressed air/canned air to gently blow particles from the optic surface. For reflective optics, Stop here.

3. External quartz windows may receive further cleaning using solvent and lens paper. Use a solvent (isopropyl alcohol) and lens tissue to wipe the optic clean, wiping slowly from the edges first with an alcohol-soaked lens tissue. One technique is to drop solvent on the unfolded lens tissue and drag from one end to the other.
4. Allow all alcohol to evaporate before powering component on.

6.6 Xenon UV Source Replacement

NOTICE

- Never power on the P66 OP UV-DOAS emitter without a properly installed xenon UV source.
- Powering on the emitter without a xenon UV source may cause an electrical short, which will permanently damage the instrument.
- Always remove the xenon UV source from the emitter prior to transporting or shipping.
- Failure to remove the xenon UV source from the emitter prior to transporting or shipping may cause destruction of the source.
- Always check the polarity of the xenon UV source for proper installation prior to powering the emitter on.
- Installing the xenon UV source with reverse polarity will permanently damage the xenon UV source and cause immediate failure.

6.6.1 Xenon UV Source Handling

The xenon UV source is stored in a protective plastic enclosure (**Figure 3**). The (+) Anode end of the UV source is labeled "+." 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. If the glass bulb is touched with bare hands, clean the glass bulb with isopropyl alcohol or acetone prior to installation.

Figure 3. The Anode end of the UV source is marked (+). The Cathode end of the UV source is marked (-).

6.6.2 Xenon UV Source Removal

1. Power off the emitter component of the analyzer and disconnect from power. Allow it to cool completely.
2. Wearing clean powder-free nitrile gloves, loosen the retaining hex screws on the bulb collar clamps at the top and bottom of the UV source.
3. Note the orientation of the source bulb as it must be reinstalled in the same orientation, with + at the top collar clamp.
4. Remove the xenon UV source from the collar clamps.

6.6.3 Xenon UV Source Installation

1. Insert the Cathode (-) end of the Xenon UV source into the lower collar clamp and gently tighten the hex screw to secure the bulb.
2. Slide the upper collar clamp over the top of the UV source Anode (+). Gently tighten the collar clamp hex screw to secure.
3. Confirm signal strength and realign the emitter as necessary before leaving the path.

6.7 Perform Bump Test

The purpose of QA audits, or bump testing, is to collect concentration measurement data required to assess analyzer performance. To facilitate a QA audit, the analyzer receiver component is equipped with an internal assembly consisting of a sealed calibration gas cell of SO_2 coupled to a linear actuator. During bump testing, the actuator is used to insert the cell into the analyzer UV beam so the gas and UV light interact. The concentration of the gas in the sealed cells is not traceable to a known standard, therefore accuracy cannot be calculated. Accuracy statistics are to be determined. Concentration measurements obtained are used to calculate measurement precision.

NOTICE

Always verify the analyzer is in maintenance mode in FTT and confirm the data are invalidated on the public website *before* proceeding with maintenance. The concentration of gas in the QA cell is high enough to trigger a public alert in one measurement.

- ❒ When maintenance is complete, check the public site for at least 15 min to ensure proper reporting (no missing data, no high values, etc.) before taking the instrument out of maintenance mode.
- ❒ If a process upset resulting in a release is suspected during the bump test, or a linear actuator failure occurs and results in a stuck QA cell in the UV beam path after the bump test, contact the project manager.
- ❒ Due to the UV-DOAS operational method, at least four sequential measurement acquisitions will be required for concentration stabilization after moving the cell into the beam. This is independent of acquisition time.

Bump Test Quality Assurance Audit Procedure

1. Document quality assurance activity and associated times, file numbers, general observations, and variance from expectations in an electronic notebook. If eSIMS is not readily available, record the activity, visit summary, and your initials in a Notepad .txt file and save the file in the QA folder for the particular test.
2. Log the date and status of the bump test in the shared Bump Test Checklist.xlsx spreadsheet. Contact the project manager for access to the checklist.
3. Use FTT to place the analyzer in planned maintenance mode and disable missing data alerts.
    a. When saving, enter your initials in the FTT note space and record that the unit is offline for bump testing.
4. Press **STOP** (if CMS is running) and configure CMS.

a. Set Path Length to 100 meters: On the UV Tab press the **Align** button. In the align window change the path length to 100 meters. Exit the align window and press **Yes** to save changes.

b. Change Data Directory:

- Click **Settings** on the left panel. If not visible, click **Advance** first.
- On the window that pops up, expand the Runtime options and click **File.**
- Modify the primary data file and the secondary summary file paths from "C:\Users\user1\Documents\Cerex\Data" to "C:\Users\user1\Documents\Cerex\Data\Bumptest"
- Click **File** on the top left and select **Save.** Confirm if prompted.
- Click **Save** or **Ok** on the bottom right to close the window.

5. Verify Planned Maintenance Mode is active in the Data Management System (DMS).
   a. Verify that at least two consecutive data are invalid on the public website for the analyzer of interest. *Do not proceed* until at least two consecutive measurements of each are reported as Invalid.
6. Open the Align window (**Stop > UV Tab > Align**) and check maximum signal intensity. If maximum signal intensity reported in the CMS align window is <30%, align the analyzer to maximize intensity.
   a. See the alignment procedure for details.
   b. If aligning the unit fails to increase signal strength >17.6%, continue the QA audit.
7. If open, exit PTCR-96. With the ALIGN window open, start the Actuonix LAC software and reposition the device to 80%. As the cell moves into the beam path, observe the align window and verify a corresponding decrease in signal intensity is observed.
   a. If it is, continue. If no decrease in signal intensity is observed, troubleshoot the actuator serial connection and operability of the actuator before proceeding.
8. Set the device to 0%, verify signal intensity increase and then dismiss the align window.
9. Press **Run** and allow the analyzer to obtain five consecutive acquisitions. When file count displayed in the status area of the UV Tab reaches at least five, press **Stop**.
10. In Actuonix LAC, set the device to 80%.
11. Press **Run** and allow the analyzer to acquire at least 16 consecutive measurements at a stable concertation of the QA gas. This will generally require at least 24 consecutive acquisitions. Press **Stop**.
12. In Actuonix LAC**,** reposition the Device to 0% and observe the align window to verify the cell has moved out of the beam path.

13. Press **Run** and allow the analyzer to obtain five consecutive acquisitions. Press **Stop**.
14. Configure CMS for normal operation:
    a. Restore original file directories
        - Click **Settings** on the left panel. If not visible click the **Advance** first.
        - On the window that pops up, expand the Runtime options and click **File.**
        - Modify the primary data file and the secondary summary file paths from “C:\Users\user1\Documents\Cerex\Data\Bumptest” to “C:\Users\user1\Documents\Cerex\Data.”
        - Click **File** on the top left and select **Save.** Confirm if prompted.
        - Click **Save** or **Ok** on the bottom right to close the window.

    b. In the align window, set the path length to 1 meter, dismiss the align window and press **Yes** to save the new settings on exit.
15. Press **Run** to resume normal analyzer operation. Leave the analyzer in Maintenance Mode.
16. Verify in the DMS that the concentrations of QA gas have returned to baseline. You should see a clear drop of gas concentrations to baseline levels.
    a. In FTT, place the analyzer in Normal Operation mode and enable missing data alerts only after the concentrations of QA gas flowing into the DMS have returned to baseline.
    b. If the concentrations of QA gas fail to return to baseline, then a QA cell is still in the beam path or a release event is occurring. Leave the analyzer in maintenance mode and contact the project manager.
17. Transfer a copy of the entire QA folder “*Facility Path QA YYYYMMDD*” to the maintenance directory for documentation and record keeping.
18. Open a blank site-specific UV Field QA Audit Workbook.xlsx spreadsheet (Section 7) and record the bump test results.
    a. Copy 16 consecutive span measurements of SO_2 from the QA Complete Data Summary.csv file into the appropriate column.
    b. Copy the corresponding signal strength or intensity into the appropriate column.
    c. The workbook will automatically calculate average, standard deviation, and precision of the measurements. Precision should be ±25% or less. If not, notify the project manager.
    d. Document the date, initials, testing gas, and any comments regarding the test or instrument on the bump test maintenance form (or electronic notebook entry).

7. Maintenance Forms

Path:_______________________________

Technician:_________________________

Date:_______________________________

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

- ❒ Notify the client and project manager of maintenance tasks.
- ❒ Using the FTT 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 (no missing data, no high values, etc.).
- ❒ Take equipment out of maintenance mode.
- ❒ Notify the project manager and client when maintenance is complete.

Upon completion, sign and date:____

Table 1. 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 drives.	
Ensure there are no obstructions between the detector and the retroreflector (such as equipment, vegetation, vehicles).	
Change out the xenon 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 as needed.

UV FIELD QA AUDIT WORKBOOK.xlsx

Span Concentration PPM*M

Date			*Version: 07312024*
Operator			
Test Gas	SO2		
Index	SO2	Intensity @ SO2	
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
Average	#DIV/0!	#DIV/0!	
STD DEV	#DIV/0!	#DIV/0!	
Precision (CV) (%)	#DIV/0!	#DIV/0!	

Comment:

Standard Operating Procedure for the Kassay RAM 2000 Open-Path FTIR

August 5, 2024

STI-8193

Contents

1. Scope and Application

This Standard Operating Procedure (SOP) covers the use of the Kassay Remote Air Monitor-2000 (RAM 2000) Open-Path Fourier Transform Infrared (FTIR) 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.

2. Introduction and Overview

The RAM 2000 FTIR is an open-path air monitor designed to detect a wide range of compounds in real time. The system works by first generating infrared (IR) radiation from an extremely hot Globar source. The light from the source is directed down the open path using a Newtonian 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 a spectrometer with a cooled Mercury Cadmium Telluride (MCT) detector. A block diagram of the RAM 2000 FTIR monitoring system is shown in Figure 1.

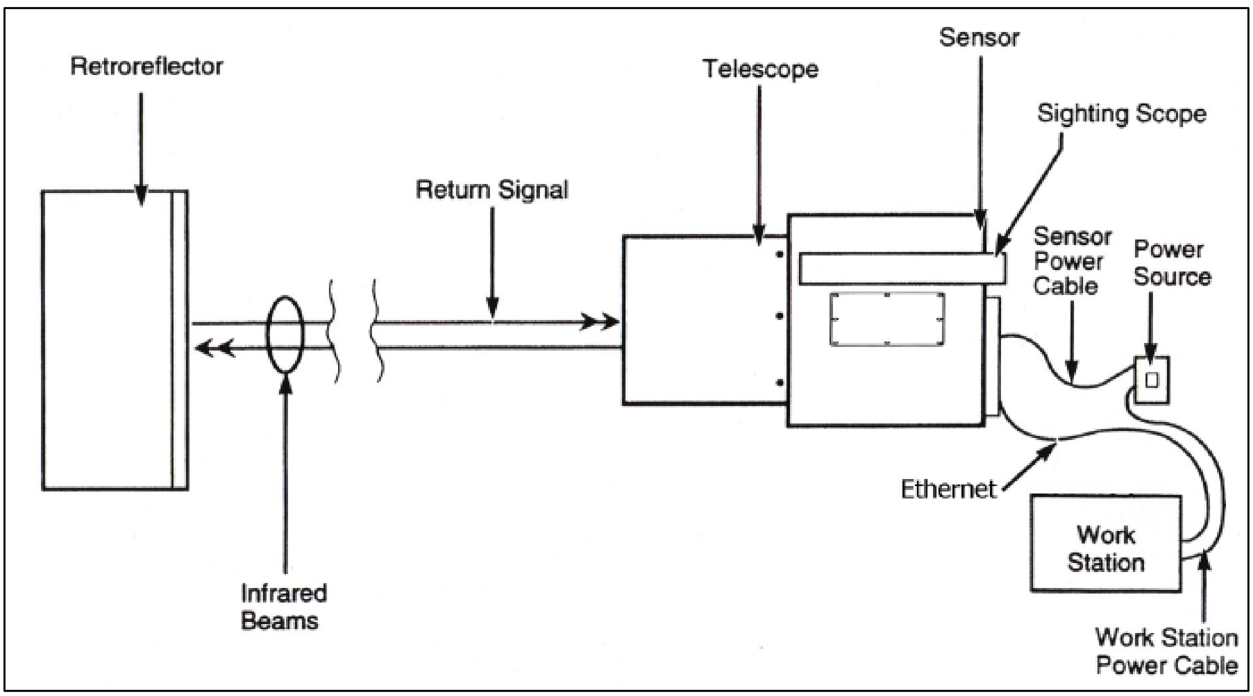


Figure 1. Block diagram of the RAM 2000 monitoring system.

3. 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, powder free nitrile or latex should be used.

Operator Qualifications

Kassay RAM 2000 FTIR analyzer Installation, operation, and servicing should only be performed by personnel trained in the operation of the system components. This includes troubleshooting, cleaning, replacing parts, IR light source installation, etc. Operators should also be fully trained and experienced in handling gas delivery and testing equipment, including the use of compressed gas cylinders, 1- and 2- stage regulators, flow controllers, and tubing connections. Operators 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 Kassay RAM 2000 FTIR 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. There is a risk of eye injury with prolonged direct exposure. Kassay 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

The QA test procedure requires handling a sealed cell containing sulfur hexafluoride (SF6). Improper handling of materials or hardware may result in serious injury, destruction of property, or damage to the Kassay FTIR analyzer. Only qualified individuals should attempt or perform analyzer QA test activities. Kassay 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 Kassay 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 *<u>before</u>* 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 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 instrument out of maintenance mode.

Notify the project manager and client when maintenance is complete.

4. Routine Operations

To set the FTIR instrument to acquire data for normal operations, the instrument and software RMMSoft must be operating and the instrument must be aligned (Steps 1 – 4 below).

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

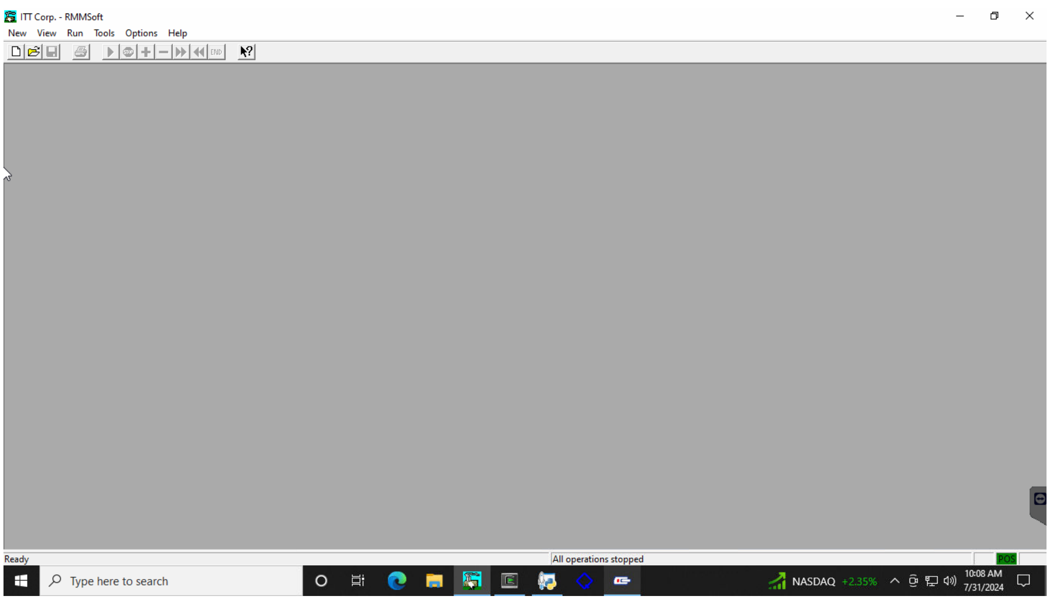


Figure 2. RMMSoft software opening screen.

2. To perform an alignment, use the peak amplitude search function under **Run** > **Find FTIR Peak Amplitude Position**. This feature provides an automated capability to find the best coordinate to point the FTIR at a retroreflector.
    a. Enter the search parameters and press **OK**. The program will display the Peak Amplitude Search View. Press **OK** to start the process as shown in Figure 3.

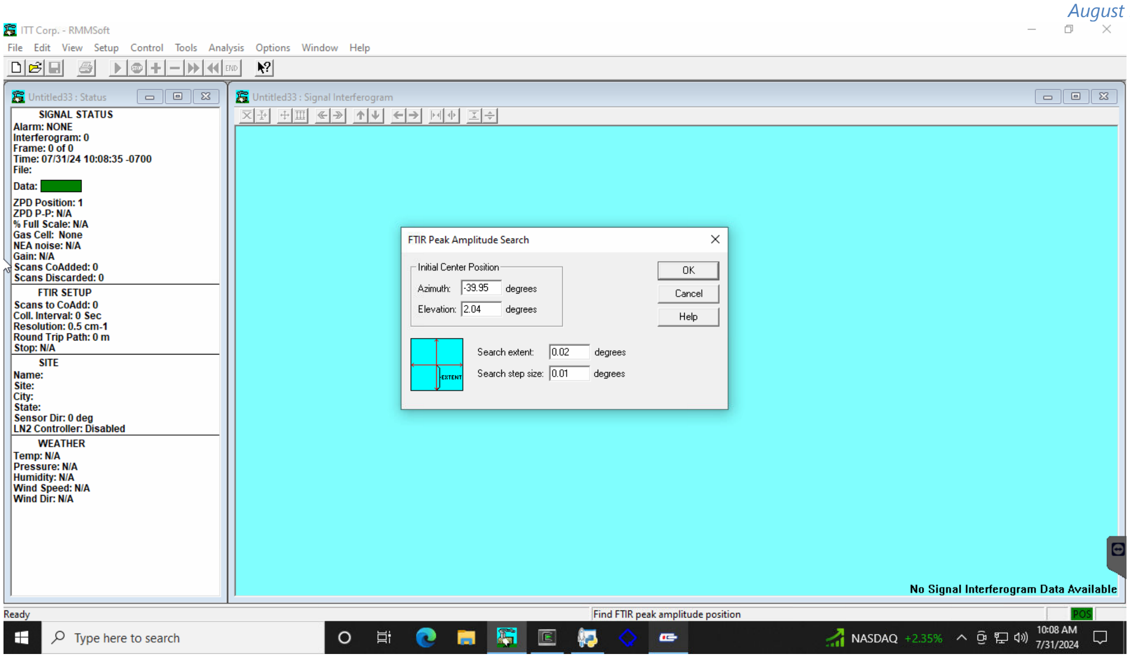


Figure 3. FTIR peak amplitude search view.

b. Once the process is complete, the program automatically displays the azimuth and elevation coordinates of the square that contains the highest returned signal (Figure 4).

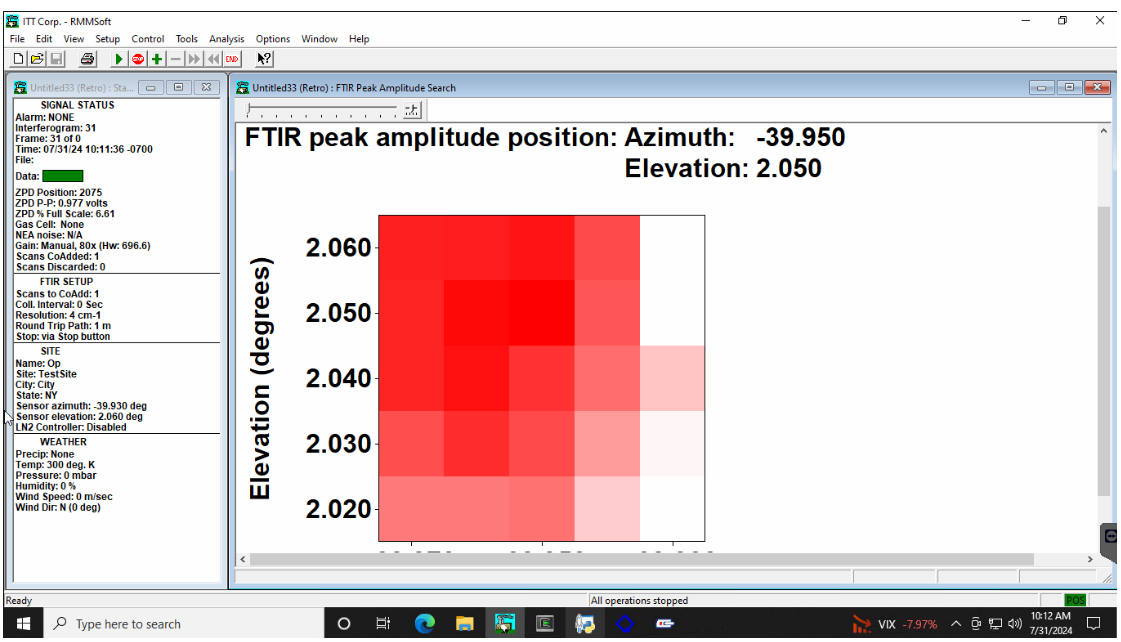


Figure 4. FTIR peak amplitude search view in progress.

c. Use these azimuth and elevation coordinates in the site setup file (Macro, Step 3).

d. Close the peak amplitude search view window.

3. Under the **Run** tab, select **Macro.** In the pop-up window, select the desired Macro for the monitoring site. Click **Run**.

4. Observe the scan via the RMMSoft graphical user interface (GUI) to ensure the instrument and software are operating properly (Figure 5).

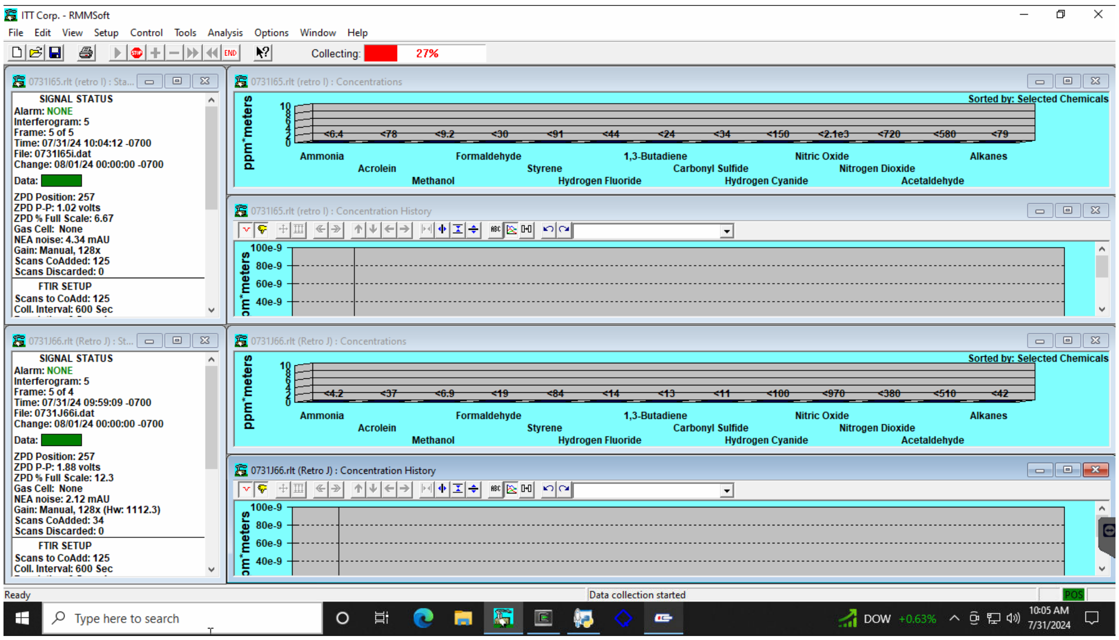


Figure 5. Operating RMMSoft with two FTIR paths.

5. Equipment and Supplies

1. Field notebook or access to e-logbook management systems, such as eSIMS
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 Kassay FTIR
4. All relevant personal protective equipment (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 analyzer (as required)
7. Kassay FTIR analyzer equipped with RMMSoft software
8. Isopropyl alcohol (≥80%)

9. Distilled water
10. Pressurized sprayers
11. Powder-free nitrile or latex gloves

6. Maintenance Activities

The following sections outline the routine checks to be carried out for each analyzer and sensor, followed by maintenance forms (Section 8) used to indicate when checks are completed and document any corrective actions taken. These activities are also expected, based on 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 alignment to verify there has been no significant physical movement. Note: this is automatically monitored as well.
- Ensure there are no obstructions between the detector and the retro-reflector.
- Realign the system after service.
- Check system response (bump test) and take corrective action if % Error exceeds the level specified in the QAPP.
- Review and verify signal levels.
- Verify system settings.
- Replace the cryocooler assembly if necessary.

6.1 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 and 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.

6.2 Perform a Bump Test

The procedure is intended to verify that the equipment detects a known concentration of calibration gas contained within a sealed cell located within the instrument. Note that this procedure is written for FTIR analyzers installed on auto-positioners that rotate between adjacent paths to allow one analyzer to cover two separate sampling paths.

Prepare for the Bump Test

1. Use the public website to evaluate site conditions and make sure there are no active, elevated concentrations of compounds detected at the site of interest before proceeding.
2. Log in to FTT and place both paths of the FTIR in planned maintenance mode.
3. When prompted to provide a reason for your changes in FTT, enter your initials followed by "bump testing."

Bump Test Procedure

1. Record the auto-positioner coordinates displayed for each path in the RMMSoft GUI, as shown in **Figure 6**.

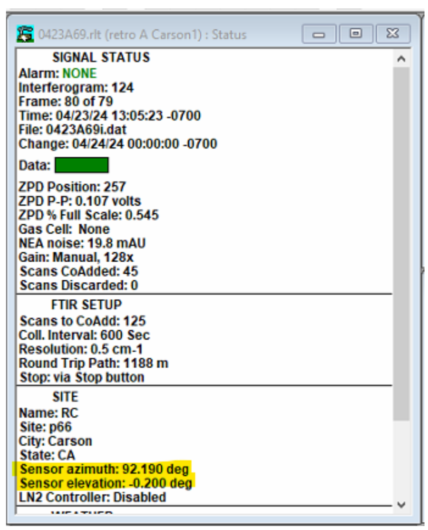


Figure 6. Location of the coordinates

2. End monitoring and save data for each path:
   a) In RMMSoft, click the red **Stop** button at the top of the window.
   b) Click **File** > **Close**.
   c) If prompted to save, click **Yes** or **OK** to save all files.

d) Repeat steps b-c again to close all paths.

3. Perform a Find FTIR Peak Amplitude Position operation to maximize the signal strength, referred to as zero path distance peak-to-peak voltage (ZPD Voltage). Perform if ZPD PP-Voltage is lower than expected based on routine operations.

    a) Click **Run** > **Find FTIR Peak Amplitude Position**

    b) The FTIR Peak Amplitude Search dialog box will open and default to the last used auto-positioner coordinates.

    c) Update the coordinates for the path of the QA audit if necessary. Use the coordinates recorded in Step 1.

    d) Record the new peak amplitude coordinate values for use in a later step.

    e) Press **Stop**, then click **File** > **Close**

    f) Repeat Steps a-e for the other path.

4. Create or confirm the existence of QA data subfolders for each path.

    a) Create/confirm subfolders in "C:\RAM2000-Data\QA_Notes\QAQC YYYY\Path#" for each path. Be mindful of the year. Create a new folder for the current year if one does not already exist.

    b) Run the **UpdateQAmacro.py** script, located in C:\RAM2000-Data\macro, and follow the prompts.

5. Run the QA Macro for the desired path:

    a) In RMMSoft click **Run** > **Macro**

    b) Select the QA Macro for the path and click **Open**.

    c) Data from the QA Audit will be written to the file directory specified in step 4: C:\RAM2000-Data\QA_Notes\QAQC YYYY\Path#\dd-mmm.

6. RMMSoft will automatically reposition the analyzer and begin collecting data.

7. Allow RMMSoft to acquire two frames then press **Stop**.

8. Open the Actuonix Linear Actuator Controller (LAC) Configuration Utility (**Figure 7**) and set the position to 100%. If inoperative, manually push the cell fully into the beam path.

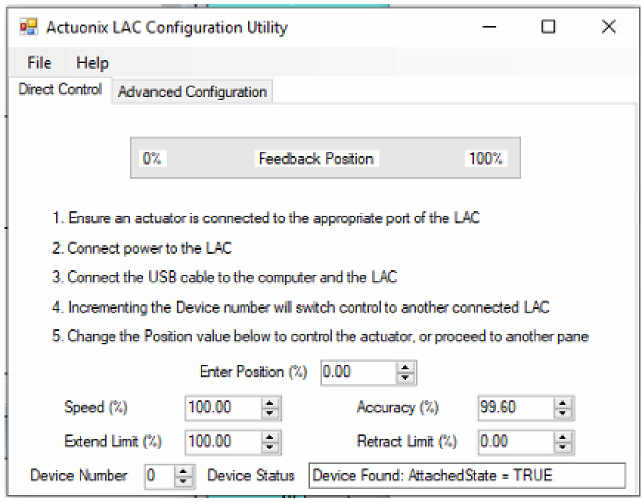


Figure 7. Actuonix LAC Configuration Utility

9. Press **Run** in RMMSoft and allow the analyzer to run continuously to acquire at least 16 frames with stable concentrations, then press **Stop**.
10. In the Actuonix LAC Configuration Utility, set the position to 0%. If inoperative, manually retract the QA cell and make sure the cell is fully out of the beam path.
11. In RMMSoft, press **Run** and allow the analyzer to acquire two more frames. Press **Stop**, then **File** > **Close**.
12. If prompted, select **OK** or **Yes** to save all files.
13. Open the new QA folder (C:\RAM2000-Data\QA_Notes\QAQC YYYY\Path#\dd-mmm), copy the Results*.txt file to your local computer, and change the file extension of the copy to .csv.
14. Open the copy in Excel.
15. Copy 16 consecutive SF6 measurements into the field QA audit workbook as shown in Figure 8. The workbook will calculate as shown in steps a – c below.

	FTIR FIELD QA AUDIT WORKBOOK.xlsx		
	Span Concentration PPM*M		
Date	X/XX/2024		*Version: 04232024*
Operator	EJH		
Test Gas	SF6		
Index	Concentration (PPM*M)		
1	29.78		
2	29.598		
3	29.115		
4	29.947		
5	29.698		
6	29.977		
7	29.42		
8	29.223		
9	28.57		
10	29.59		
11	29.266		
12	29.468		
13	29.055		
14	30.116		
15	29.741		
16	30.989		
Average	29.597		
STD DEV	0.543		
Precision (CV) (%)	**1.833**	**within ±25% TO PASS**	
Comment:			

Figure 8. Example of field QA audit workbook

a) =AVERAGE(Nonzero measurements, omitting the first and last nonzero values) – This is the average of the measurements.

b) =STDDEV.S(Same Cell Range as Above) – This is the sample standard deviation of the measurements.

c) =(AVERAGE above/STDDEV.S above)*100 – This is the relative standard deviation (precision) of the measurements.

d) Precision should be 25% or less. Refer to the acceptance levels specified in the project QAPP.

e) Document the date, initials, testing gas, and any comments regarding the test or instrument on the bump test maintenance form (or electronic notebook entry).

f) Transfer a copy of the entire folder to the secured cloud-base drive under the most current project folder for documentation and record keeping.

16. Record all activities and a brief summary of the test results in a site logbook either in hard or electronic form. If using an eSIMS logbook entry, select **Tasks** > **Site Visit**.

17. Repeat Steps 5-16 for the other path.

18. When bump testing is complete on both paths, press **Run** > **Macro**, select the Site Macro for both paths and click **Open** to run.
19. Observe the scans to make sure data are again collecting between the two FTIR paths successfully in RMMSoft. Make sure the data acquisition script is running as shown in Figure 9. If it is not, run the following batch file to start it:

    C:\Users\user1\Desktop\[Site_#_FTIR] \startTASFTIRWare.bat

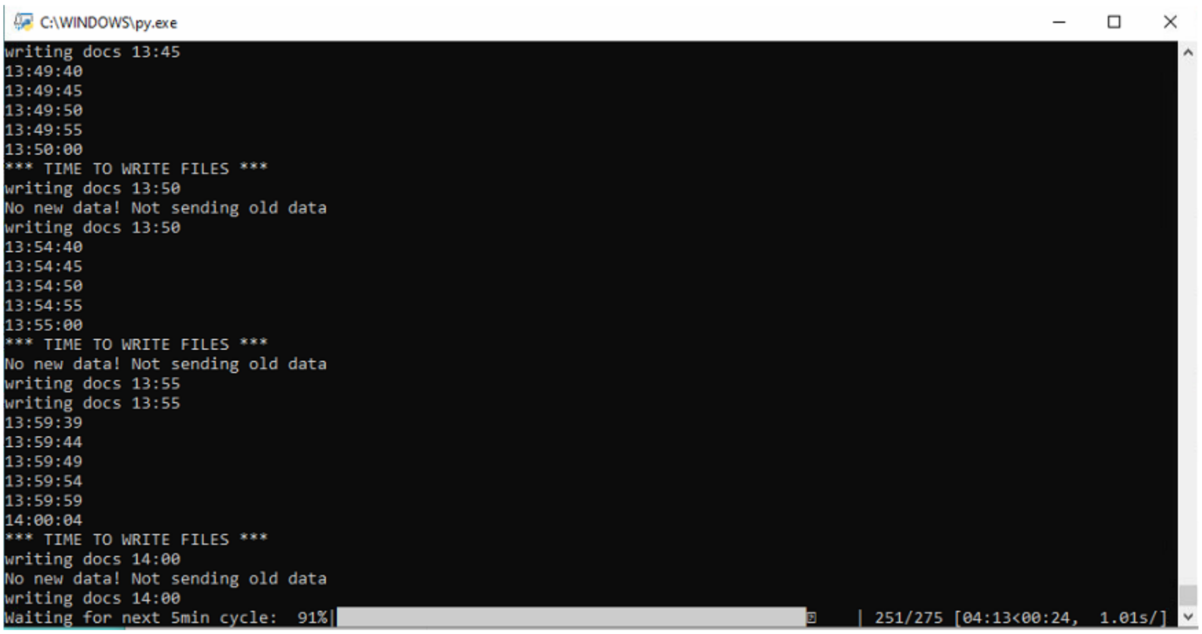


Figure 9. Data acquisition script.

20. In FTT, place both analyzers in Normal Operation mode and enable missing data alerts.

6.3 Data Management

Raw instrument data are stored on the analyzer and site computers. Data archiving should be performed on a monthly basis to the portable hard drives connected to the site computer. The spectral data consist of information regarding the absorbance and transmittance spectrum, interferogram, and a summary result file. These file formats are described in the Kassay RAM 2000 System Operator Manual.[1] Details on the proper procedure for archiving data files from the instrument are as follows.

[1] Kassay RAM 2000 System Operator Manual, Document Number 0752-467392 Rev: C2, December 2011.

1. If the folder structure has not been established, follow this recommended structure to create the sub-folders on the hard drive. Certain folder layers may not be applicable or necessary for the monitoring project of interest.
    - Site
    - Monitor Type
    - Path #
    - Year
    - Quarter or Month
2. Begin copying and pasting the files to the appropriate folders on the hard drive. It is recommended to work with a small batch of folders or files at a time. Verify the total size by selecting and right clicking the items to view Properties.
3. On the hard drive where the files are backed up, create a digital logbook using Notepad or Microsoft Word. Use a name for the file that is easily identifiable, e.g. ReadMe.txt or Logbook.docx.
4. In the logbook, document the action, date, your initials, and any other notes that may help other technicians understand the status.
5. Once archiving is complete, make sure all critical software and applications needed for normal data collection remain operational before logging out of the onsite computer.

6.4 Clean Optics on the 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.

6.4.1 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 finish removing any salt or dust build-up on the retroreflector.
4. Once the retroreflector has been cleaned and dried, repower the any electrical equipment you powered down, and clean any spills you created while cleaning.

6.4.2 Window and Scope Cleaning

If ZPD voltages are low or visual inspection reveals soiled optics, cleaning optical surfaces can improve light throughput. **Before cleaning any mirror, check the latest service report or notes from the manufacturer**, as excessive cleaning of optics can result in scratches and wear over time. If the optic is obviously soiled and this 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.

Scope Cleaning

1. Log in to FTT and place both paths of the FTIR in planned maintenance mode.
2. Remove the scope from the instrument.
3. Place the scope on the ground at a slight angle to allow the cleaning solution to drain out.
4. Use a pressurized sprayer with distilled water to lightly rinse any heavy dust or dirt off the primary and secondary mirrors of the scope.
5. 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.
6. Let the scope dry for 20-30 minutes before placing it back on the instrument.
7. Return the unit to normal operations via the FTT.

7. Monthly Bump Test Forms

FTIR FIELD QA AUDIT WORKBOOK.xlsx

Span Concentration PPM*M

Date			*Version: 04232024*
Operator			
Test Gas			
Index	Concentration (PPM*M)		
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
Average	#DIV/0!		
STD DEV	#DIV/0!		
Precision (CV) (%)	**#DIV/0!**	**within ±25% TO PASS**	

Comment:

Standard Operating Procedure for Teledyne T101 H_2S Point Monitors

July 31, 2024

STI-7024

Contents

Tables

Figures

1. Scope and Application

This document is the standard operating procedure (SOP) for the maintenance and calibration of the Teledyne T101 analyzer, which measures concentrations of ambient hydrogen sulfide (H_2S). The calibration system described herein presumes the use of a Teledyne T700 gas dilution calibrator, an external zero air generator, and a National Institute of Standards and Technology (NIST)-traceable H_2S gas cylinder. However, other suitable calibration equipment may be used for the purpose of performing maintenance and verification on the T101 analyzer.

2. Safety

This procedure requires the handling of hazardous compounds (H_2S and SO_2) in the forms of compressed gas cylinders, permeation tubes, and exhaust gas from the analyzer. H_2S and SO_2 must be discharged outdoors and away from all personnel after passing through a scrubber or filtration system. Improper handling may result in acute, long-term health impacts. Personnel must be properly trained and qualified prior to performing any procedure in this SOP.

3. Method Overview

The Teledyne T101 determines the concentration of H_2S by converting it to sulfur dioxide (SO_2), which is then measured by ultraviolet (UV)-induced fluorescence. Ambient air is drawn by an internal pump through a sample particulate filter to remove particles, a hydrocarbon scrubber to remove hydrocarbons, and finally an SO_2 scrubber to remove ambient SO_2 prior to introducing it into the converter. The sampling flow rate is 700 standard cubic centimeters per minute (sccm). H_2S in the ambient air is converted to SO_2 through high-temperature catalytic oxidation, and the converter is most efficient at 315°C. The resulting SO_2 is exposed to 214 nm of UV light to create an excited state molecule (SO_2*). The SO_2* molecule quickly returns to a lower energy ground state by releasing excess energy in the form a photon (at 330 nm). The amount of emitted light at 330 nm is directly related to the SO_2 concentration, which is used to quantify H_2S concentration. The system can also measure the SO_2 concentration present in the ambient air by bypassing the sampling flow from the SO_2 scrubber and the catalytic converter, if desired.

4. Equipment and Supplies

Before beginning the quality control (QC) check and maintenance, ensure you have the following:

- NIST-certified H_2S gas cylinder with regulator or H_2S permeation tube
- NIST-certified SO_2 gas cylinder with regulator or SO_2 permeation tube (for converter efficiency check)
- Gas calibrator

- Zero air generator
- Certified, NIST-traceable flow meter
- Technician's tool bag, including screwdrivers, pliers, wrenches, etc.
- Inlet filter opening wrenches
- Replacement particulate filters
- Replacement converter catalyst
- Pump rebuild kit

5. Maintenance Schedule

A list of regular maintenance activities, and the corresponding sections of the T101 user manual where they are described in detail, is shown in **Table 1**. Additional information regarding frequency of service is presented in the facility's Quality Assurance Project Plan (QAPP).

Table 1. QC and maintenance schedule for the T101 series H_2S analyzer.

Activity	SOP Section	User Manual Reference
Perform Zero and Span (Z/S) check	6.1	5.2
Review and verify test functions	6.2	6.72
Review and verify test functions	6.2	6.7.2
Inspect sample lines	6.3	--
Change inlet particulate filter	6.4	6.6.1
Perform flow check	6.5	6.6.9.3
Perform multi-point check	6.1	--
Replace SO_2 scrubber material and sintered filters.	6.6	6.6.3
Check for H_2S -> SO_2 converter efficiency (CE), replace or service the converter if CE < 96%	6.7-6.8	6.6.5.2
Service the critical flow orifice assembly, replace as needed	6.9	6.6.7
Perform pump check, and rebuild pump diaphragm as needed	6.10	6.6.9.1
Perform leak check	6.10	6.6.9.1
UV lamp adjustment	6.11	6.7.10.3
PMT sensor hardware calibration	6.12	6.7.10.4
Calibrate offset and slope	6.13	5.2

6. Field Operation and Maintenance

Common maintenance and QC activities are described below. Additional information about maintenance activities, troubleshooting, and fault codes can be found in the T101 user manual.[1]

For regulatory projects, the analyzer should <u>never</u> be taken offline or put into Maintenance Mode if ambient H_2S concentrations are elevated (>10 ppb), especially if they are approaching a public notification level. Report any observations of concern to the Project Manager immediately <u>before</u> performing maintenance.

6.1. Perform Zero/Span or Multi-Point Check

A zero/span check evaluates analyzer performance without altering the response curve (slope and offset values), and is a recommended regular maintenance item. A multi-point check similarly evaluates performance across the analyzer's measurement range and shall be conducted only after the analyzer is calibrated. The multi-point check can be used to confirm linearity of analyzer response.

6.1.1. Manual Verification

1. Verify that the ambient conditions are acceptable (e.g. H_2S concentration is < 10 ppb) to proceed with gas verification. Put the H_2S channel into Maintenance Mode from the Field Tech Tool**.**
2. Connect the sources of zero and span gas as shown in **Figure 1**, depending on the instrument configuration. The zero air generator can be replaced by a zero air cylinder. If using the T700 dilution calibrator, make sure the calibrator contains the accurate gas standard concentration under cylinder setup.
3. Generate the instrument Zero using the zero air source.
4. From the T101 analyzer with NumaView software, view the concentration and stability responses by clicking the Home Tab and the blue H_2S icon. Verify the T101 mode remains in SAMPLE at the lower right corner of the display. This ensures the verification is conducted through the inlet probe.
5. Wait at least 15 minutes until the analyzer stability (STAB) is below 0.5 ppb (wait longer than 15 minutes if more time is needed for STAB to be < 0.5 ppb). Record the reading. If the stability threshold cannot be achieved, contact the Project Manager and proceed to additional troubleshooting steps.

[1] https://www.teledyne-api.com/prod/Downloads/083730101B%20-%20MANUAL,%20USER,%20NVS,%20T101-T102.pdf

6. From the dilution calibrator, select one of the following options:

    a. **Span Check:** Set the target H_2S span gas on. The target value should be at least 80% of the full measurement range.

    b. **Multi-Point Check:** Set the target H_2S concentrations appropriate for the monitoring project. An example of multi-point check concentrations is shown in Table 2.

Table 2. Example of multi-point check concentrations.

Multi-point check concentration (ppb)
450
225
120

7. Wait at least 45 minutes until the analyzer stability (STAB) is below 0.5 ppb for each concentration level (wait longer than 15 minutes if more time is needed for STAB to be < 0.5 ppb at each level). Record the readings. If the stability threshold cannot be achieved, contact the Project Manager and proceed to additional troubleshooting steps.

8. Refer to the facility's QAPP for the test acceptance criteria.

9. Purge the sampling line and the analyzer by generating a high flow of zero air for at least 5 minutes. This step helps the analyzer return to sampling ambient conditions.

10. At the conclusion of the check, put the calibrator into STANDBY Mode.

    IMPORTANT: Failing to change the calibrator to STANDBY Mode means the analyzer will continue to detect zero air or span gas fed to the inlet, resulting in INVALID ambient data.

11. Verify the T101 status remains in SAMPLE Mode at the lower right corner of the display.

12. Observe and make sure the H_2S reading has returned to ambient concentrations **before** putting the channel back to Normal Operations from the Field Tech Tool.

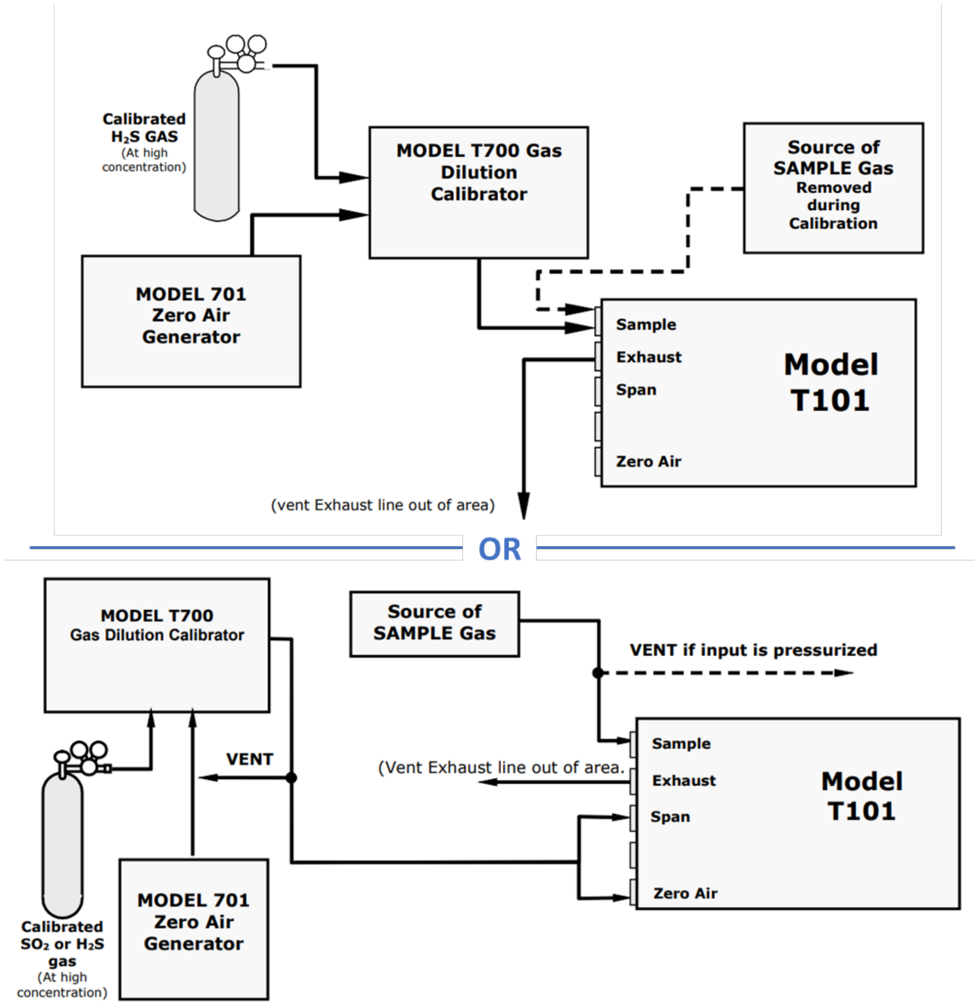


Figure 1. Connection setup for verification and calibration with basic configuration (top) or zero/span valves option (bottom).

6.1.2. Automated Verification

For some monitoring sites, automated verification may be configured and initiated manually. Note the following procedure is only applicable when the Teledyne T101 analyzer and T700 dilution calibrator are used together.

The preset sequences are set up such that an abundance of time (at least 15 minutes for zero and 45 minutes for any non-zero concentration level) is built in to achieve stabilized readings from a properly functioning, calibrated analyzer.

1. Verify the ambient conditions are acceptable (H_2S < 10 ppb) to proceed with gas verification. Put the H_2S channel into Maintenance Mode from the Field Tech Tool**.**

2. Connect the zero and span gas sources as shown in Figure 1, depending on instrument configuration. The zero air generator can be replaced by a zero air cylinder. Make sure the T700 dilution calibrator contains the accurate gas standard concentration under cylinder setup menu.

3. If the verification is to be initiated remotely via the NumaView Remote Software, open the software, and launch the analyzer and calibrator of interest.

4. From the T700 dilution calibrator, go to Generate > Sequence to view a selection of preset sequences, as shown in Figures 2 and 3.

5. Select the sequence to be initiated and click Generate.

6. Verify the calibrator begins the steps by observing the Instant Mode in the Generate menu or Mode at the lower right corner of the display.

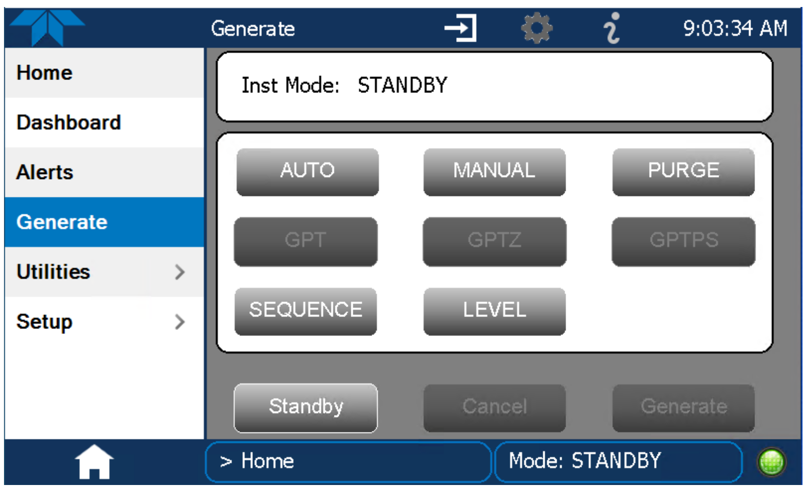


Figure 2. Screenshot of the Generate menu on T700 calibrator.

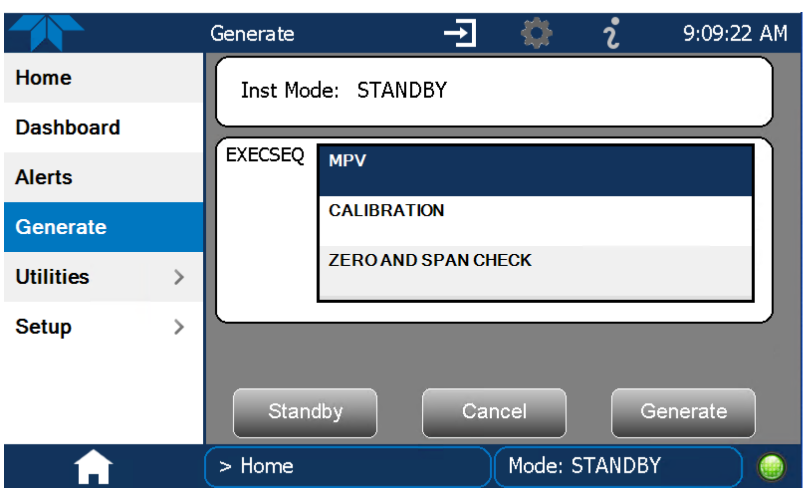


Figure 3. Screenshot of preset automated sequences on T700 calibrator.

7. From the T101 analyzer with NumaView software, view the concentration and stability responses by clicking the Home Tab and the blue H_2S icon. Verify the analyzer remains in SAMPLE Mode during Zero/Span check and multi-point check at the lower right corner of the display. This ensures the verification is conducted through the inlet probe.
8. Review the **entire** check results to confirm the completion of a Zero/Span check or multi-point check using Sonoma Technology's Insight data management system (DMS).
9. When the check is finished, verify the calibrator has been switched back to STANDBY Mode and the analyzer has been switched back to SAMPLE Mode.

   IMPORTANT: Failing to change the calibrator to STANDBY Mode means the analyzer will continue to detect zero air or span gas that is fed to the inlet, resulting in INVALID ambient data.
10. Observe and make sure the H_2S value has returned to ambient concentrations **before** putting the channel back to Normal Operations from the Field Tech Tool.

6.2. Review and Verify Test Functions

Test functions on the Dashboard should be carefully reviewed and verified during each scheduled site visit. Minimally, operators should check and verify that major test functions remain within the nominal range shown in **Table 3** (also included in the maintenance checklist). Operators should also review active warning alerts to determine if troubleshooting or corrective actions are required.

Table 3. Major Diagnostics for Teledyne API T101 H_2S analyzer.

Diagnostics	Acceptable Value Range
H_2S Slope	1 ± 0.3
H_2S Offset (mV)	< 250 mV
Converter Temp (°C)	315 ± 1 °C
Sample Flow (ccm)	585-715 ccm (650 ccm ± 10%)
Pressure (inHg)	~ 5 inHg < ambient pressure
UV Lamp Signal (mV)	2,000-4,000 mV
UV Lamp Ratio (%)	30-120%

Refer to the T101 user manual for a detailed list of test functions, nominal values, and possible causes for out-of-range values. Additionally, the acceptable ranges for these functions of a specific analyzer can be found in the *Final Test and Validation Data Sheet* shipped with the instrument.

6.3. Inspect Sample Lines

Contaminated or kinked sample line can adversely impact sampling data over time. Check for any sample line flow restriction, and visible dirt or condensation accumulation along the sampling path between the sample inlet and the analyzer sampling port, as well as the calibration lines. Replace the sample and calibration lines as needed.

6.4. Change Sample Particulate Filter

The sample particulate filter inside this instrument needs to be changed monthly even without obvious signs of dirt, as filters with 1 and 5 µm pore size can clog even when they look clean. A schematic of the particulate filter is shown in **Figure 4**.

1. Turn OFF the analyzer to prevent drawing debris into the sample line.
2. Open the T101’s hinged front panel and unscrew the knurled retaining ring of the filter assembly.
3. Carefully remove the retaining ring, glass window, PTFE O-ring, and filter element.
4. Use a tweezer to carefully replace the filter element, centering it at the bottom of the holder. Alternatively, wear latex gloves if handling the filter to avoid contamination.
5. Re-install the PTFE O-ring with the notches facing up, replace the glass cover, screw on the hold-down ring, and hand-tighten the assembly. **Inspect the (visible) seal between the edge of the glass window and the O-ring to assure proper gas tightness.** This is critical for ensuring that the sample flow does not drop.
6. Restart the analyzer and perform a leak check.

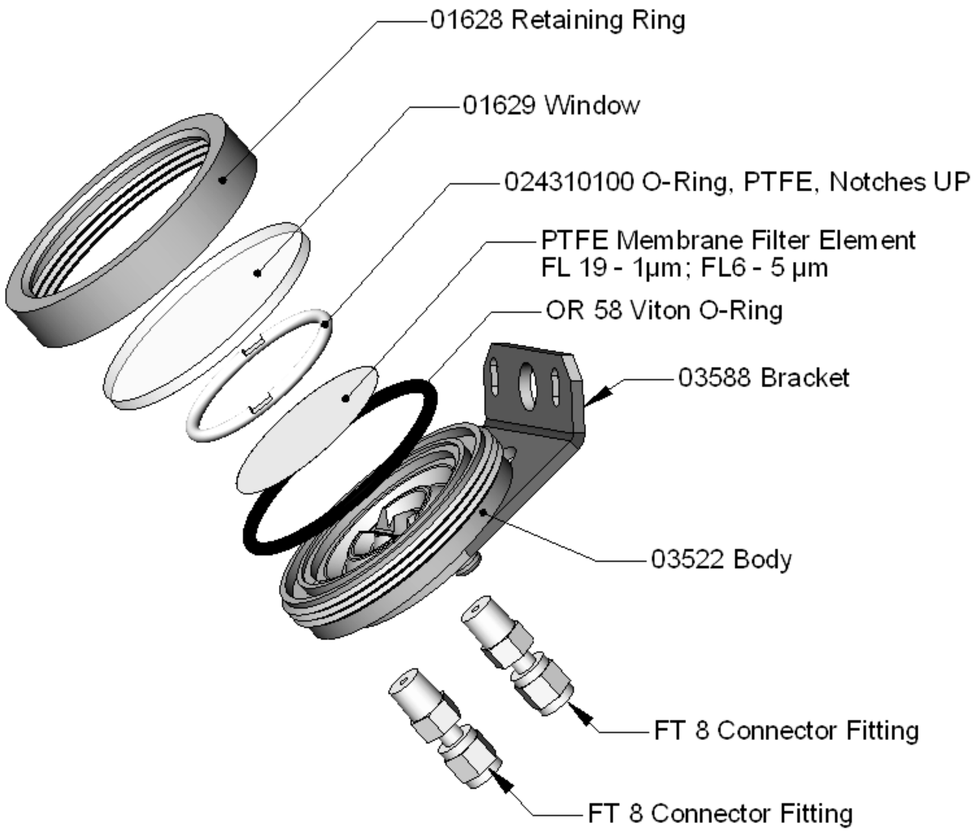


Figure 4. Particulate filter assembly.

6.5. Perform Flow Check

Use an external, calibrated NIST-traceable flow meter capable of measuring the instrument's flow specifications for this check. Do not use the built-in flow measurement viewable in the Dashboard as this value is only calculated, not measured. A decreasing, actual sample flow may point to slowly clogging pneumatic paths, most likely critical flow orifices or sintered filters.

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a suitable flow meter to the rear panel SAMPLE port.
3. The sample flow measured with the external flow meter should be within 650 cc/min ± 10%.
4. Record the sample flow reading from the external flow meter.

6.6. Change the SO_2 Scrubber (Activated Charcoal)

1. Input zero air for 5 minutes.
2. Turn off the analyzer.
3. Remove the instrument cover.

4. Locate the SO_2 scrubber cartridge in the front of the analyzer (looks like a big white cylinder).
5. Undo the two 1/8″ fittings on the top of the scrubber.
6. Remove the two screws holding the scrubber to the instrument chassis, and remove the scrubber.
7. Take the two Teflon fittings off the instrument.
8. Empty the SO_2 scrubbing material and discard the sintered filters into a hazmat bin.
9. If any SO_2 scrubber residual is visible in the line, disconnect the line and clear the line of powder with compressed air.
10. Fill each side of the scrubber with new SO_2 scrubber material until it is ½″ from the bottom of the thread lines (about ½″ from the top of the scrubber); do not fill it too high or the fitting will crush the material.
11. Install a new set of sintered filters. The filters should be leveled at the bottom of the fittings.
12. Remove the Teflon tape from both of the removed fittings, and retape them with new Teflon tape.
13. Install both fittings back onto the scrubber.
14. Put the scrubber back into the analyzer and replace the two screws on the bottom.
15. Screw the two 1/8″ fittings back onto the top of the scrubber.
16. Return analyzer to normal operation.

6.7. Check for H_2S -> SO_2 Converter Efficiency

1. Set the analyzer to SO_2 measurement mode.
2. Supply a gas with a known concentration of SO_2 to the sample gas inlet of the analyzer.
3. Wait until the analyzer's SO_2 concentration measurement stabilizes. This can be determined by setting the analyzer's display to show the SO_2 STB test function. SO_2 STB should be 0.5 ppb or lower before proceeding.
4. Record the stable SO_2 concentration.
5. Set the analyzer to H_2S measurement mode.
6. Supply a gas with a known concentration of H_2S, equal to that of the SO_2 gas used in steps 2-4 above, to the sample gas inlet of the analyzer.
7. Wait until the analyzer's H_2S concentration measurement stabilizes. This can be determined by setting the analyzer's display to show the H_2S STB test function. H_2S STB should be 0.5 ppb or lower before proceeding.
8. Record the stable H_2S concentration.
9. Divide the H_2S concentration by the SO_2 concentration.

EXAMPLE: If the SO_2 and H_2S reference concentration of the two test gases used is 500 ppb:

Measured SO_2 Concentration = 499.1 ppb
Measured H_2S Concentration = 490.3 ppb
Converter Efficiency = 490.3 ÷ 499.1
Converter Efficiency = 0.982 (98.2%)

10. It is recommended that the H_2S -> SO_2 converter catalyst material be replaced if the converter efficiency falls below 96%. Proceed to the next section to change the converter catalyst material.

6.8. Change H_2S -> SO_2 Converter Catalyst Material

The H_2S -> SO_2 converter is located at the center of the instrument. The converter is designed for replacement of the cartridge only; the heater with built-in thermocouple can be reused. A schematic of the H_2S to SO_2 converter assembly is shown in **Figure 5**.

1. Turn off the analyzer power, remove the cover, and allow the converter to cool down.
2. Remove the top lid of the converter and the top layers of insulation until the converter cartridge is visible.
3. Remove the tube fittings from the converter.
4. Disconnect the power and the thermocouple of the converter. Unscrew the grounding clamp of the power leads with a Phillips-head screw driver.
5. Remove the converter assembly (cartridge and band heater) from the can. Make a note of the orientation of the tubes relative to the heater cartridge.
6. Unscrew the band heater and loosen it. Take out the old converter cartridge.
7. Wrap the band heater around the new replacement cartridge and tighten the screws using a high-temperature anti-seize agent such as copper paste. Make sure to use proper alignment of the heater with respect to the converter tubes.
8. Replace the converter assembly, route the cables through the holes in the housing, and reconnect them properly. Reconnect the grounding clamp around the heater leads for safe operation.
9. Re-attach the tube fittings to the converter and replace the insulation.
10. Replace the instrument cover and power up the analyzer.

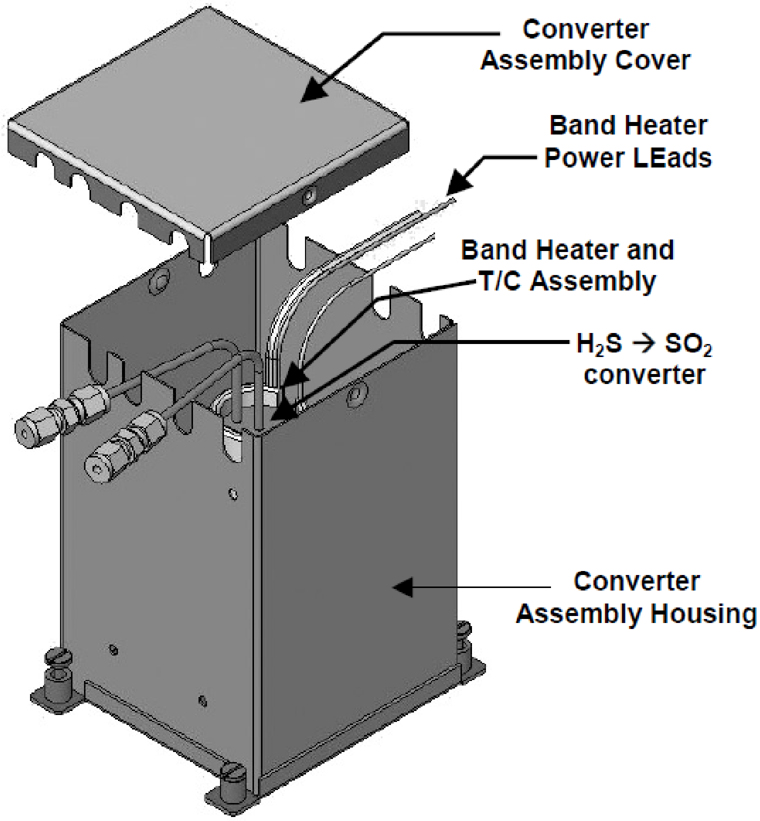


Figure 5. H_2S -> SO_2 converter assembly.

6.9. Service the Critical Flow Orifice Assembly

The critical flow orifice assembly shown in **Figure 6** can clog despite protection by sintered stainless steel filters, particularly if the instrument operates without a sample filter or in an environment with very fine, sub-micron particle-size dust.

1. Turn off power to the instrument and vacuum pump.
2. Locate the critical flow orifice on the pressure sensor assembly.
3. Disconnect the pneumatic line.
4. Unscrew the NPT fitting.
5. Remove the assembly components: 1 spring, 1 sintered filter, 2 O-rings, and 1 critical flow orifice. You may need to use a scribe or pressure from the vacuum port to remove parts from the manifold.
6. Discard the sintered filter. Inspect the two O-rings and replace as needed.
7. Inspect the critical flow orifice. Replace as needed.
8. Re-assemble the parts using a new filter and O-rings.

9. Reinstall the NPT fitting and connect all tubing.
10. Power up the analyzer and allow it to warm up for 60 minutes.
11. Perform a leak check.

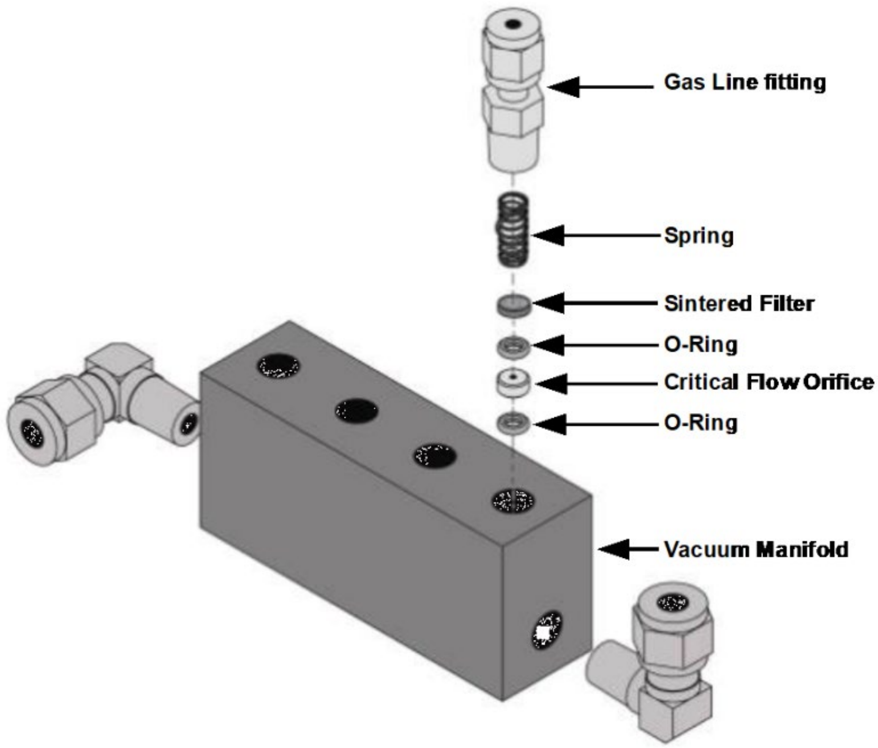


Figure 6. Critical flow orifice assembly.

6.10. Perform Leak Check/Pump Check

Leaks are the most common cause of analyzer malfunction. **A leak check should be carried out whenever the pneumatic flow path is disrupted.** Examples can include, but are not limited to, changing the sample inlet filter, changing the SO_2 scrubber materials, or opening the critical flow orifice assembly. The method described here is easy, fast, and detects (but does not locate) most leaks. It also verifies the sample pump condition, thus acting as a pump check. An in-depth pressure leak check may also be performed with additional tools and can be found in the T101 user manual.

1. If not already running, turn the analyzer on and allow at least 30 minutes for flows to stabilize.
2. Cap the sample inlet port (cap must be wrench-tight).
3. After several minutes when the pressures have stabilized, go to Dashboard to view the readings.

- If Sample Flow < 10 ccm, the instrument is free of large leaks. If not, the leak point should be identified and rectified.
- If Sample Pressure is < 10 in-Hg-A, the pump is in good condition. If not, the pump diaphragm needs to be replaced.

4. When finished, switch off the pump and SLOWLY open the cap to the sample inlet port to minimize in-rush flow.

6.11. UV Lamp Adjustment and Calibration

The UV lamp output can be affected by line voltage change, aging lamp, or lamp position. Two metrics need to be considered when assessing the lamp life: UV lamp intensity and lamp ratio. Lamp intensity should be 2,000-4,000 mV and the lamp ratio should be 30-120%. These values will decrease over time. To optimize signal intensity, perform the following steps. Note that a UV Lamp adjustment and calibration must be followed by a PMT sensor hardware calibration (Section 6.12).

IMPORTANT: DO NOT grasp the UV lamp by the cap when changing the lamp's position – always grasp the main body of the lamp. Inattention to this detail could twist and potentially disconnect the lamp's power supply wires, which COULD DAMAGE THE INSTRUMENT AND VOID WARRANTY.

1. Let the instrument run for one hour to stabilize the UV lamp.
2. Set the Dashboard to show the UV lamp function.
3. Slightly loosen the large brass thumbscrew located on the shutter housing so that the lamp can be moved.
4. While watching the UV LAMP reading, slowly rotate the lamp clockwise and counter-clockwise, and move lamp up and down vertically until the UV LAMP reading is at its maximum.
5. Finger-tighten the thumbscrew.
6. Assess whether the lamp signal is within optimal intensity (3,500 ± 200 mV).
7. If the signal intensity is too high or too low, locate the UV reference detector adjustment potentiometer screw and turn the screw clockwise to increase the signal or counter-clockwise to decrease the signal until signal intensity is optimal.

IMPORTANT: Increasing UV reference detector adjustment potentiometer to its maximum introduces measurement noise and results become unstable. If the potentiometer has to be maxed out to achieve optimal signal, the lamp should be replaced.

Visual instructions of the lamp adjustment process performed by the manufacturer can be found at: https://www.youtube.com/watch?v=PF6MGK1FftQ.

Now the optimal lamp signal is achieved, the lamp must be calibrated to reset the lamp ratio. Based on the lamp ratio, the Model T101 compensates for variations in the intensity of the available UV light by adjusting the H_2S concentration calculation. The lamp ratio results from dividing the current UV lamp intensity by a value stored in the CPU's memory from the last lamp calibration. Once the lamp ratio is < 30% or > 120%, the CPU can no longer compensate for the difference in the current signal from the last saved signal. Calibrate the lamp by doing the following:

1. From the Home page, navigate to Utilities > Diagnostics > Lamp Cal.
2. Press Calibrate, and the CPU will save the current lamp signal intensity automatically.
3. Confirm the lamp calibration is complete by checking if the lamp ratio is close to 100% (± the average fluctuation of lamp intensity).
4. If the lamp ratio is not close to 100%, power the T101 off and then on again. The lamp ratio should be close to 100% and the lamp calibration is complete. If not, repeat the lamp calibration steps.

6.12. PMT Sensor Hardware Calibration

At times when the instrument's slope and offset values exceed the acceptable range (see Table 3 in Section 6.2) and all other more obvious causes for this problem have been eliminated, the PMT sensor may be calibrated to reset the PMT output.

1. Set the instrument reporting range to SINGLE.
2. Perform a zero calibration using zero air.
3. Run a UV lamp calibration (Section 6.11). This is required to ensure proper scaling of the NORM PMT value.
4. Locate the pre-amplifier board installed on top of the PMT assembly.
5. Locate the following components on the pre-amplifier board (**Figure 7**):
    a. High voltage power supply (HVPS) coarse adjustment switch (range 0-9, then A-F)
    b. HVPS fine adjustment switch (range 0-9, then A-F)
    c. Gain adjustment potentiometer (full scale is 10 turns).

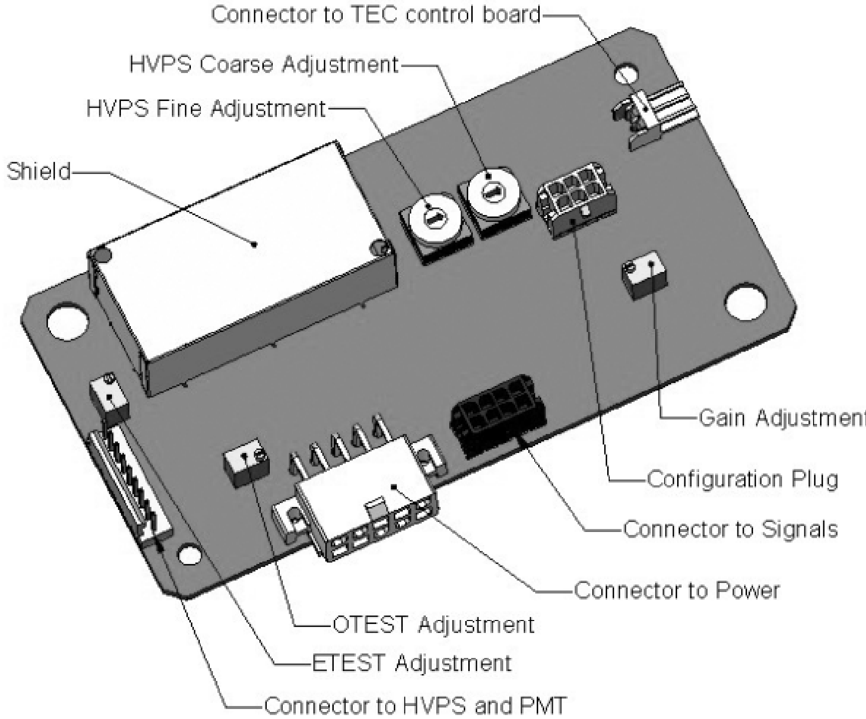


Figure 7. Pre-amplifier board layout.

6. Turn the gain adjustment potentiometer 12 times counterclockwise to its minimum setting, then 4 turns clockwise to have some voltage to work with.
7. While feeding at least 80% of measurement range value to the analyzer and waiting until the STAB value is below 0.5 ppb, calculate the target concentration by multiplying the span concentration by the analyzer slope. For example, target concentration = 400 ppb H_2S x 1.25 = 500 ppb H_2S.
8. Note the position of the two HVPS adjustment switches. Carefully use a flathead or slotted screwdriver to adjust the HVPS coarse and fine adjustments until the instrument concentration reads close to the target concentration calculated in the previous step.
9. **IMPORTANT:** DO NOT overload the PMT by accidentally setting both adjustment switches to their maximum setting (mark F). Start at the lowest setting and increase by increment slowly.
10. Perform a span calibration. The slope should now be close to 1.0 and the concentration should be close to the span gas concentration.
11. Use the Dashboard or Home page to review the NORM PMT value. This value should be double the span gas concentration in ppb. With 400 ppb H_2S, the NORM PMT should show 800 mV on a properly calibrated analyzer.
12. Review and record the new slope and offset as part of the calibration procedure.

6.13. Calibrate Offset and Slope

Generally, a calibration is required when Zero/Span or multi-point check results fail or are marginal, and after major part repairs. Care should be taken to troubleshoot and eliminate all other more obvious causes for the check failures before proceeding with calibration.

Navigate to the Calibration menu as shown in **Figure 8** to perform calibration. On the units with a zero/span valve option installed, select the calibration gas source (Zero or Span) accordingly. Detailed screenshots can be found in the T101 user manual.

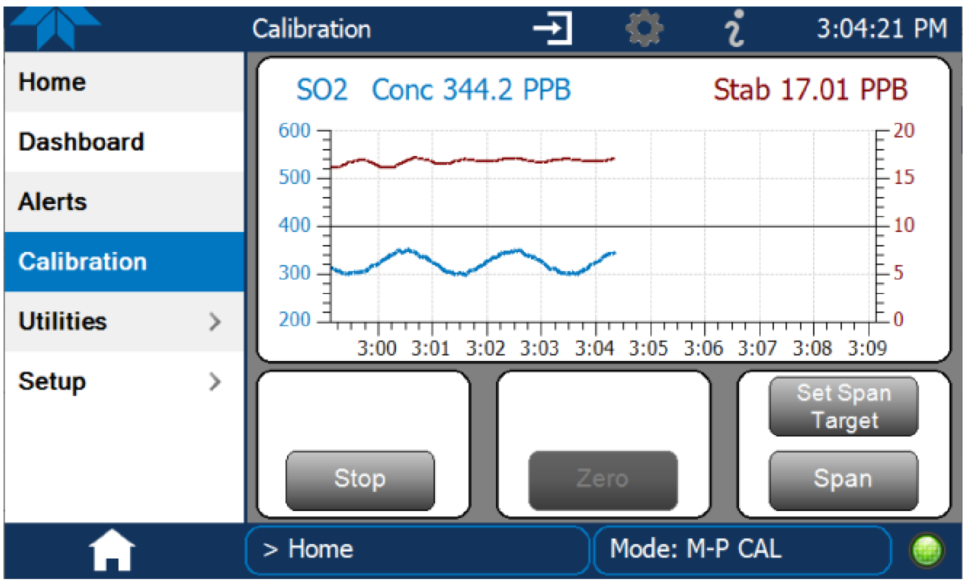


Figure 8. Calibration page.

6.13.1. Manual Calibration

IMPORTANT: Before any calibration, record the as-found Slope and Offset in the maintenance form. <u>You will NOT be able to retrieve the values once the analyzer is calibrated.</u>

NOTE: If the ZERO or SPAN buttons are not displayed during the zero and span calibration, the measured concentration value is too different from the expected value and the analyzer does not allow zeroing or spanning the instrument.

Zero calibration:

1. From the calibrator, generate the zero air.
2. From the analyzer, select Calibration > Start.
3. Wait until the analyzer stability (STAB) is below 0.5 ppb.
4. Click Zero to calibrate.

5. Click Stop and verify the reading.

Span calibration:

6. From the calibrator, generate the desired span gas concentration.
7. From the analyzer, select Calibration > Start.
8. Wait until the analyzer stability (STAB) is below 0.5 ppb.
9. Click Set Span Target > Enter the actual reading from the calibrator > Done. Use the target concentration if the actual reading is not available.
10. To perform calibration (i.e. adjust the slope and offset) click Span.
11. Click Stop and verify the reading.
12. At the conclusion of Zero and Span calibration, verify the new slope and offset are within the acceptable range shown in Table 3. If they are outside of the acceptable range, some parts may be causing the slope and offset to over-compensate and corrective action is needed.
13. Record the new slope and offset in the maintenance form.
14. Proceed to Section 6.1 to perform a post-calibration multi-point check.

    IMPORTANT: On the units with a zero/span valve option installed, DO NOT rely on the Sample dropdown option in the Calibration page to return to the sampling mode. Instead, navigate to Home page to ensure the analyzer is back in SAMPLE mode.

6.13.2. Automated Calibration

For some monitoring sites, automated calibration may be configured and initiated manually. Note the following procedure is only applicable when the Teledyne T101 analyzer and T700 dilution calibrator are used together.

The preset calibration sequence is set up such that an abundance of time (at least 15 minutes for zero and 45 minutes for any non-zero concentration) is built in to achieve stabilized readings before the analyzer is automatically calibrated.

Due to the close similarity between the automated verification and automated calibration feature, this section describes only the major highlights when initiating an automated calibration sequence. Read this section thoroughly before proceeding to Section 6.1.2 to perform an automated calibration.

- Before any calibration, record the as-found slope and offset in the maintenance form. <u>You will NOT be able to retrieve the values once the analyzer is calibrated.</u>
- Make sure the T700 dilution calibrator contains the accurate gas standard concentration information in the cylinder setup menu.

- Once the calibration sequence is initiated, verify the calibrator begins the steps by observing the Instant Mode in the Generate Menu or Mode at the lower right corner of the display.
- At the conclusion of Zero and Span calibration, verify the new slope and offset are within the acceptable range shown in Table 3. If not, some parts may be causing the slope and offset to over-compensate and corrective action is needed.
- Record the new slope and offset in the maintenance form.
- Proceed to Section 6.1 to perform a post-calibration multi-point check.

7. Maintenance Form Template

Examples of the maintenance checklist and response summary are shown in **Figures 9 and 10**. This may be used as a template to be customized to meet the specific monitoring project goals.

H2S Monitor - Teledyne - T101

Instrumentation SNs	
H_2S Teledyne T101	
Calibrator (Teledyne T700)	
Gas Cylinder	
Gas Cylinder Expiration Date	
ZAG (Teledyne 701)	

Maintenance Notifications	
Notify field operations	☐
Enable missing data alerts	☐
Disable maintenance mode	☐

Verification Type	
Verification Type	Monthly

Maintenance Checklist		Completed?
BOTH Analyzer and Calibrator cleared of all active alerts?		☐
Perform Zero/Span gas test for analyzer response. If the test fails, investigate the root cause, and calibrate as needed.		☐
Inspect sample line tubing and inlet.		☐
Inspect and empty out water trap.		☐
Replace inlet particulate sample filter.		☐
Perform multi-point gas test for analyzer response. If the test fails, investigate the root cause, and calibrate as needed.		☐
Perform a flow check.		☐
Replace SO2 scrubber media.		☐
Perform zero air generator and dilution calibrator maintenance.		☐

Figure 9. Example of T101 H_2S analyzer checklist.

Instrument Diagnostics	
As Found H_2S Slope As Left	
As Found H_2S Offset As Left (mV)	
Concentration (ppb)	
H2S STB (ppb)	
Sample Flow (sccm)	
Sample Pressure (in Hg)	
UV Lamp (mV)	
Lamp Ratio (%)	
HVPS (V)	
Box Temperature (°C)	
Converter Temperature (°C)	

Span Test	
Measured Zero (ppb)	
H2S STB (ppb)	
Expected Concentration (ppb)	
Measured Concentration (ppb)	
H2S STB (ppb)	
% Error	
Pass/Fail	

Figure 10. Example of T101 H_2S diagnostics and span test summary.

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

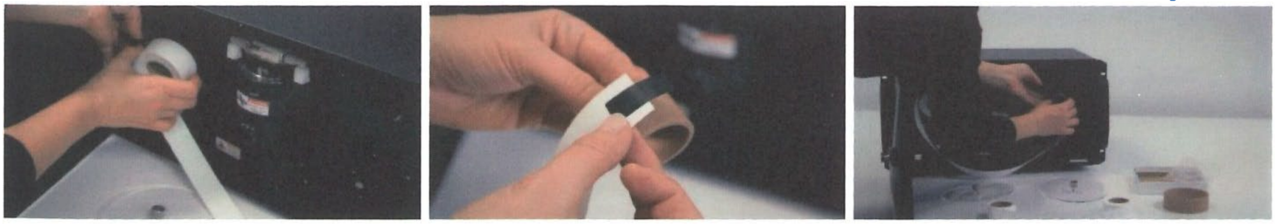
Supplies for this procedure: new roll of filter tape, adhesive tape. See Section 9.2 of the user's manual for reference.

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.

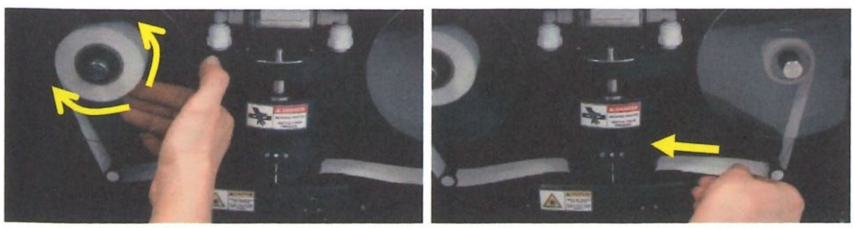
1. If the instrument is running, press **Stop** on the front panel.
2. Open the front door of the instrument.
3. Loosen the thumb screws and remove the transparent plastic covers from both the "supply" spool (on the left hand side), and the "collection" spool (on the right-hand side).
4. Using thumb 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.

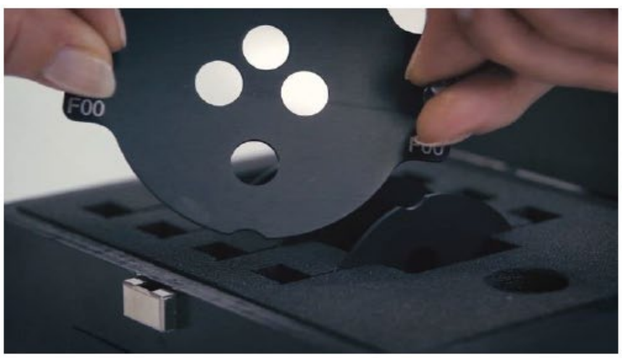
The test routine compares two measurement values from an external flow meter: one taken at the rear port of the instrument, and the other taken at the sample point of entry (which may be outdoors). The routine requires the use of the black rubber Flow Calibration Pad. During this test, data will be flagged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

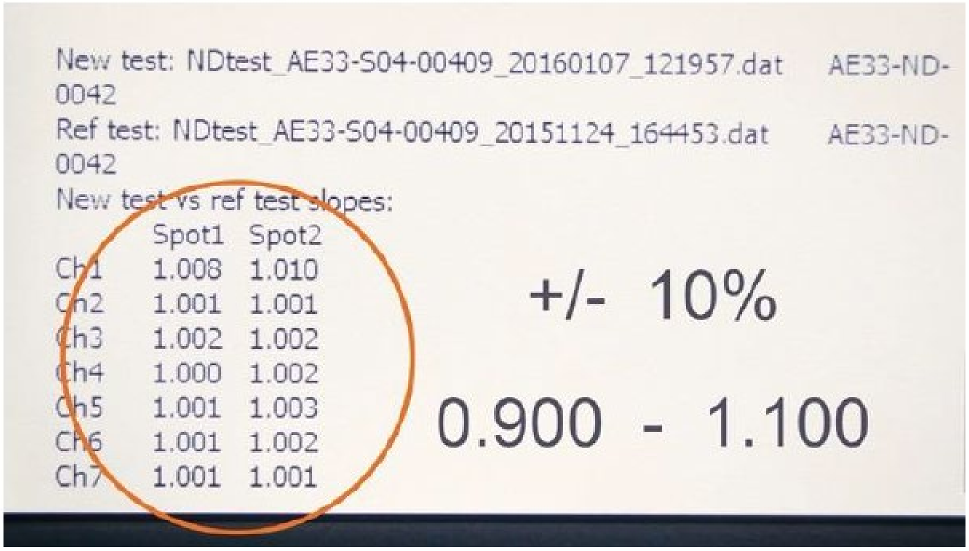
6.5. Perform Neutral Density (ND) Filter Test

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. $PM_{10-2.5}$ 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 µg/m^3 Action level is 0.1-0.3 µg/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.

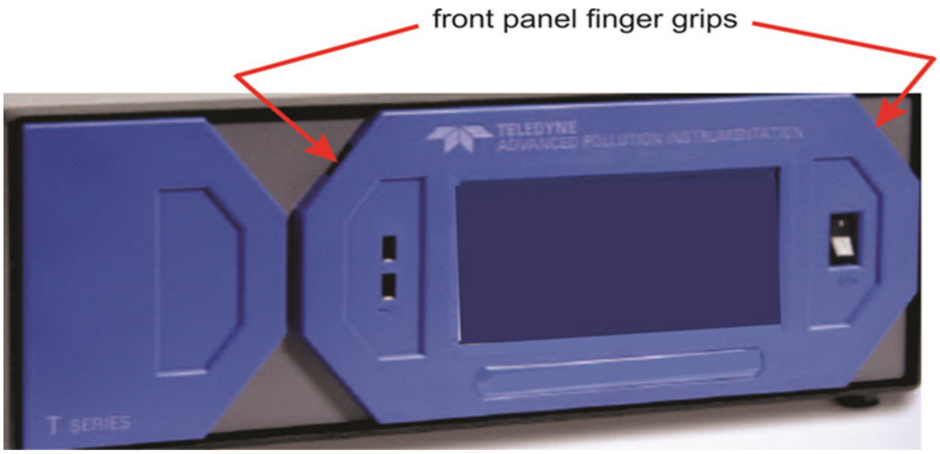


Figure 3. Opening the front panel.

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**).

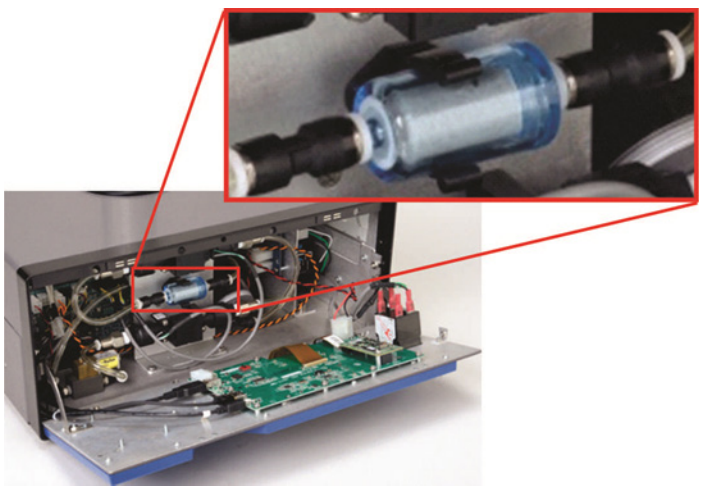


Figure 4. Internal DFU.

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.

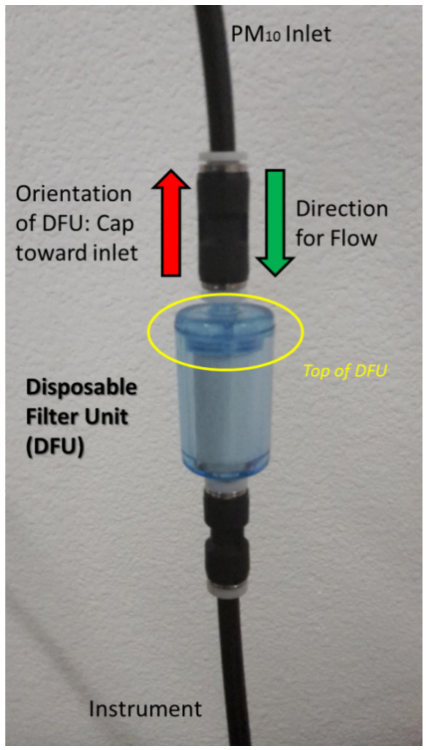


Figure 5. External DFU.

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.

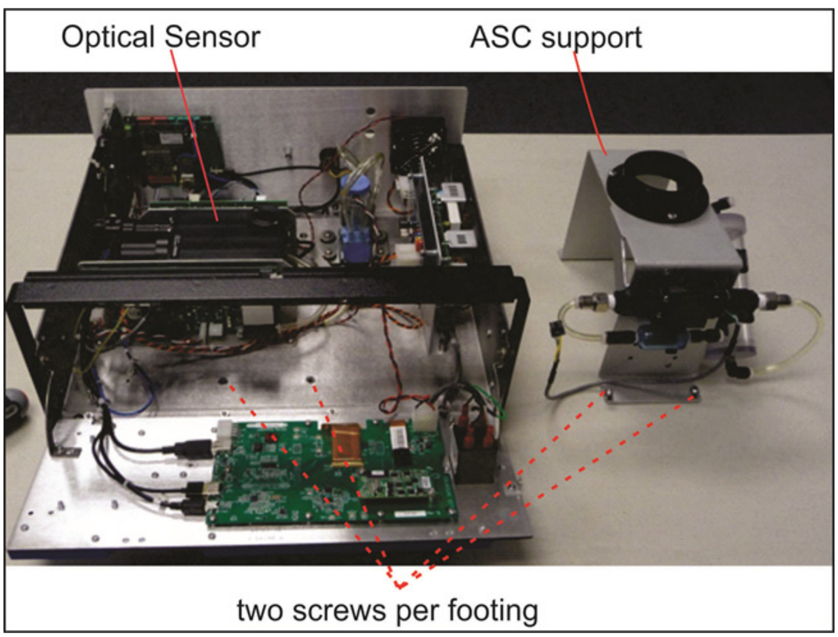


Figure 7. Maintenance of the optical chamber and RH/T sensor access.

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

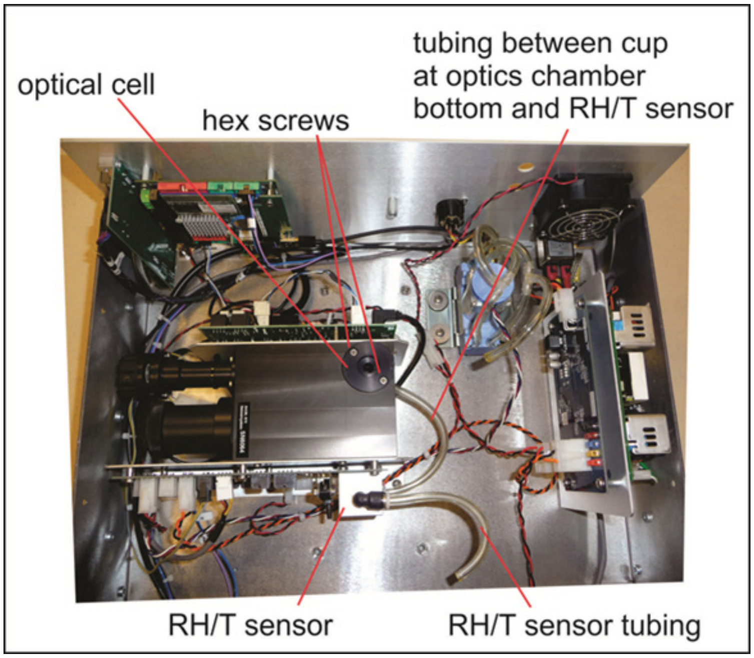


Figure 8. Maintenance: location of the optics chamber and RH/T sensor.

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.

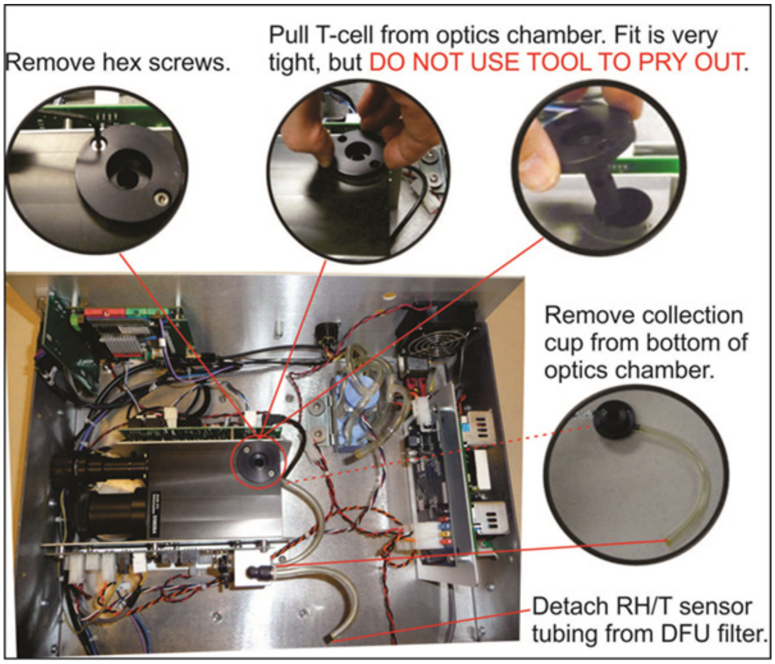


Figure 9. Maintenance: Optical Chamber Disassembly

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

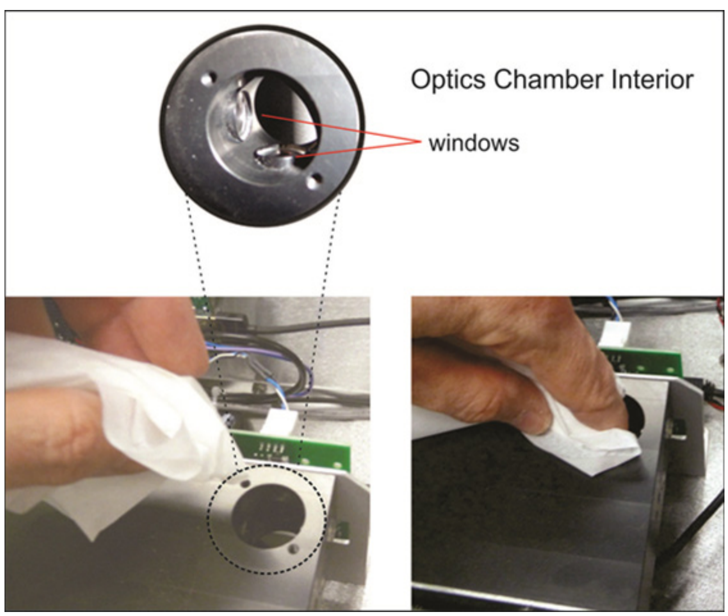


Figure 10. Maintenance: optics chamber windows.

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**).

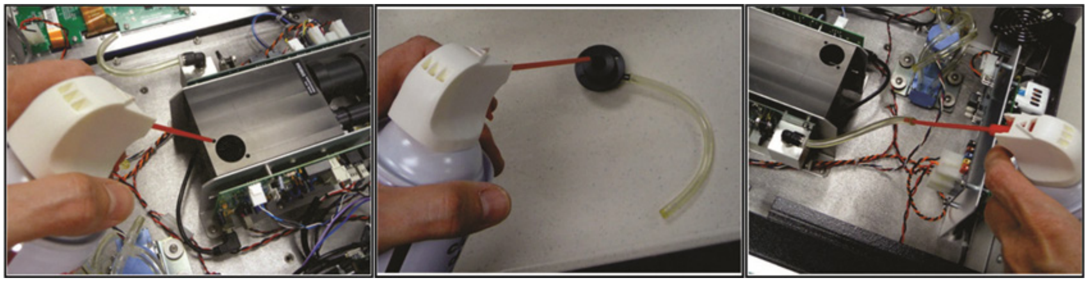


Figure 11. Maintenance: final dusting.

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.

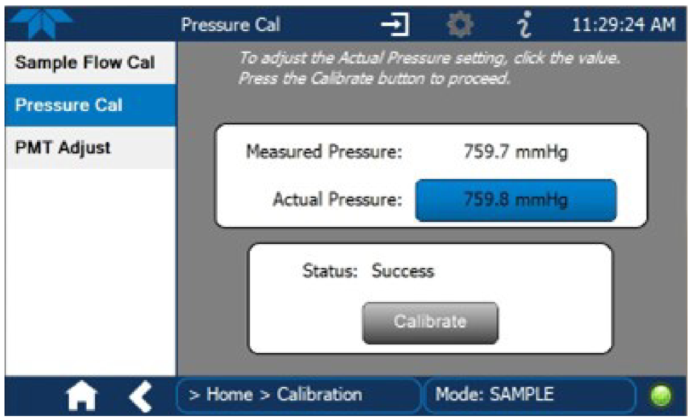


Figure 14. Pressure calibration screen.

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.

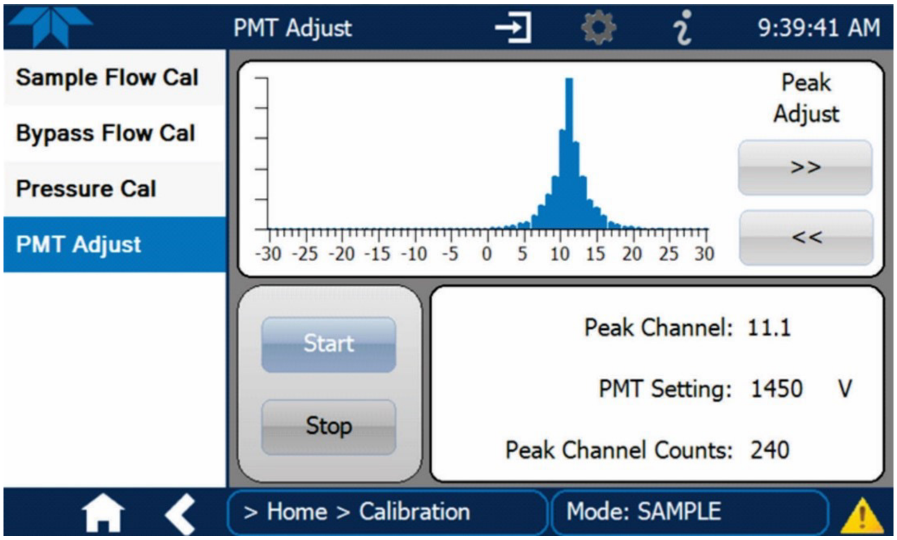


Figure 16. PMT adjust screen.

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.

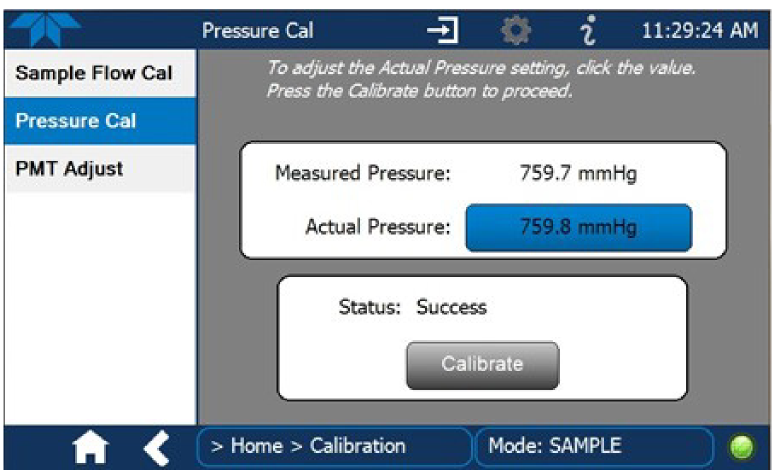


Figure 17. Pressure calibration screen. IMPORTANT: Perform this calibration prior to any flow calibration.

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.

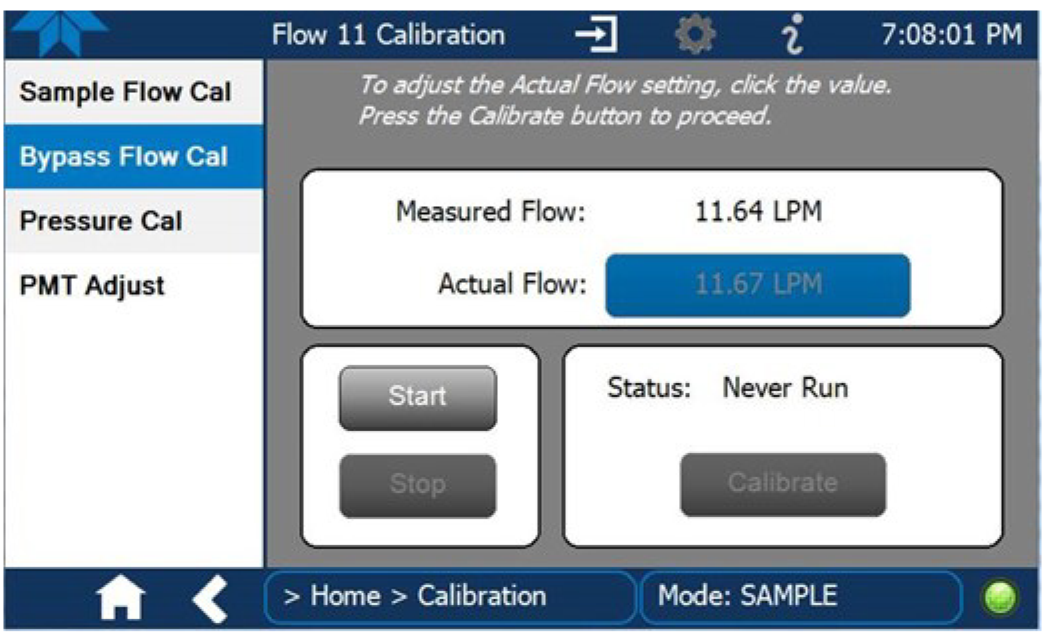


Figure 19. Bypass Flow calibration screen.

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=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 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.

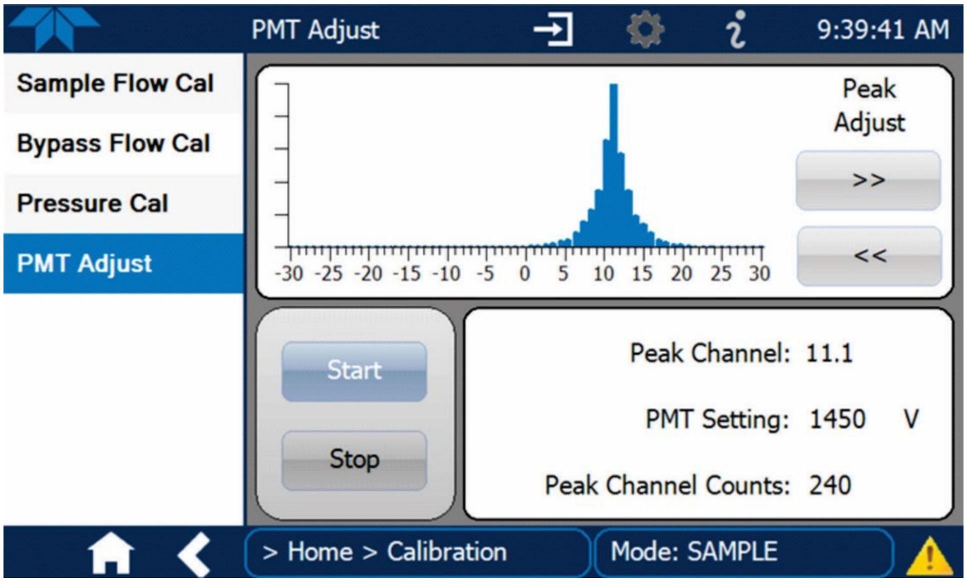


Figure 20. PMT adjust screen.

12. Allow 30 sec for the Peak Channel reading on this screen to respond. If the value is not ± 0.5 of the SpanDust^{TM} 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^{TM} 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**).

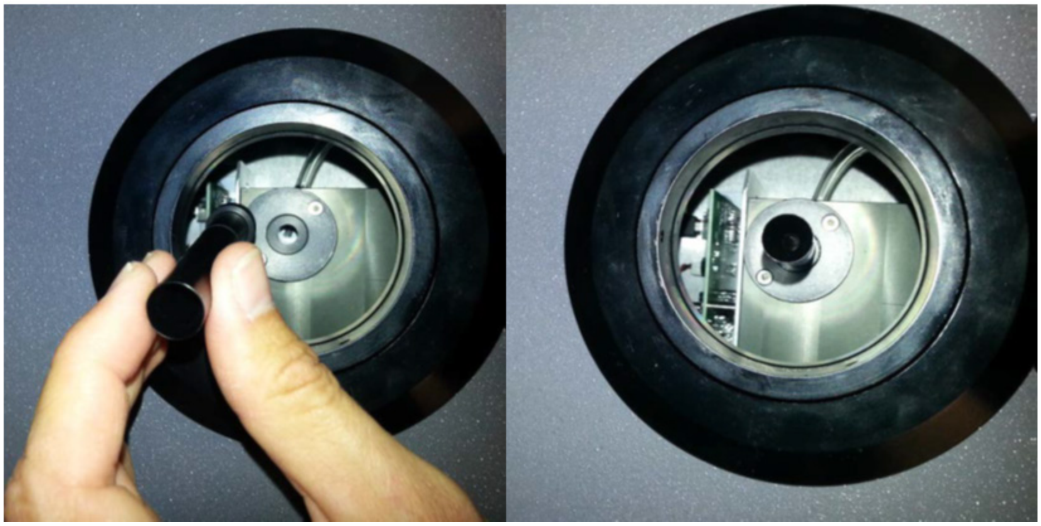


Figure 21. ASC Setup: inlet nozzle.

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

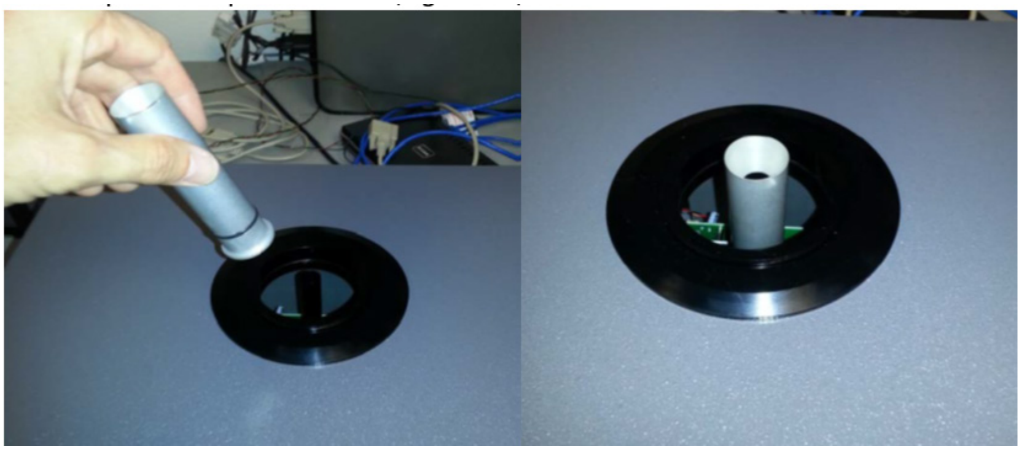


Figure 22. ASC setup: aluminum adapter.

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.

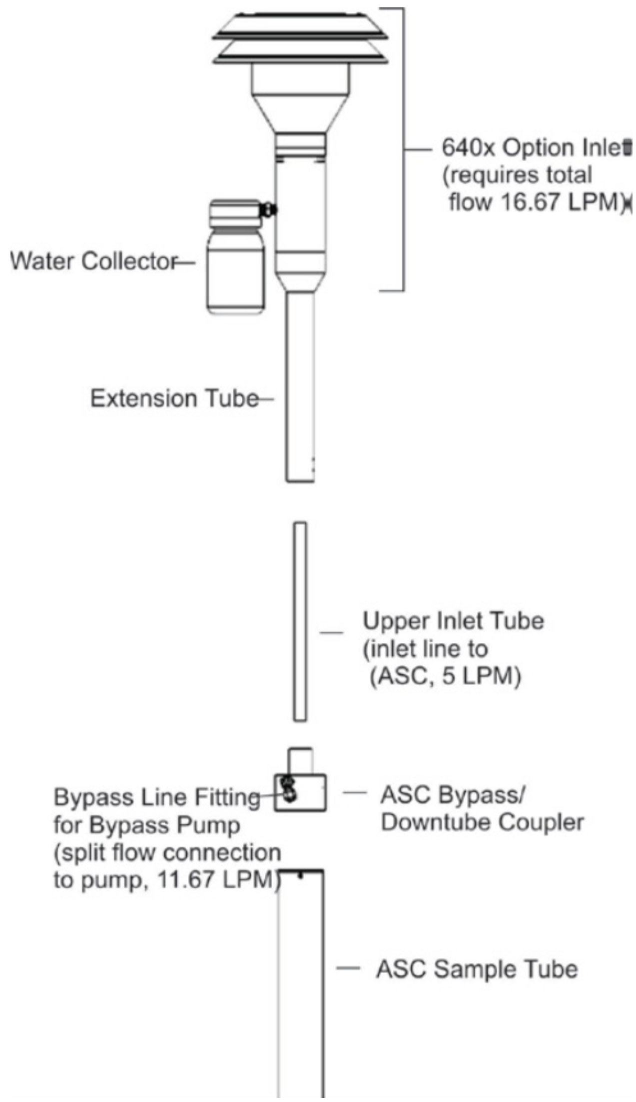


Figure 24. 640x inlet and ASC assembly.

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**.

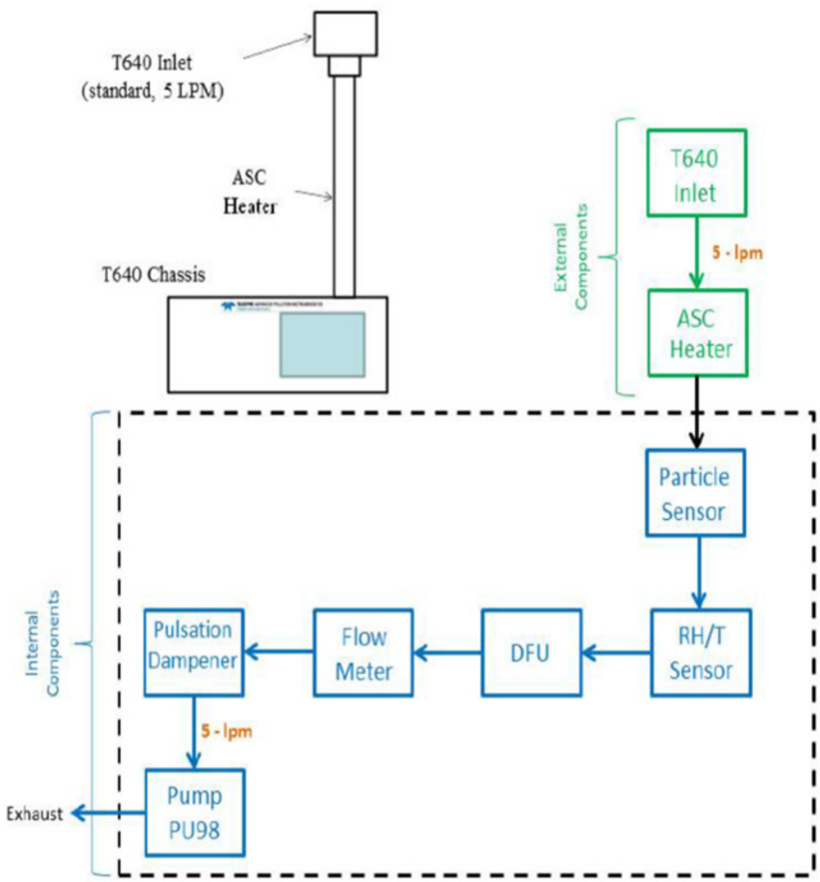


Figure 27. T640 pneumatics.

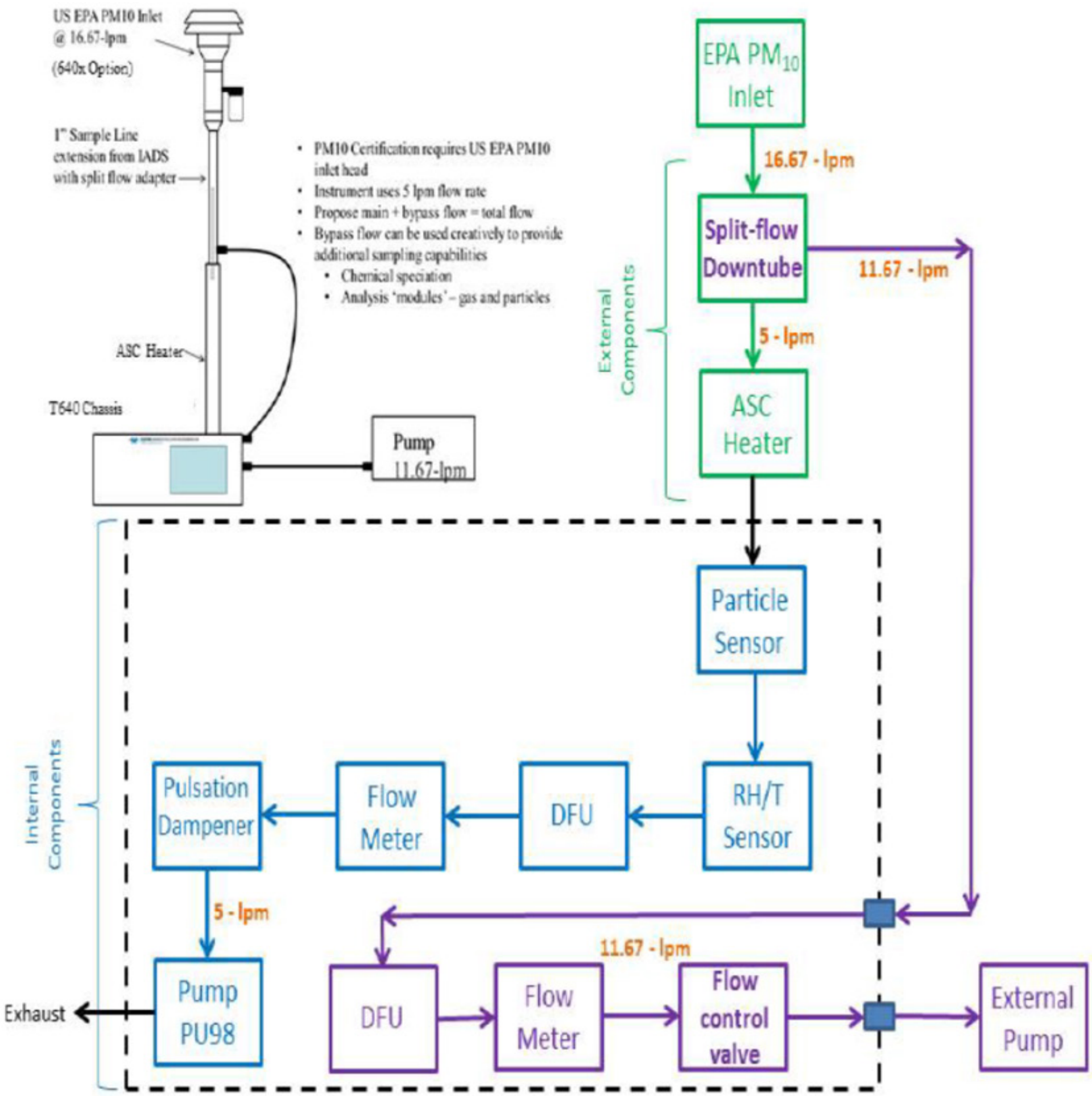


Figure 28. T640 with 640x option pneumatics.

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. =				+ 0.5 value displayed on SpanDust™ bottle, (e.g., 11.1 or 11.3)
	PMT Setting =				
	Peak Ch. Counts =				

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 Procedures for Meteorological Instruments

August 5, 2024

STI-8195

Contents

1. Scope and Applicability

This standard operating procedure (SOP) provides instructions for servicing meteorological instruments measuring wind speed, wind direction, temperature, and relative humidity. Operating procedures for these instruments are listed in Section 3.

2. Routine Maintenance

Routine maintenance tasks are designed to maintain the meteorological equipment in good working condition and reduce the frequency of non-routine maintenance. They are described in detail below.

2.1 Maintenance Checklist

Table 1 shows the maintenance activities that must be performed during each site visit to ensure all instruments are performing correctly.

Table 1. Routine maintenance checklist.

Item	Action
Tower[a]	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 whether 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/ Sensor 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 and that the cables are not fraying.
	Clean the glass domes on the sensors with an alcohol wipe or a soft, clean towel and water. Replace the silica gel desiccant when needed (it will turn from blue to pink when it needs to be replaced).
	Check that the air intake tube at the bottom of the pressure sensor housing is not blocked. Clean with cotton swab and water if needed.
	Check that cable connections are secure.

Item	Action
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.
Cables	Check the integrity of the cables connecting the data logger box from the data logger to the sensors.
	Check that the sensor cables are attached to the tower.
Guy Wires	Where guy wires are used, check that they are taut and that the attachment points are tight. If the attachment points are loose, call Sonoma Technology for instructions.
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.

[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

- Record the current weather observations on the Maintenance Site Visit form. This observation should include general wind direction, wind speed, approximate temperature, clouds, current weather, the time, and any other observations that could impact meteorological data. For example, an observation might read:

  "Moderate southwest breeze, temps in the 50s F, damp with fog and rain at 1030 PST"

- Observe all of the meteorological data parameters on the data logger screen and determine whether or not they are physically plausible and reasonable (i.e., is a value that should be positive shown as negative, etc.).
- Monitor wind speed and wind direction on the screen and compare with the visually estimated orientation of the wind monitor and strength of the wind. **Note:** The typical range for wind speed is 0 m/s to 10 m/s. Use Tables 2 and 3 to help estimate wind speed and temperature.

Table 2. Wind speed estimation.

Description	Wind Speed Range (m/s)	How to Estimate Speed
Calm	0 to 0.2	Calm, smoke rises vertically
Light air	0.3 to 1.5	Smoke drifts with the wind
Light breeze	1.6 to 3.3	Wind felt on face; leaves rustle
Gentle breeze	3.5 to 5.4	Leaves and small twigs in constant motion; wind extends light flags
Moderate breeze	5.5 to 7.9	Raises dust and loose paper; small branches are moved
Fresh breeze	8.0 to 10.7	Small trees with leaves begin to sway

Table 3. Temperature conversions.

	Temperature											
°F	25	30	35	40	45	50	55	60	65	70	75	80
°C	-4	-1	2	4	7	10	13	16	18	21	24	27

- If any parameter appears unreasonably high or low, or simply implausible, try to identify the cause (check cables, connections, etc.). If you cannot find the source of the problem, contact Sonoma Technology.

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

Audits are conducted on meteorological instrumentation 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 is 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 Sonoma Technology servers. Notes on what was performed are also to be recorded in the station logbook. The performance criteria for meteorological sensors are listed in Table 4.

Table 4. EPA-recommended meteorological specifications.

Meteorological Variable	Accuracy	Measurement Resolution
Wind Speed	±0.2 m/s	0.2 m/s
Wind Direction	±5°	3°
Ambient Temperature	±0.5°C	0.3°C
Relative Humidity	±5% RH	1.0% RH
Barometric Pressure	±1 hPa	0.3 hPa
Vertical Temperature Difference	±0.1°C	0.1°C
Solar Radiation	10 W/m^3 below 200 W/m^3 above 200 W/m^3 ±5%	1.0 W/m^2

3.1 Wind Direction Calibration

The wind direction calibration is performed by comparing the wind direction sensor readouts on the data acquisition system (DAS) and chart recorder (if applicable) with known wind directions established by using a theodolite or precision compass. Several points over the measurement range are verified using a calibration fixture, assigned compass reference points, or established distant sighting targets. Differences between reference and sensor measured directions are recorded. The starting threshold for the direction vane is checked using a torque disc or watch gauge.

3.1.1 Materials Needed

- Pocket transit or precision compass with tripod
- RM Young Model 18212 Vane Angle Fixture
- RM Young Model 18331 Vane Torque Gauge
- Current magnetic declination angle for the site to be calibrated

3.1.2 Procedure

Calibration procedures are in accordance with the guidelines of the *EPA Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Version 2.0 Final* (U.S. Environmental Protection Agency, 2008b).

1. For wind direction instruments that have crossarms, prior to lowering the tower or the crossarm, determine the crossarm alignment by sighting along it using a precision compass corrected for magnetic declination. Current magnetic declination should be obtained using the latitude/longitude or UTM coordinates of the site and a magnetic declination calculation computer program. Optionally, if a solar viewing is possible, a theodolite can be set up and oriented using a solar angle computer program. Using this method, a technician can view the crossarm through the theodolite to verify alignment with reference to True North.
2. Once the crossarm is lowered, position the wind vane exactly parallel to the crossarm and record the reading.
3. Determine the sensor's accuracy and linearity by mounting a direction template or calibration fixture, and fixing the vane in 30-degree increments around the full 360- or 540-degree range of the sensor. The vane is rotated sequentially through the increments clockwise and counter-clockwise, and the DAS readouts are recorded. The tip and the tail of the vane may also be pointed at established distant sighting targets.
4. The difference between the station and calibration wind directions is calculated using the following equation:

   Difference = Station Wind Direction - Reference Wind Direction

   The differences calculated above are compared with the EPA State and Local Air Monitoring Stations (SLAMS)–recommended criteria of "5E for the entire system" (orientation plus linearity). If results exceed these criteria, recalibrate the sensor or replace the potentiometer or sensor.
5. Determine the starting threshold of the wind vane by measuring the shaft rotational torque of the sensor using a torque gauge or disc. The measured torque should be less than the maximum allowable torque provided by the manufacturer corresponding to a 0.5 m/s wind speed threshold.

   If the measured torque exceeds this value, replace the bearings or sensor. If necessary, calculate the torque value that corresponds to the starting threshold of 0.5 m/s for a 10E deflection by using the "k" value provided by the manufacturer and the following equation:

   $T = kU^2$ (*Where: T = torque in gm-cm, U = wind speed in m/s, and k = constant*)

   This torque gauge test determines if the wind vane starting threshold is less than or equal to the required specifications. The wind vane is considered to be within the recommended criteria if the indicated torque value is less than or equal to the calculated or stated maximum starting torque value.

3.2 Wind Speed Calibration

The wind speed calibration is performed by temporarily replacing the anemometer cups or propeller with a synchronous motor, and comparing the speed corresponding to the rotation rate (supplied by the manufacturer) with the equivalent wind speed displayed by the instrument and recorded by the DAS. Starting thresholds are checked using a torque disc to measure shaft rotational torque.

3.2.1 Materials Needed

- RM Young Model 18810 anemometer drive
- RM Young Model 18310 Torque Disc

3.2.2 Procedure

Calibration procedures conform to the guidelines of the *EPA Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Version 2.0 Final* (U.S. Environmental Protection Agency, 2008b).

1. The starting threshold is calibrated by checking the sensor shaft's rotational torque with a torque disc. With the anemometer sensor in the horizontal position, remove the propeller and install the RM Young Model 18310 Torque Disc on the anemometer shaft. Use the manufacturer-provided allowable torque values, or calculate the torque value that corresponds to the starting threshold of 0.5 m/s using the "k" value provided by the manufacturer and the following equation:

   $T = kU^2$ *(Where: T = torque in gm-cm; U = wind speed in m/s; and k = constant)*

   Install the 0.1 gm screw weight in the appropriate hole of the torque disc that corresponds to the calculated torque value, and position the weight so that it is level with the anemometer shaft. Release the weight and note whether the torque disk and anemometer shaft rotate freely. To measure the actual starting torque, change the position of the screw weight starting at the location closest to the shaft, and move outward until the weight rotates freely from the horizontal. The weight of the screw multiplied by the distance from the shaft equals the torque in gm-cm.

2. The accuracy of wind speed measurements are tested at zero and at least two speeds within the operational range of the sensor. The RM Young Model 18810 selectable speed anemometer drive is used to generate stable calibration input speeds over the range of the sensor. Remove the propeller and join the wind speed sensor shaft to the calibration motor with a coupling device.

3. Calculate the difference between the system and calibration wind speeds using the following equation:

   $$\text{Difference} = \text{Station Wind Speed} - \text{Reference Wind Speed}$$

The differences calculated above are compared with the EPA SLAMS recommended criteria of "0.25 m/s when speeds are ≤5 m/s; ±5% when speeds are >5 m/s, not to exceed ±2.5 m/s."

3.3 Temperature Calibration

3.3.1 Materials Needed

- A NIST-traceable digital thermometer
- Three thermos bottles—one with hot water, one with warm water, and one with ice

3.3.2 Procedure

Calibration procedures are in accordance with the guidelines of the *EPA Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Version 2.0 Final* (U.S. Environmental Protection Agency, 2008b).

1. Temperature sensing systems are calibrated by collocated intercomparison with a calibrated reference standard.
2. If immersion in water is possible:
   a. The station temperature sensing system thermistor and the calibrated audit thermometer is immersed in a common stirred water bath.
   b. Readings are compared at 3 points over the expected temperature range.
3. If delta-temperature is measured, simultaneously insert both temperature sensors in the same medium and compare the outputs.
4. Calculate the difference between the station and audit temperatures using the following equation:

$$Difference = Station\ Temperature - Reference\ Temperature$$

5. The differences calculated above will then be compared with the EPA-recommended criteria of 1.0°C. If the delta temperature is calibrated, the difference between the output of the two sensors is compared with the EPA-recommended criteria of 0.1ºC.

3.4 Relative Humidity Calibration

3.4.1 Materials Needed

- Calibrated digital relative humidity (RH) probe, or a Sato or similar motor aspirated psychrometer
- Booklet of psychometric tables and a portable barometer (if motor aspirated psychrometer is being used)

- Water
- Large plastic bucket (approx. 5 gallon size)

3.4.2 Procedure

Calibration procedures are in accordance with the guidelines of the E*PA Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV, Version 2.0 Final* (U.S. Environmental Protection Agency, 2008b).

1. The relative humidity calibration is performed by collocating the calibrated RH sensor or motor-aspirated psychrometer adjacent to the site sensor. The sensors are placed in a shaded location and allowed to equilibrate.
2. Multiple readings are taken over several hours.
3. Calculate the difference between the station and reference relative humidity readings using the following equation:

$$\%\ RH\ Difference = Station\ \%\ RH - Reference\ \%\ RH$$

4. Compare the mean of the percent differences calculated above with the EPA-recommended criteria of 10% relative humidity.

4. 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.

5. Maintenance Form: Quarterly Meteorology Station Checklist

DATE: ____________________ Location: ______________________________________

Item	Action	Observation / Completion Date
Tower[a]	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 whether 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/ Sensor 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 and that the cables are not fraying.	
	Clean the glass domes on the sensors with an alcohol wipe or a soft, clean towel and water. Replace the silica gel desiccant when needed (it will turn from blue to pink when it needs to be replaced).	
	Check that the air intake tube at the bottom of the pressure sensor housing is not blocked. Clean with cotton swab and water if needed.	

Item	Action	Observation / Completion Date
	Check that cable connections are secure.	
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.	
Cables	Check the integrity of the cables connecting the data logger box from the data logger to the sensors.	
	Check that the sensor cables are attached to the tower.	
Guy Wires	Where guy wires are used, check that they are taut and that the attachment points are tight. If the attachment points are loose, call Sonoma Technology for instructions.	
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.	

Estimated Temperature	Temp Sensor Reading	Difference / Comment
____________________°C	__________________°C	____________________________________

Estimated RH	RH Sensor Reading	Difference / Comment
____________________%	__________________%	____________________________________

Estimated Wind Speed	Wind Sensor Reading	Difference / Comment
__________________mph	________________mph	____________________________________

Estimated Wind Direction	Wind Direction Reading	Difference / Comment
____________________°	____________________°	____________________________________

Additional Comments:

6. Maintenance Form: Meteorology Station Calibration

DATE: ___________________ Location: ____________________________________

6.1 Temperature/RH Sensor Test:

Temp Standard Model: ________________________
Temp Standard Serial Number: ________________________
Temp Standard Cal Due Date: ________________________

RH Standard Model: ________________________
RH Standard Serial Number: ________________________
RH Standard Cal Due Date: ________________________

Temp/RH Sensor Model: ________________________
Temp/RH Sensor Serial Number: ________________________

As Found:

Temp Standard Reading	Temp Sensor Reading	Difference
________________________°C	________________________°C	________________________°C
________________________°C	________________________°C	________________________°C
________________________°C	________________________°C	________________________°C
________________________°C	________________________°C	________________________°C
________________________°C	________________________°C	________________________°C

RH Standard Reading	RH Sensor Reading	Difference
________________________%	________________________%	________________________%
________________________%	________________________%	________________________%
________________________%	________________________%	________________________%
________________________%	________________________%	________________________%
________________________%	________________________%	________________________%

As Left (if sensor was changed or adjusted):

New Temp/RH Sensor Model: ______________________

New Temp/RH Sensor Serial Number: ______________________

Temp Standard Reading	Temp Sensor Reading	Difference
______________________°C	______________________°C	______________________°C
______________________°C	______________________°C	______________________°C
______________________°C	______________________°C	______________________°C
______________________°C	______________________°C	______________________°C
______________________°C	______________________°C	______________________°C

RH Standard Reading	RH Sensor Reading	Difference
______________________%	______________________%	______________________%
______________________%	______________________%	______________________%
______________________%	______________________%	______________________%
______________________%	______________________%	______________________%
______________________%	______________________%	______________________%

6.2 Anemometer Sensor Test:

Driver Model: ______________________
Driver Serial Number: ______________________
Driver Cal Due Date: ______________________

Anemometer Model: ______________________
Anemometer Serial Number: ______________________
Propeller Serial Number: ______________________

Compass Model Number: ______________________
Compass Serial Number: ______________________

GPS Coordinates: ______________________
Magnetic Declination: ______________________

As Found:

Wind Direction:

Expected	Measured	Difference
0° CW	______________________°	______________________°
45° CW	______________________°	______________________°
90° CW	______________________°	______________________°
135° CW	______________________°	______________________°
180° CW	______________________°	______________________°
225° CW	______________________°	______________________°
270° CW	______________________°	______________________°
315° CW	______________________°	______________________°
360° CW	______________________°	______________________°
315° CCW	______________________°	______________________°
270° CCW	______________________°	______________________°
225° CCW	______________________°	______________________°
180° CCW	______________________°	______________________°
135° CCW	______________________°	______________________°
90° CCW	______________________°	______________________°
45° CCW	______________________°	______________________°
0° CCW	______________________°	______________________°
355° CCW	______________________°	______________________°
5° CCW	______________________°	______________________°

Directional Torque:

CW ______________________gm-cm

CCW ______________________gm-cm

Wind Speed:

Expected (m/s)	Measured	Difference
0 m/s (0 RPM)	______________________m/s	______________________m/s
1.54 m/s (300 RPM)	______________________m/s	______________________m/s
3.07 m/s (600 RPM)	______________________m/s	______________________m/s
6.14 m/s (1200 RPM)	______________________m/s	______________________m/s
13.31 m/s (2600 RPM)	______________________m/s	______________________m/s
25.60 m/s (5000 RPM)	______________________m/s	______________________m/s
18.43 m/s (3600 RPM)	______________________m/s	______________________m/s

Wind Torque: ______________________ gm-cm

Alignment:

Expected	Measured	Difference
______________________°	______________________°	______________________°

As Left (if sensor was changed or adjusted):

New Anemometer Model: ______________________

New Anemometer Serial Number: ______________________

New Propeller Serial Number: ______________________

Wind Direction:

Expected	Measured	Difference
0° CW	______________________°	______________________°
45° CW	______________________°	______________________°
90° CW	______________________°	______________________°
135° CW	______________________°	______________________°
180° CW	______________________°	______________________°
225° CW	______________________°	______________________°
270° CW	______________________°	______________________°
315° CW	______________________°	______________________°
360° CW	______________________°	______________________°
315° CCW	______________________°	______________________°
270° CCW	______________________°	______________________°
225° CCW	______________________°	______________________°
180° CCW	______________________°	______________________°
135° CCW	______________________°	______________________°
90° CCW	______________________°	______________________°
45° CCW	______________________°	______________________°
0° CCW	______________________°	______________________°
355° CCW	______________________°	______________________°
5° CCW	______________________°	______________________°

Directional Torque:

CW ______________________gm-cm

CCW ______________________gm-cm

Wind Speed:

Expected	Measured	Difference
0 m/s (0 RPM)	______________________m/s	______________________m/s
1.54 m/s (300 RPM)	______________________m/s	______________________m/s
3.07 m/s (600 RPM)	______________________m/s	______________________m/s
6.14 m/s (1200 RPM)	______________________m/s	______________________m/s
13.31 m/s (2600 RPM)	______________________m/s	______________________m/s
25.60 m/s (5000 RPM)	______________________m/s	______________________m/s
18.43 m/s (3600 RPM)	______________________m/s	______________________m/s

Wind Torque: ______________________gm-cm

Alignment:

Expected	Measured	Difference
______________________°	______________________°	______________________°

NOTES:

Sonoma Technology

Standard Operating Procedures for the Belfort Model 6400 Visibility Sensor

February 21, 2024

STI-6991

Contents

Summary

This document describes the steps necessary to calibrate and maintain the Belfort Instrument Visibility Sensor Model 6400. The procedure is intended to verify that the equipment is performing to expectations and the detection and communication links are functioning correctly. Hard copies of this procedure and associated audit forms will be kept on site. Upon completion of the audit procedure, a copy of the audit form showing the results will be sent to the Refinery Project Manager.

Safety

Work should conform to manufacturer guidance and site health and safety practices. Standard refinery personal protective equipment (PPE) should be worn at all times, including laser safety glasses with side shields, a hard hat, goggles, steel-toed boots, hearing protection, fire-retardant clothing (FRC), an H_2S monitor, and appropriate gloves that are adequate for this procedure.

Personnel Qualifications

Installing, operating, and servicing Belfort visibility sensors should only be performed by personnel who are trained in the operation of the system components and are familiar with handling the testing equipment. These procedures should not be performed by personnel who do not understand the system, technology, or hazards of the materials involved.

General Maintenance

Belfort Instrument Company suggests conducting the initial visibility sensor maintenance three months after installation. The technician will need to adjust this time frame based on the individual site environment where the instrument is installed. Factors may include but are not limited to insects at the site, weather conditions, dust, blowing debris, and deposits from water spray. **Table 1** provides a schedule of maintenance activities for the sensor.

The technician should periodically inspect the sensor for dirt, spider webs, bird nests, and other obstructions. When necessary, carefully clean the protective glass windows in the Receiver and Transmitter with a commercially available glass cleaner. When maintenance is complete, the maintenance forms on page 8 of this document should be saved in the maintenance folder for the project located on Sonoma Technology's shared drive.

There are no user serviceable components in the sensor. Should a failure occur, return the sensor to Belfort Instrument for repair. 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.

Table 1. Schedule of maintenance activities for the Belfort Model 6400 Visibility Sensor.

Activity	Monthly	Annually
Visually inspect the system, including all cables.	✓	
Inspect optics on detector and clean if necessary.	✓	
Check calibration.		✓

Contact Belfort Instruments or Sonoma Technology to receive a digital copy of the manual.

Prepare for Calibration

Before beginning the calibration, make sure you have these materials:

- Serial cable with hook or alligator clips
- Opaque filter
- Scatter plate
- Laptop with terminal emulator

If the calibration is being performed in the field, select a clear day with low wind speeds (less than 10 knots). Fog will also affect calibration results, so choose a day that isn't foggy. For calibration to be valid, visibility must be at least 1 mile. The sensor needs to have been powered on for at least 45 minutes before beginning calibration. Check that the sensor windows are clean and clear of any noticeable dirt, spider webs, or other obstructions before getting started.

The technician will need to set up a serial connection with the sensor, perform a zero calibration, and complete a span calibration (in that order).

Set Up the Serial Connection

1. Disconnect the three serial wires connected to the CR310 data logger's terminals and reconnect them to the serial cable with hooks (or alligator clips). Note: the red wire is RX, the brown wire is TX, and the bare wire is the ground. Next, connect the serial cable to a laptop.
2. Use **Device Manager** to check the com port you are connected to under the **Ports** section.
3. Open a terminal emulator, such as **Tera Term**, and set it to the com port you have connected to. Make sure the serial settings match that of the Belfort 6400 (baud rate 9600, 8 bit, no parity, 1 stop bit, no flow control).
4. Test the connection by typing the FL command into the terminal without pressing Enter. Immediately, a list of values should be returned similar to this:

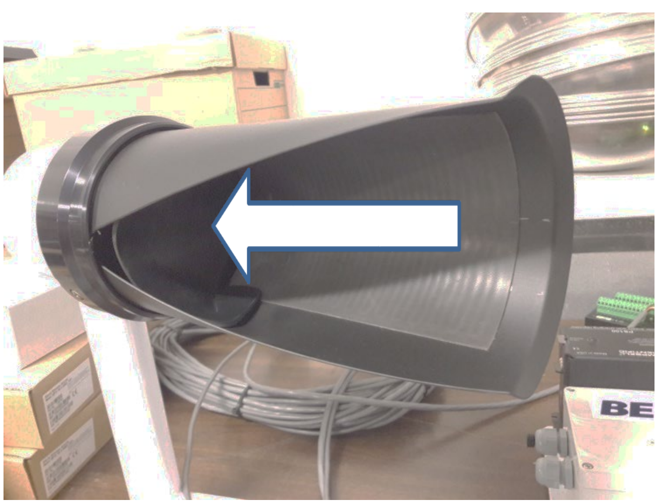
   P,00223, 1, 0.19333965, 40.33408642, 1.45484,Mi, 1.281314 0000

If nothing is returned, try swapping the red and brown wires. If it still doesn't work, check the serial settings to make sure they are correct.

5. Before the calibration commands can be entered, the terminal must be given super user privilege. Hold down the **Ctrl** key and press the **V** key. Then type in the password **foggy** and press **Enter**. You should see the message, "Password accepted, Operator is now Super User." To stop being a super user at any time, press **Ctrl-V** and **Enter** again without entering the password. Turning the sensor off and on will also end super user status. **DO NOT USE ANY COMMANDS NOT STATED IN THIS SOP WHILE IN SUPER USER MODE**. Doing so could compromise the sensor's functionality.

Zero Calibration

1. Push the black foam opaque filter into the receiver hood, which is the hood on the left when facing the front of the sensor (see **Figure 1**). You are facing the front when you can see the "Belfort" logo on the device. Make sure the filter is completely blocking the receiver window. *Warning:* the hood might be hot to the touch if the heaters are on.
2. In the terminal emulator, enter the command **FZ**. The sensor will ask for verification before starting the calibration routine. Type the letter **Y** to accept (or **Esc** to abort).
3. The zero calibration routine will run for 3 minutes, allowing the sensor to reach a stable zero state, after which it will run for 2 more minutes while taking an average of the zero offset.
4. At the end of the zero calibration routine, the operator will be prompted to accept the new zero offset value. If the operator does not respond within 3 minutes, the sensor aborts the calibration (discarding the value generated). After accepting the new value, record it along with the previous value in eSIMS or a laboratory/field notebook.
5. Do not forget to remove the opaque filter after doing the zero calibration, as failure to do so will result in constant high visibility readings regardless of actual conditions.



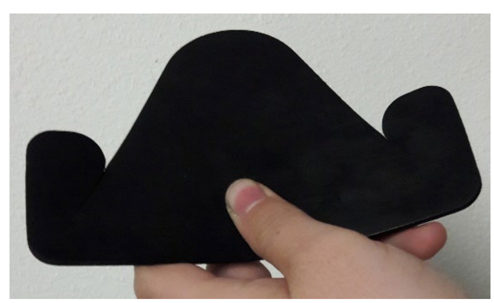


Figure 1. Inserting the opaque filter.

Span Calibration

1. Make sure the opaque filter has been removed from the receiver hood. Check the scatter plate for smudges and scratches. Clean off any smudges with a commercial glass cleaner (**do not use harsh solvents as they will melt the plastic on the scatter plate**). If the scatter plate is badly scratched, contact the manufacturer before use.

2. Carefully hang the scatter plate on the sensor by hooking the top bracket over the top of the sensor's cross arm. Center the scatter plate on the cross arm an equal distance from the edge of each hood to the plate. Make sure the plate is secure and not swinging or rotating on the sensor's cross arm (see **Figure 2**).

3. In the terminal emulator, enter the command **FN**. A list of configuration parameters will be returned. Verify that the value of **Cal_ExtCo** (Calibration Extinction Coefficient) is equal to the value marked on the scatter plate's label. If they do not match, enter the command **FC**. A similar list of parameters will appear, followed by a prompt to change them. The prompt will go through each parameter one by one. Press **Enter** to go to the next parameter until you reach the **Cal_ExtCo** parameter. Enter the value found on the scatter plate's label and press **Enter**. Then press **Esc**. **DO NOT CHANGE ANY OTHER PARAMETERS**. Doing so could compromise the sensor's functionality.

4. Enter the **FS** command. When the sensor asks for verification before starting the calibration routine, type the letter **Y** to accept (or **Esc** to abort).

5. The span calibration routine will run for 3 minutes, allowing the sensor to reach a stable span state, after which it will run for 2 more minutes making periodic adjustments to the slope as it attempts to minimize the error.

6. At the end of the span calibration routine, the operator will be prompted to accept the new span factor value. If the operator does not respond within 3 minutes, the sensor aborts the calibration (discarding the value generated). After accepting the new value, record it along with the previous value in eSIMS or a laboratory/field notebook.

7. Do not forget to remove the scatter plate from the sensor and carefully put it away in a safe place.

8. Record the procedure details, results, date, operator name, etc., in eSIMS or a laboratory notebook.

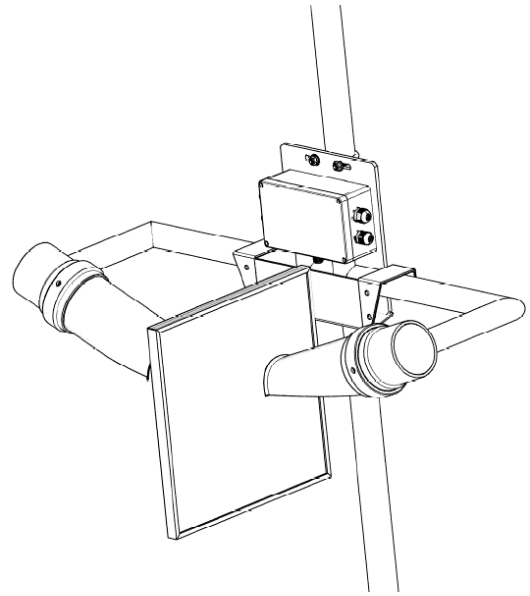


Figure 2. Scatter plate mounting.

Completing the Process

1. Disconnect the serial cable from the laptop, disconnect the Belfort 6400's three serial wires from the cable, and reconnect them to the CR310 data logger. The red wire goes to the **C1** terminal, the brown wire goes to the **C2** terminal, and the bare wire goes to the **G** terminal of the CR310.
2. Connect to the CR310 through Loggernet (either via a micro-USB cable to a field laptop or via the DMZ server connection) and check to see if values are coming in and if they make sense. Note: the values might initially be lower than expected, so wait 5 to 10 minutes for the sensor to adjust.

Belfort Model 6400 Visibility Sensor Audit Record

DATE:_______________ Location: ____________________________

Test Technician 1 :_________________________
Test Technician 2 :_________________________

Zero State Calibration

Start Time: __________________________________

Previous Zero Offset: _________________________

New Zero Offset: _____________________________

Stop Time: ___________________________________

Notes:

Span Calibration

Start Time: ____________________________

Scatter Plate ExCo: ____________________

Span Factor: _________________________

New Span Factor: _____________________

Stop Time: ____________________________

Notes:

Sonoma Technology

Standard Operating Procedure for Data Verification and Validation

August 5, 2024

STI-8194

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.

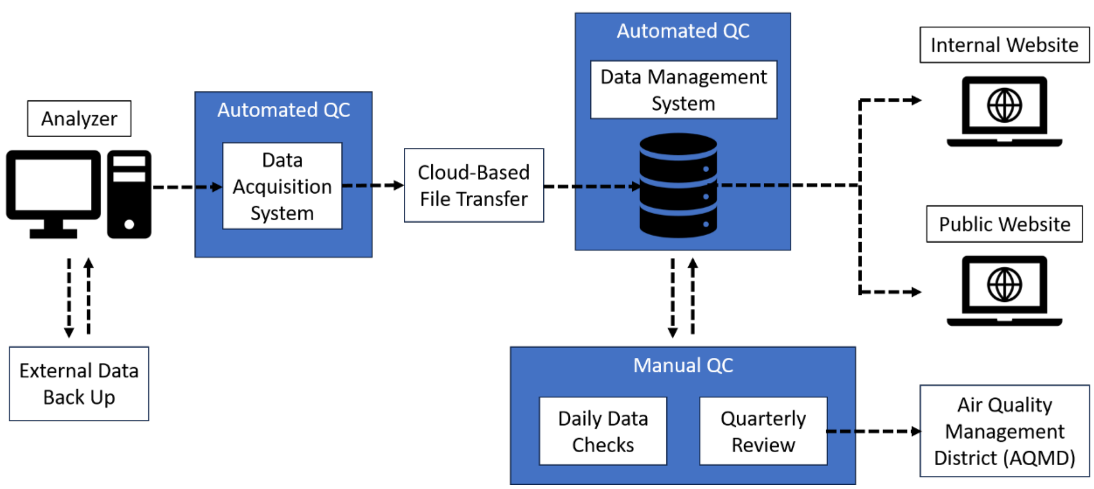


Figure 1. Data flow and QC schematic.

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

[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 minimum detection limit) 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.
Signal Strength (UV-DOAS)	This parameter is commonly >10%. A pattern of low signal strength can indicate poor instrument alignment.
Signal Strength (FTIR)	This parameter is commonly >0.1 V. 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.
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 minimum detection limit, 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 "<MDL." 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.

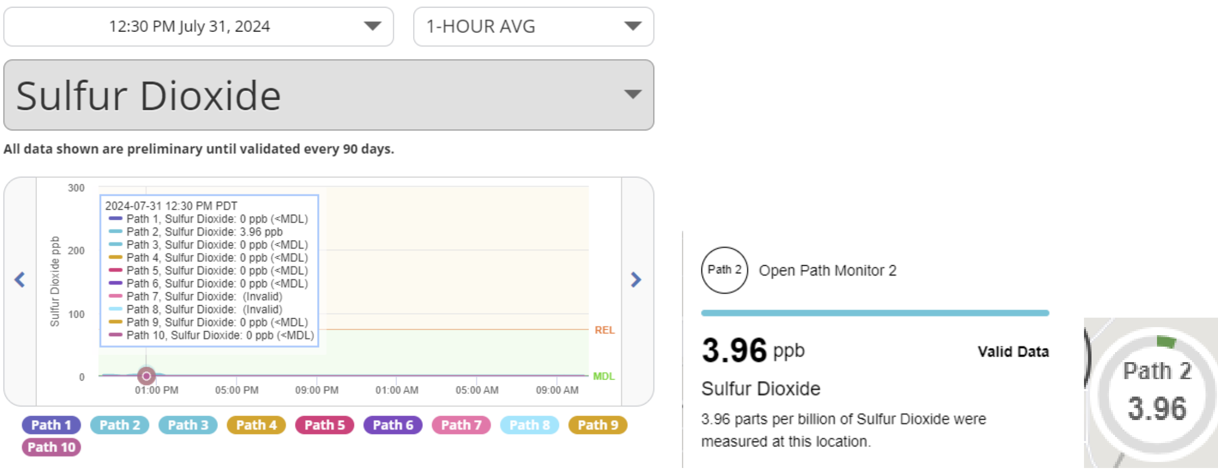


Figure 2: Example of valid detections as displayed on the public website.

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 "<MDL."

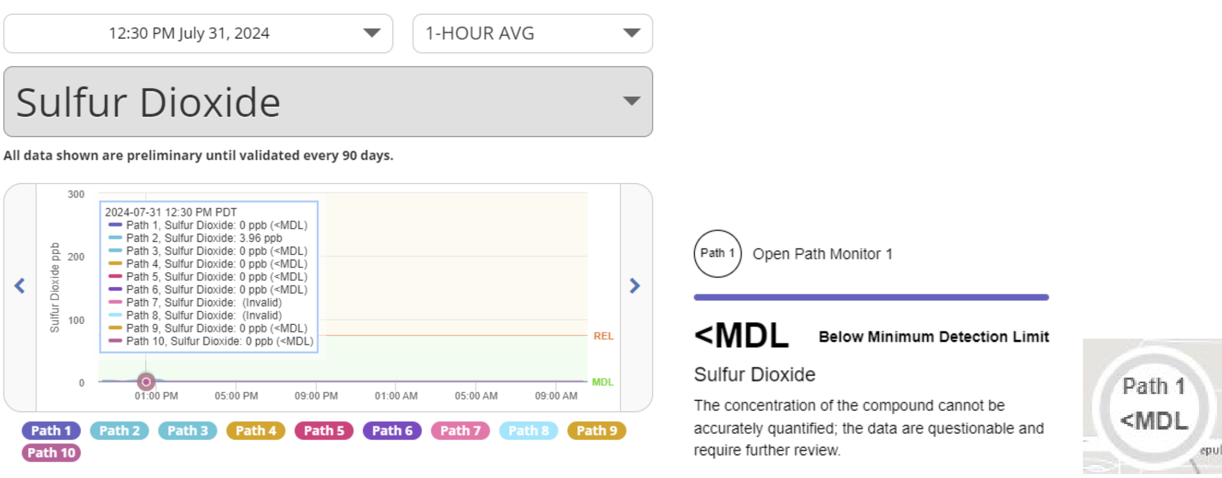


Figure 3: Example of valid non-detections as displayed on the public website.

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.

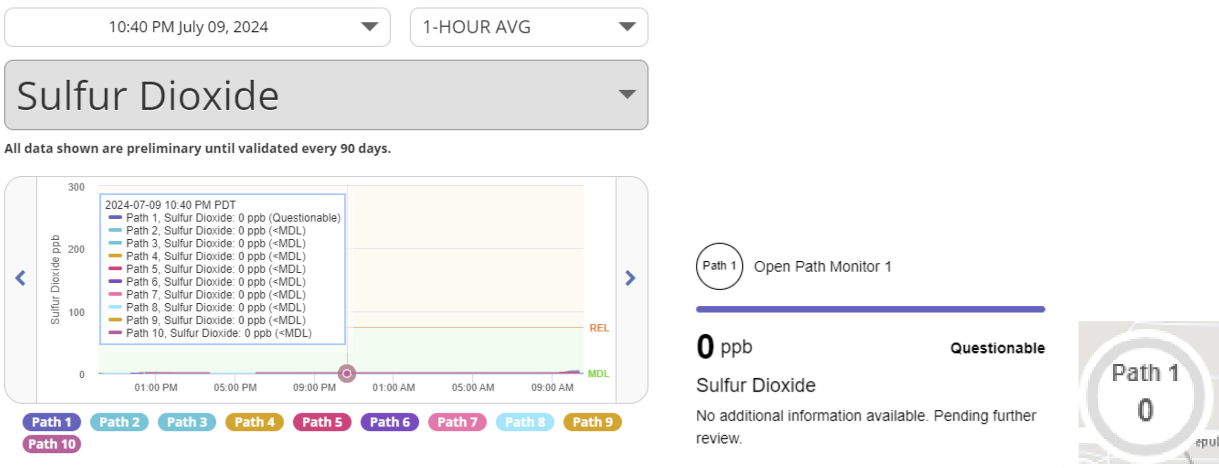


Figure 4: Example of questionable data as displayed on the public website.

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.

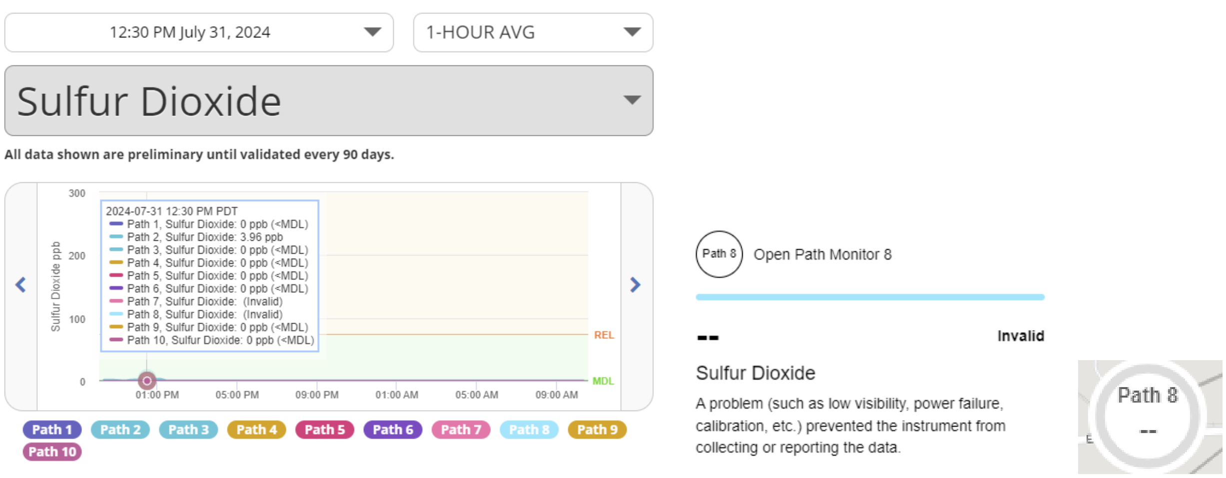


Figure 5: Example of invalid data as displayed on the public website.

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).

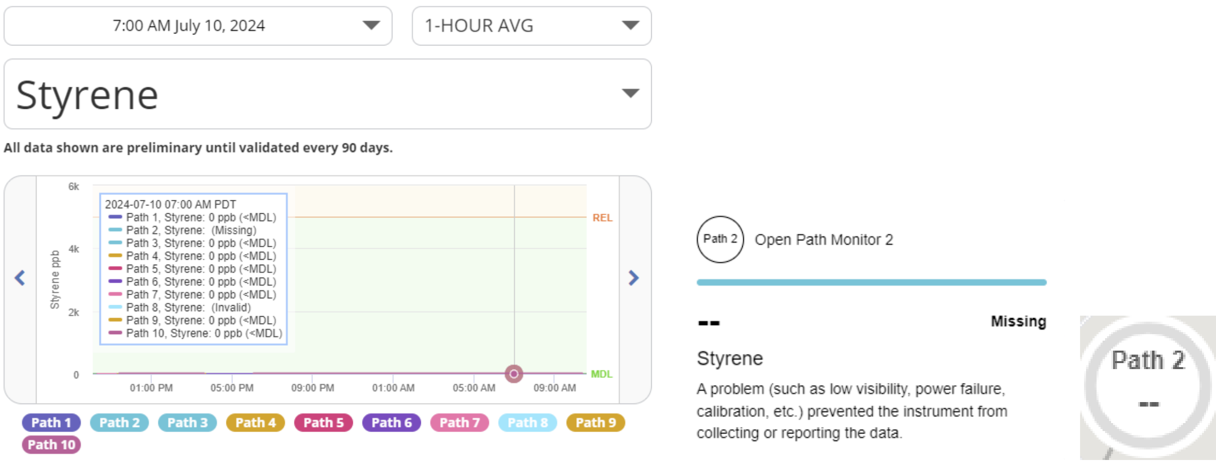


Figure 6: Example of missing data as displayed on the public website.

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		
Signal Intensity	Confirm that values ≥10%	
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 ≥0.1 V	
Zero Path Distance (ZPD) Position	Confirm that values are 256–257	
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 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 nitrogen dioxide 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 benzene detection events	
	Record any toluene detection events	
Optical Tent System (Wilmington Refinery Only)	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	
All Compounds	Record any instances of missing data	

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.

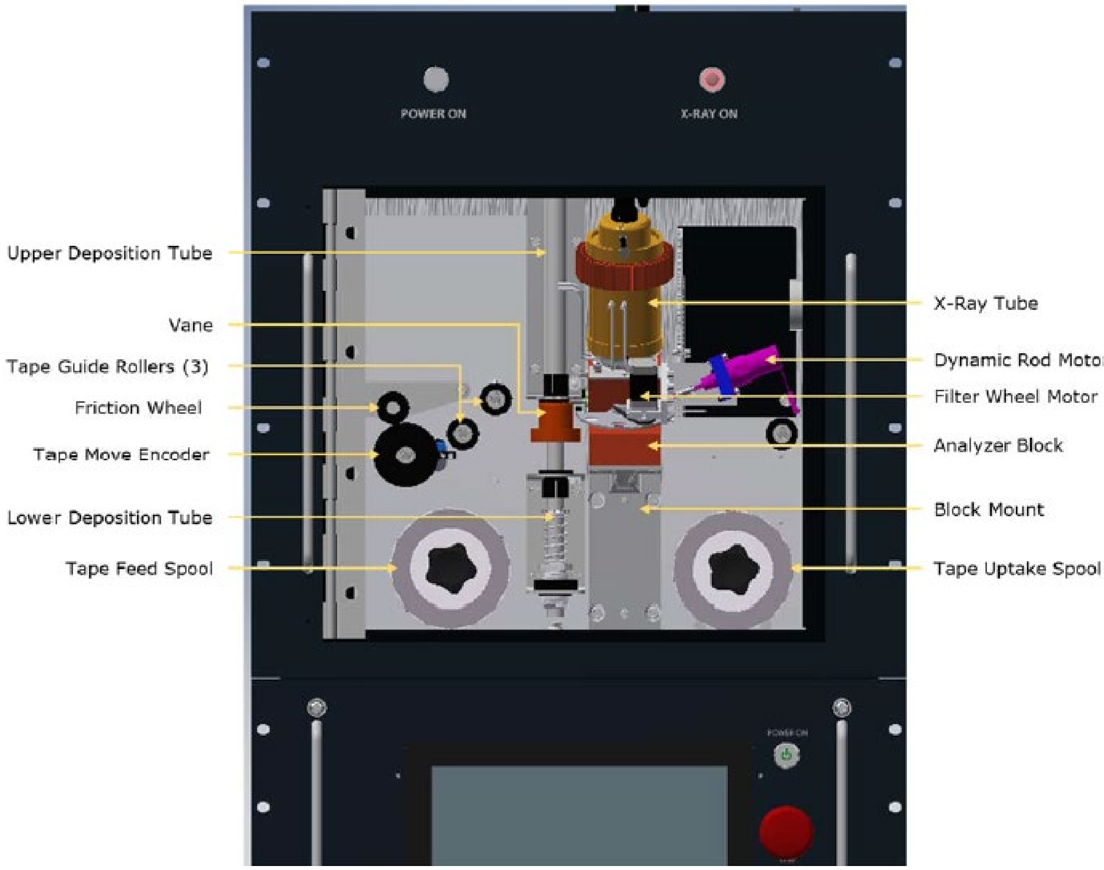


Figure 1. Schematic of the Xact 625i analyzer.

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

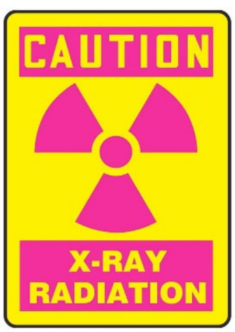
The following information is intended to provide guidance to ensuring a safe work environment.

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.

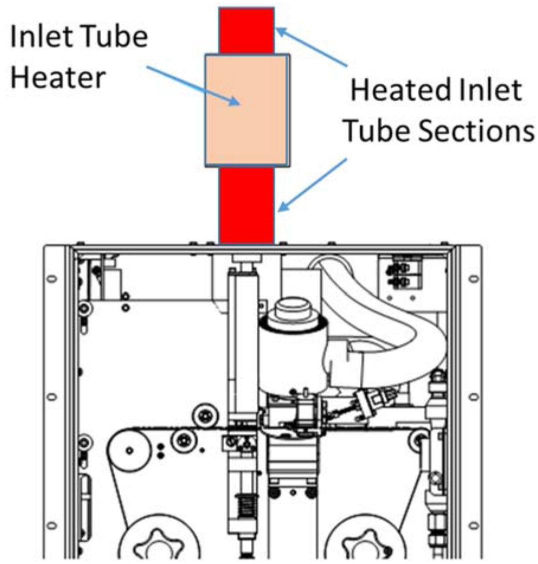
Hazard Warnings



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 <u>for at least 15 min</u> 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

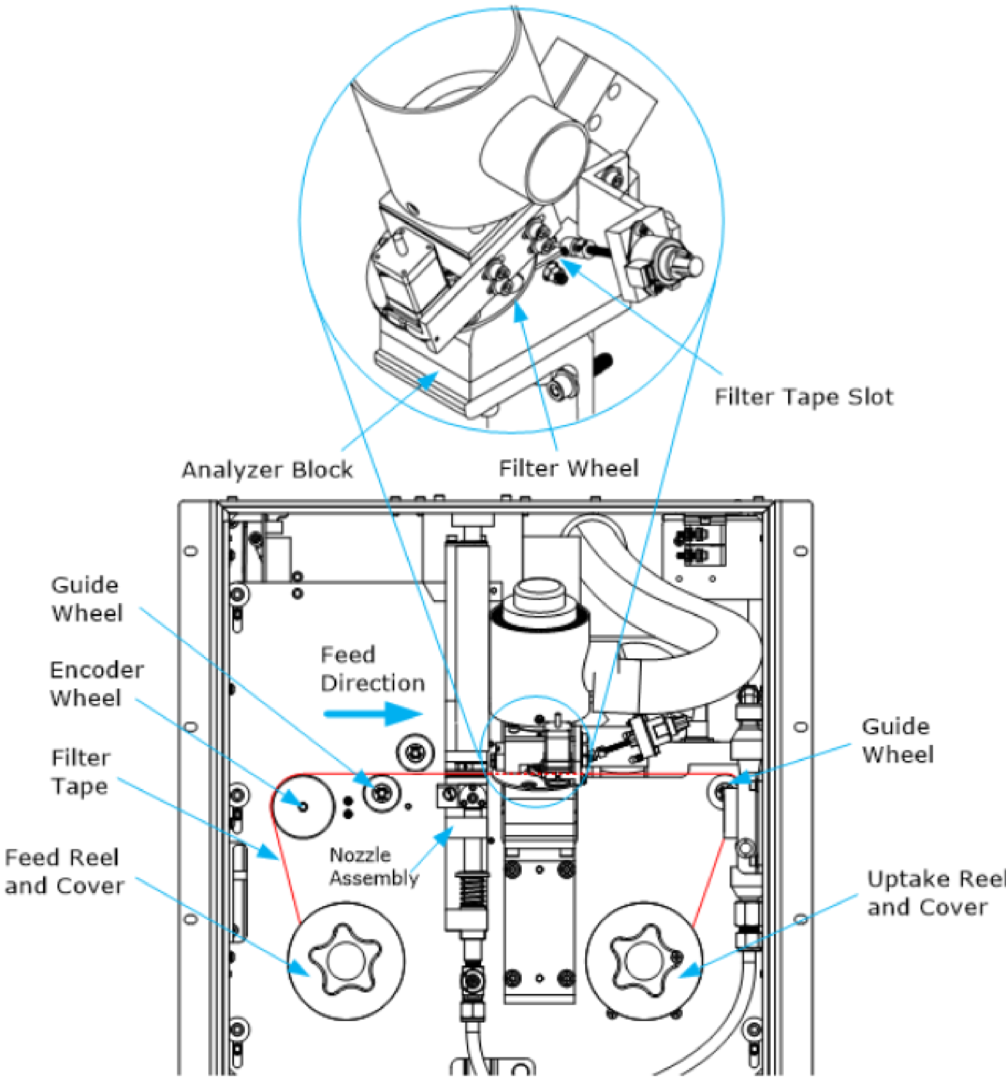
1. Ensure that the instrument is running and that the data look reasonable.
2. Clean and correct any obvious problems with the system (e.g., the presence of cobwebs, rodent nests, etc.).
3. Inspect all electrical cables for wear; replace as needed.
4. Indicate that these visual checks are complete on 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.

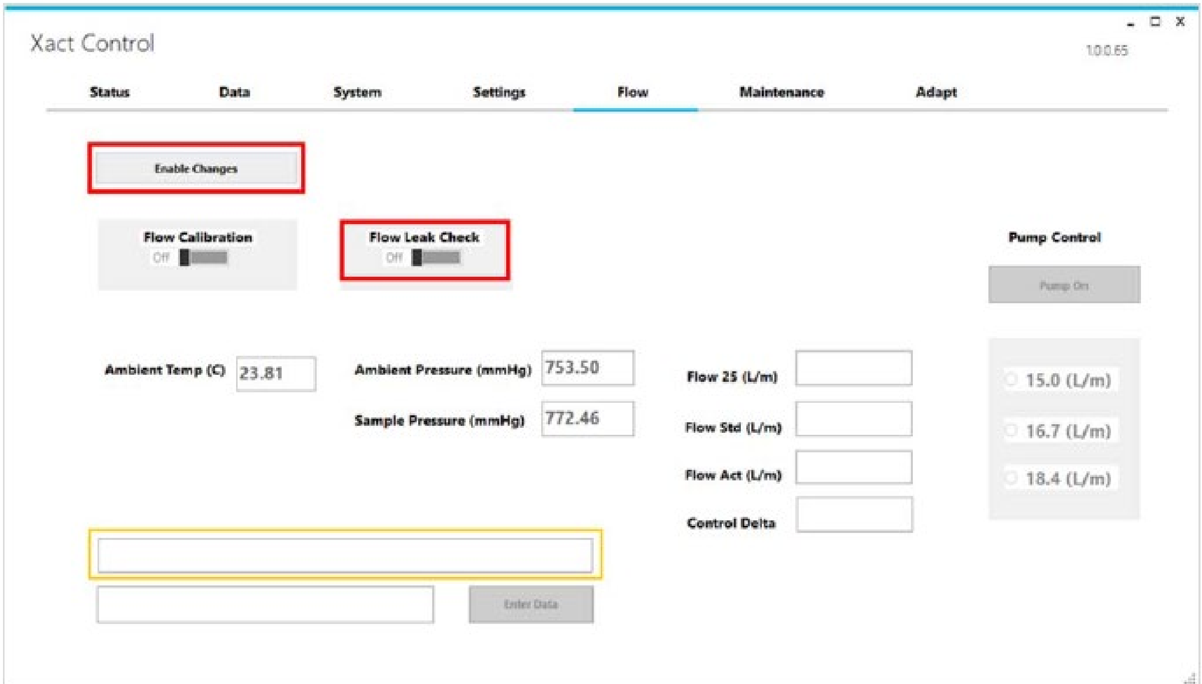
IMPORTANT*: Ensure that the tape is in the tape slot and not the filter wheel slot. Properly installed tape should be flat and not angled.*

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

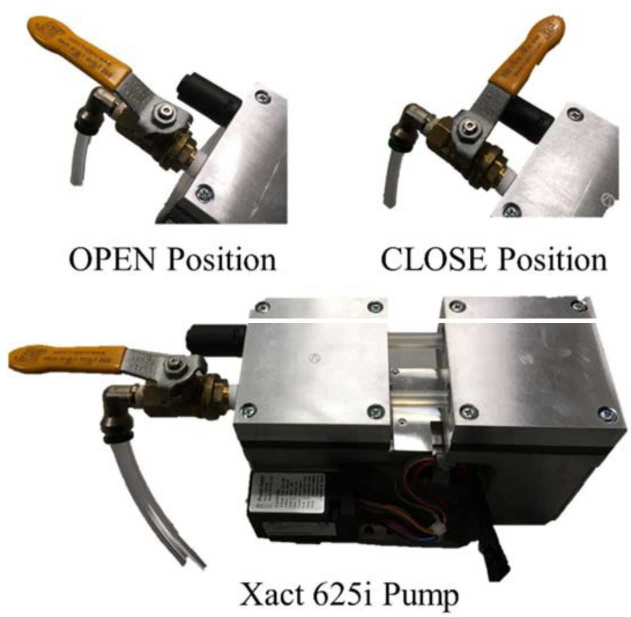
1. Ensure the filter tape is properly installed and the Xact 625i is in STOP mode.
2. Remove all PM inlets and install the leak tester over the PM inlet tube.
3. Open the "Flow" page tab.
    a. Click "Enable Changes"
    b. Turn on "Flow Leak Check"
4. Instructions will appear in the status window (i.e.,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



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.

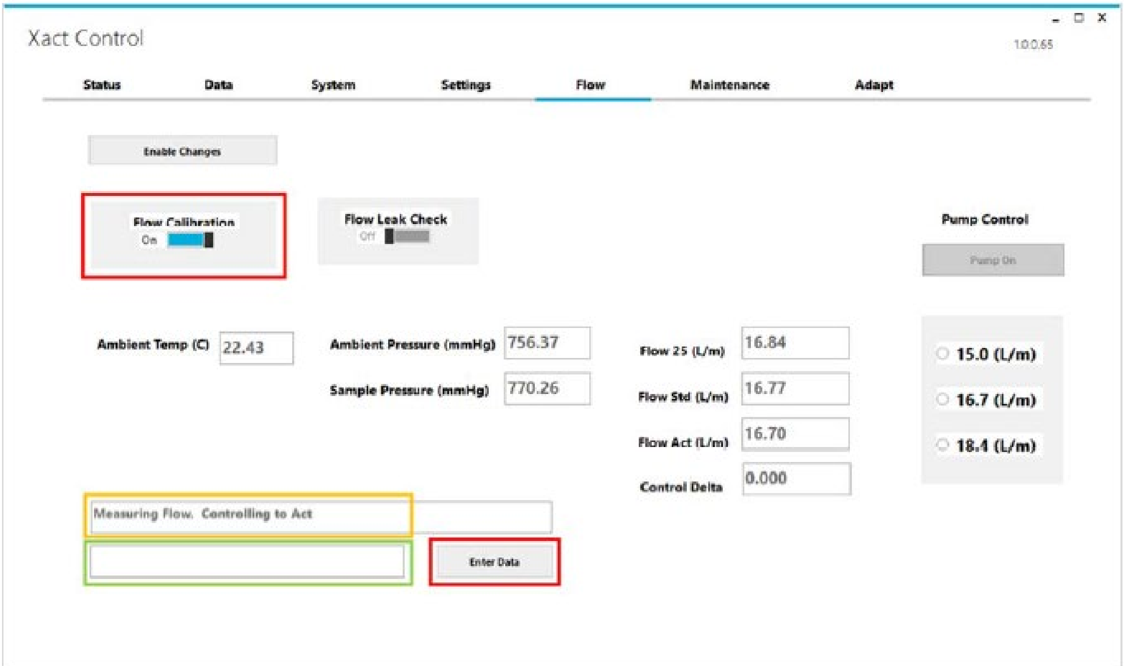
9. To complete the flow check, click on "Disable Changes."

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.

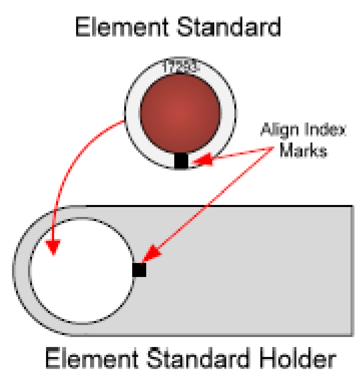
To manually perform the QA Check:

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.

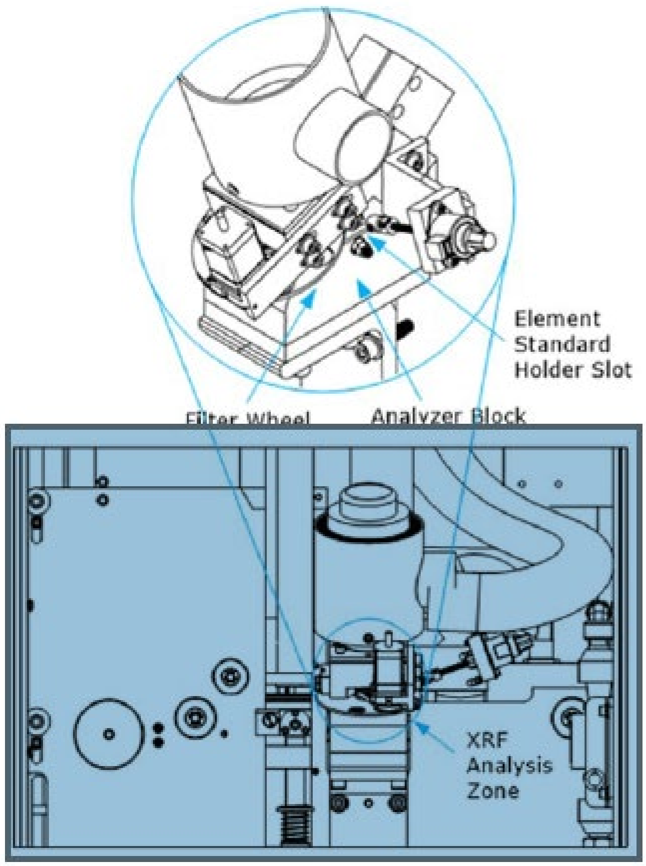
CAUTION: *Always handle Element Standards by their plastic ring edge. Store them in their individual containers when not in use. Nitrile gloves or powderless latex gloves are recommended during this procedure, although they are not mandatory.*

5. Remove the filter tape from the analysis block.

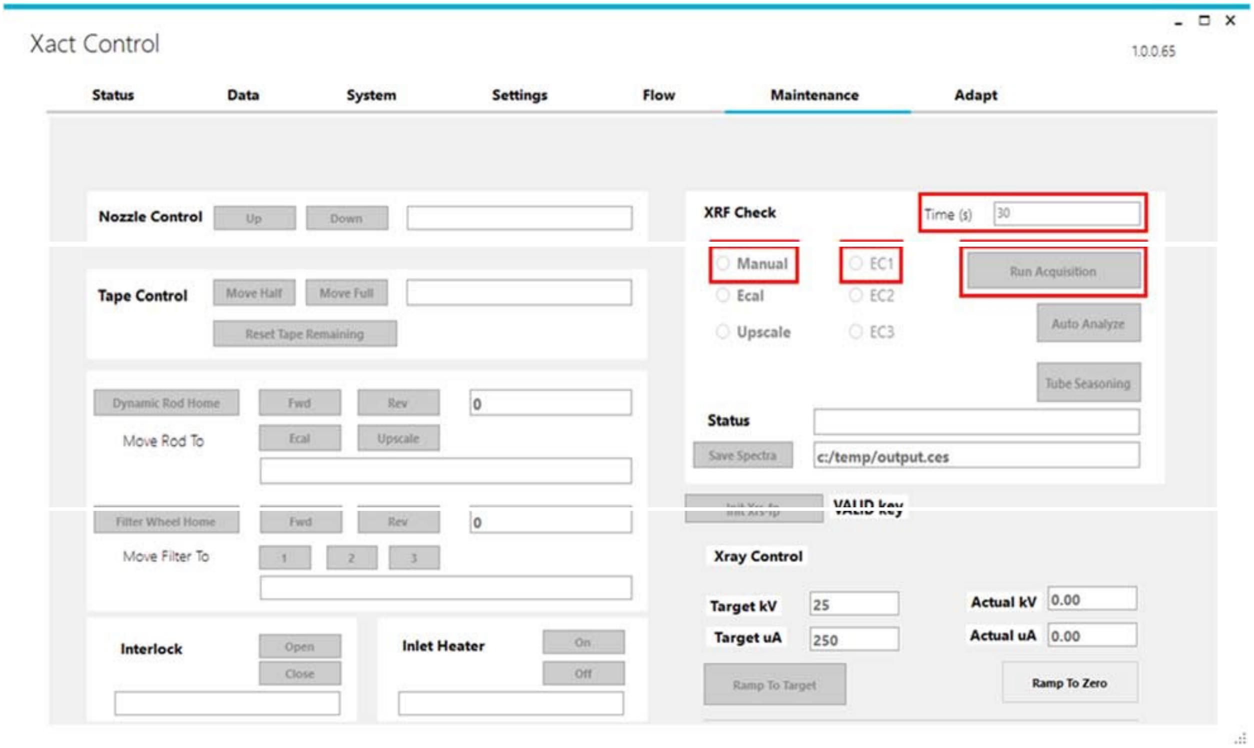
6. Place the first Element Standard into the Element Standard holder; the Standard should be oriented with the plastic ring up. Align the index mark on the Element Standard with the index mark on the Element Standard holder. The Element Standards are very fragile! Extreme care should be taken not to damage or contaminate the deposit.



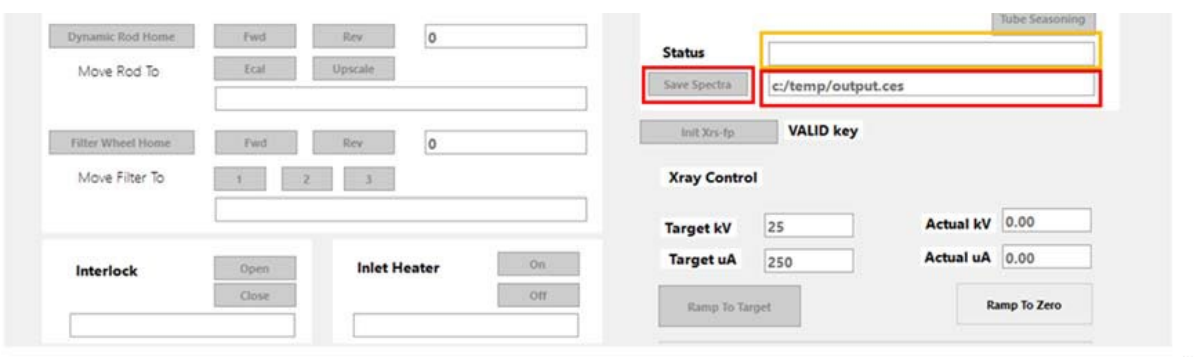
7. Insert the Element Standard holder in the slot under the filter wheel (on the right side of the analyzer block) in the analysis zone. The Element Standard holder takes the place of the filter tape in the analysis block. Be sure to push the Element Standard holder as far into the analysis zone as possible.



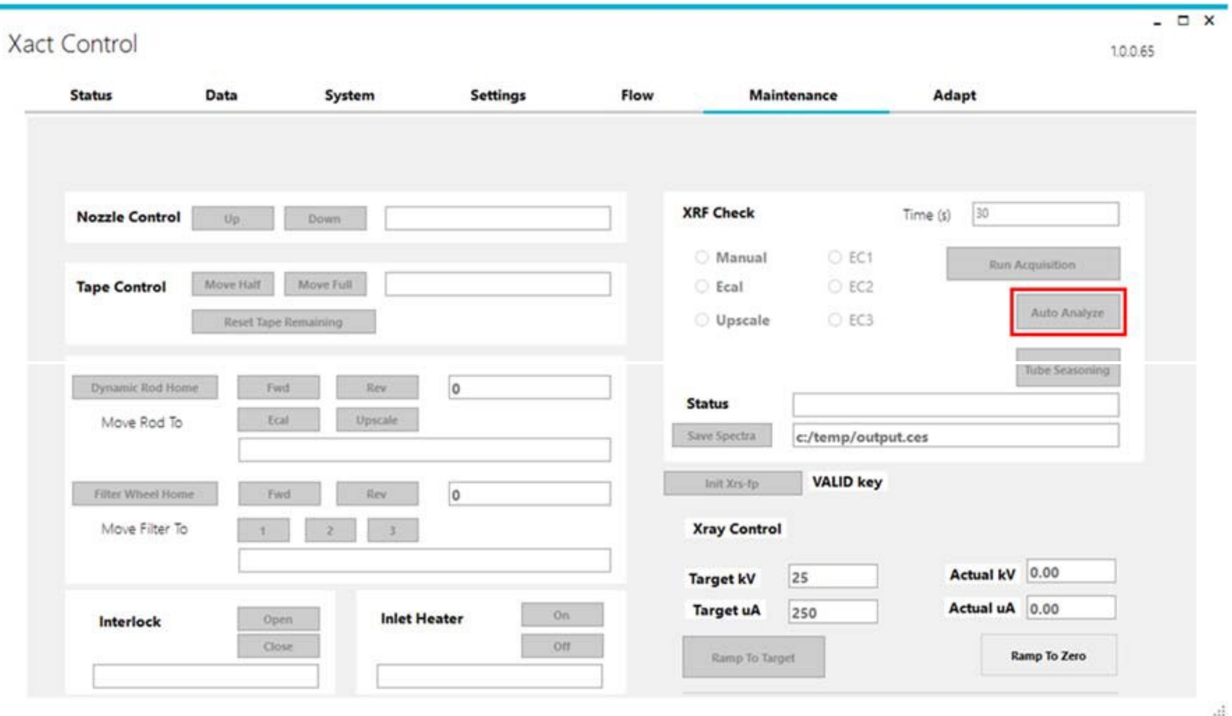
8. Close and lock the front door of Xact 625i.
9. Navigate to Maintenance page within 'XRF Check' section.
   a. Select "Manual" and "EC1" for Ca Element Standard.
   b. Enter the acquisition time from the Calibration guide into the time text box.
   c. Click "Run Acquisition" To initiate acquisition.



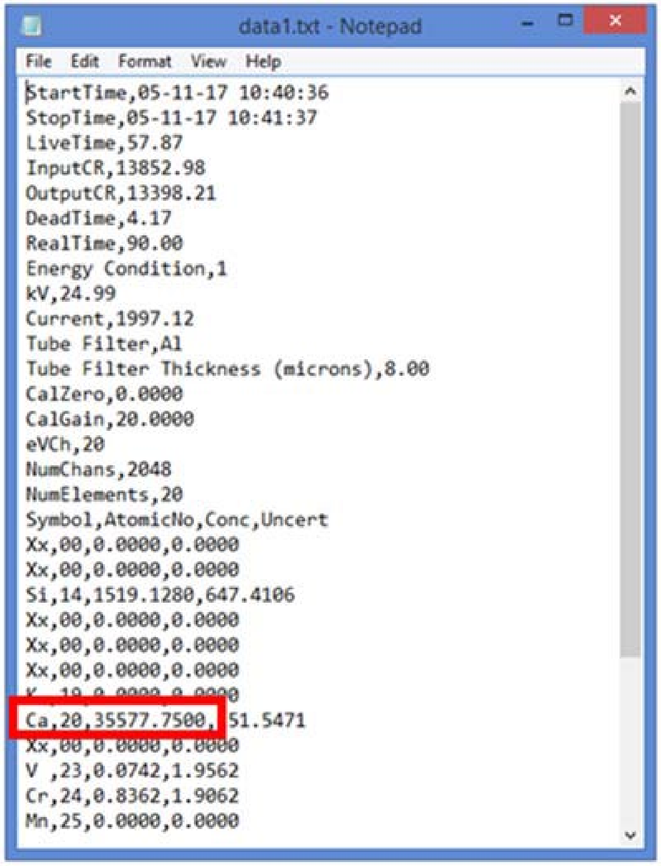
10. After acquisition is complete, the 'Status' window of 'XRF Check' section will prompt you to save the spectra. Enter the folder path, save the file with .ces extension (example: C:/temp/20_Ca_12345_XRF_Check.ces), and click "Save Spectra."



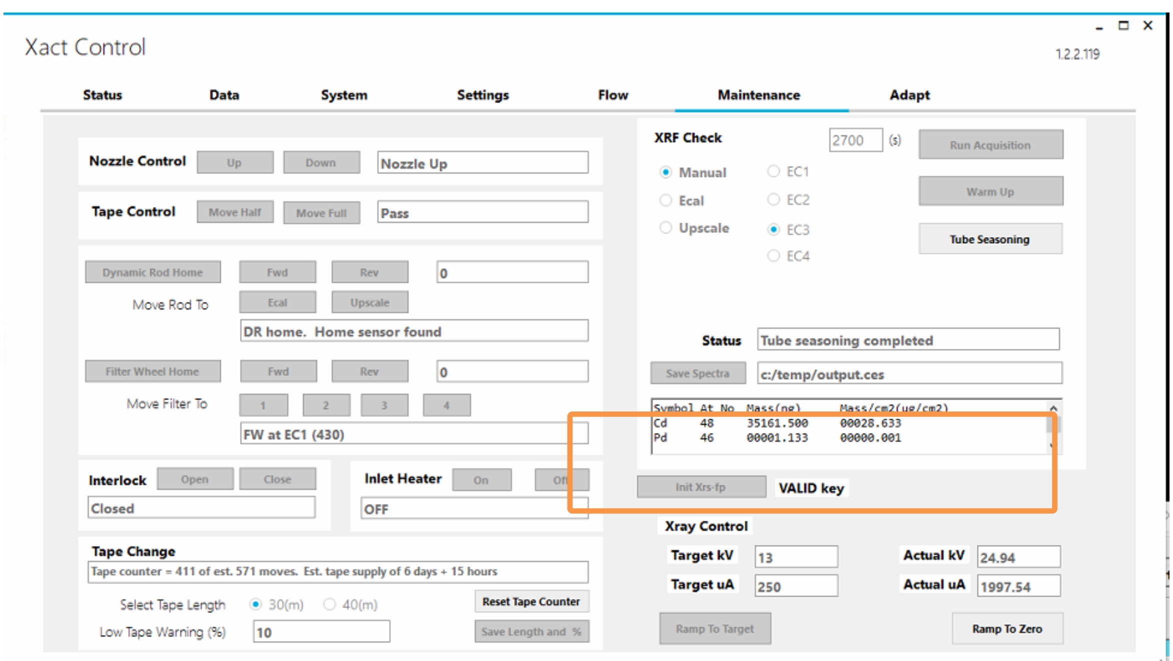
11. Wait until the status indicates that the X-rays have started to ramp down, then click "Auto Analyze".



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.



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

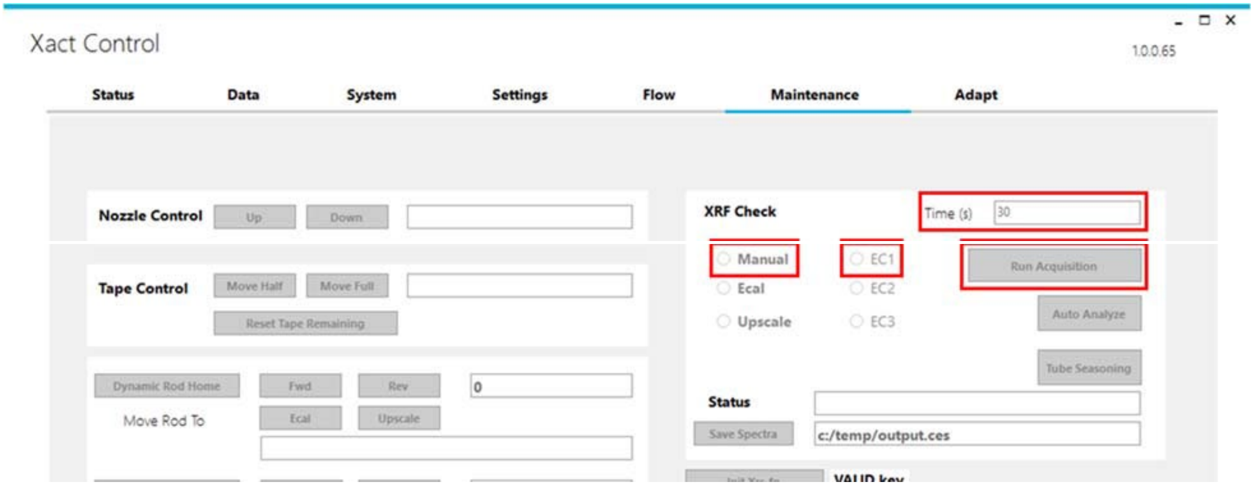
Xact Recalibration is performed when a new X-ray tube is installed or if the user wants to change Xact 625i settings for monitoring to focus on a group of elements different from those the instrument was calibrated for at the factory. Since Xact 625i is a precisely calibrated instrument for user requested 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.

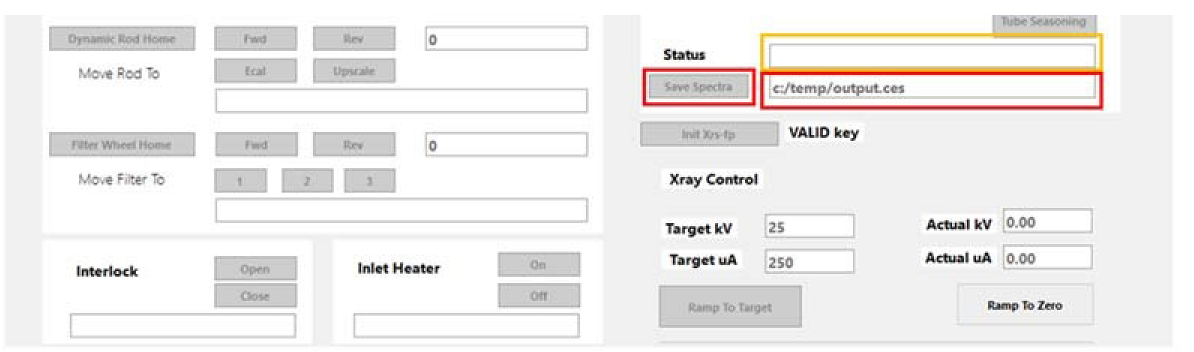
1. Within 'XRF Check' section:
   a. Select "Manual" and "EC1"
   b. Enter the acquisition time for EC1 in seconds (Refer to table below)
   c. Click "Run Acquisition"



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 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 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	[illegible]	[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]	[illegible]	60483				X	A	65			
Br	35	[illegible]	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	[illegible]	41856	29.4	36120							X	A	2700
In	49	[illegible]	41857	48.9	60066							X	I	1800
Sn	50	[illegible]	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.