# Fenceline Air Monitoring Plan for the Chevron Refinery in El Segundo, California

October 17, 2025

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# Contents

# Figures

# Tables

# Document Control

| Revision No. | Revision Date | Description |
|---|---|---|
| 0 | 11/28/2018 | Initial submission to South Coast AQMD |
| 1 | 10/15/2019 | Updated in response to South Coast AQMD feedback |
| 2 | 8/5/2024 | Updated in response to the January 5, 2024, adoption of amended Rule 1180 |
| 3 | 10/17/2025 | Updated in response to comments received by South Coast AQMD |

# 1. Introduction

## 1.1 Background

Petroleum refineries in the South Coast Air Basin are required to conduct real-time fenceline monitoring of numerous air pollutants according to Rule 1180, which was first adopted in December 2017 by South Coast Air Quality Management District (AQMD). The purpose of this rule is to provide air quality information to the public about levels of various air pollutants at or near the property boundaries of petroleum refineries and in nearby communities via continuous measurements and a real-time display on a publicly accessible website.

Amendments to Rule 1180 were adopted by the South Coast AQMD Governing Board on January 5, 2024, to remove a prior exemption for facilities producing fewer than 40,000 barrels per day (bpd). That ruling includes facilities that process alternative feed stocks and expands the applicability of Rule 1180 to related facilities (e.g., terminals, hydrogen plants, and sulfur-recovery plants). The target compound list was also expanded based on a report by the California Office of Environmental Health Hazard Assessment (OEHHA), which defined a "priority list" of compounds associated with refinery processes that have adverse health effects.

This fenceline air monitoring plan (FAMP) for the Chevron El Segundo Refinery (Facility ID 800030) was developed in accordance with amended Rule 1180: Fenceline and Community Air Monitoring for Petroleum Refineries and Related Facilities[1] ("Rule 1180") and the Rule 1180 and Rule 1180.1 Fenceline Air Monitoring Plan Guidelines[2] ("Guidelines").

## 1.2 Plan Summary

According to South Coast AQMD Rule 1180 and the Guidelines, a FAMP shall describe how to meet the following key objectives:

- Provide measurements of various air pollutant levels (i.e., air pollutant concentrations) in real-time (when feasible) and in 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;

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[1] Rule 1180: Fenceline and Community Air Monitoring for Petroleum Refineries and Related Facilities (South Coast AQMD). Adopted December 1, 2017, and amended January 5, 2024.
[2] Rule 1180 and Rule 1180.1 Fenceline Air Monitoring Plan Guidelines (South Coast AQMD). January 2024.

- Track long-term air pollutant levels, variations, and trends over time at or near the property boundaries of refineries;
- Provide context to the data so that local communities can understand differences (if any) in air quality in their location from other locations in the South Coast Air Basin and understand the potential health impacts associated with local air quality near facility operations;
- Notify subscribers when fenceline concentrations exceed pre-determined thresholds (e.g., the relevant health-based notification standards or information-based notification standards listed in the rules); and
- Provide quarterly reports summarizing the measurements, data completeness, and quality assurance (QA).

### 1.2.1 Current Fenceline Monitoring System

Chevron is actively monitoring in accordance with Rule 1180 at the El Segundo Refinery. Benzene, toluene, ethylbenzene, xylenes (BTEX), nitrogen dioxide ($NO_2$), and sulfur dioxide ($SO_2$) are measured by ultraviolet differential optical absorption spectroscopy (UV-DOAS) open-path analyzers. Hydrogen cyanide, 1,3-butadiene, ammonia, acrolein, formaldehyde, acetaldehyde, carbonyl sulfide, styrene, and total volatile organic compounds (Total VOCs, a sum of ethane, propane, butane, and pentane concentrations, each normalized to the molecular weight of propane) are measured by Fourier transform infrared (FTIR) open-path analyzers. All open-path analyzers at the El Segundo Refinery are installed in a monostatic configuration, meaning the emitter and detector are on the same side of the sampling path with a mirror (referred to as a retroreflector) at the opposite end. These open-path analyzers transmit light across a given path and detect the amount of energy absorption at specific wavelengths to identify and quantify the concentration of target compounds.

Hydrogen sulfide ($H_2S$) and black carbon (BC) are measured by point monitors located at six locations at the El Segundo Refinery.

Visibility sensors are installed on the east and west sides of the refinery to assess low-visibility conditions that can cause open-path analyzers to produce invalid measurements; meteorological sensors provide measurements of wind speed and direction.

Fenceline monitoring sampling locations—including the proposed additional monitoring described in Section 1.2.2—are shown in Figure 1. The monitoring equipment inventory, latitude and longitude, and elevation of each fenceline monitoring site are detailed in Table 1.

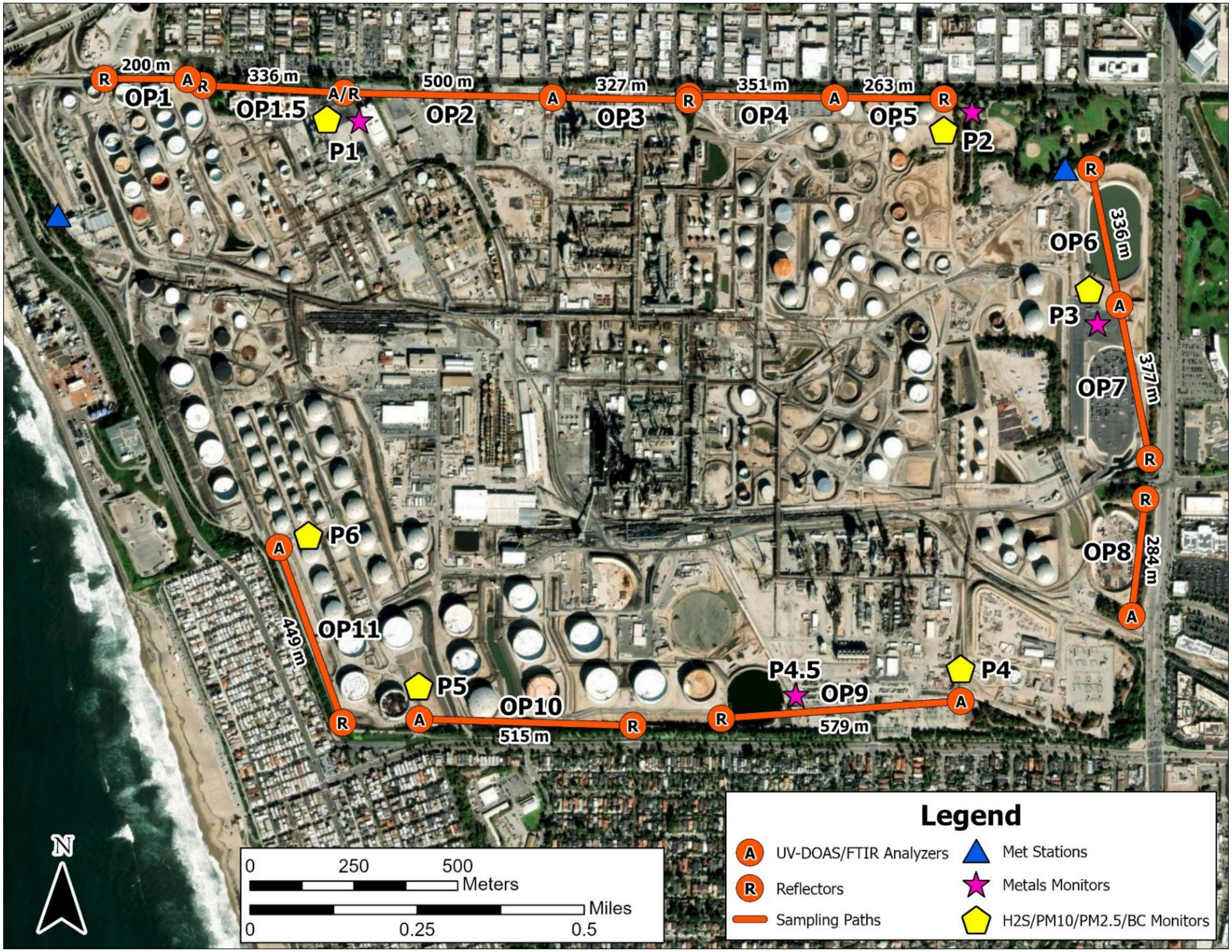

**Figure 1.** Fenceline monitoring sampling locations for the Chevron El Segundo Refinery.

**Table 1.** Equipment inventory, latitude and longitude, and elevation of each monitoring site.

| Description | Site [a] | Equipment | Latitude | Longitude | Elevation Above Grade (ft) |
|---|---|---|---|---|---|
| Retroreflectors | OP1 | UV-DOAS and FTIR Retroreflectors | 33.916288 | -118.423778 | 10 |
| Analyzer Skid | OP1 | UV-DOAS and FTIR Analyzer | 33.916304 | -118.421614 | 10 |
| Retroreflectors | OP1.5 | UV-DOAS and FTIR Retroreflectors | 33.916170 | -118.421212 | 10 |
| Analyzer Skid/Analyzer Cabinet | OP1.5, P1 | UV-DOAS and FTIR Analyzers<br>$H_2S$, BC, PM Monitor, Metals Monitor [b] | 33.916094 | -118.417576 | 7 (open-path)<br>8 (point) |
| Retroreflectors | OP2 | UV-DOAS and FTIR Retroreflectors | 33.916005 | -118.417499 | 10 |
| Analyzer Skid | OP2, OP3 | UV-DOAS and FTIR Analyzers | 33.916014 | -118.412091 | 10 |
| Retroreflectors | OP3 | UV-DOAS and FTIR Retroreflectors | 33.915998 | -118.408551 | 10 |
| Retroreflectors | OP4 | UV-DOAS and FTIR Retroreflectors | 33.916088 | -118.408540 | 10 |
| Analyzer Skid | OP4, OP5 | UV-DOAS and FTIR Analyzers | 33.916094 | -118.404749 | 11 |
| Retroreflectors | OP5 | UV-DOAS and FTIR Retroreflectors | 33.916104 | -118.401901 | 13 |
| Analyzer Cabinet | P2 | $H_2S$, BC, PM, and Metals Monitor [b] | 33.91616 | -118.401910 | 9 |
| Retroreflectors | OP6 | UV-DOAS and FTIR Retroreflectors | 33.914632 | -118.398046 | 10 |
| Analyzer Skid/Analyzer Cabinet | OP6, OP7, P3 | UV-DOAS and FTIR Analyzers<br>$H_2S$, BC, PM Monitor, and Metals Monitor[b] | 33.911671 | -118.397255 | 7 (open-path)<br>8 (point) |
| Retroreflectors | OP7 | UV-DOAS and FTIR Retroreflectors | 33.908342 | -118.396414 | 10 |
| Retroreflectors | OP8 | UV-DOAS and FTIR Retroreflectors | 33.907464 | -118.396513 | 8 |
| Analyzer Skid | OP8 | UV-DOAS and FTIR Analyzers | 33.904916 | -118.396829 | 4 |
| Analyzer Skid | OP9, P4 | UV-DOAS and FTIR Analyzers<br>$H_2S$, BC, and PM Monitor [b] | 33.903015 | -118.401243 | 7 (open-path)<br>8 (point) |
| Analyzer Cabinet | P4.5 | Metals Monitor | 33.902880 | -118.405540 | 8 |
| Retroreflectors | OP9 | UV-DOAS and FTIR Retroreflectors | 33.902570 | -118.407479 | 9 |
| Retroreflectors | OP10 | UV-DOAS and FTIR Retroreflectors | 33.902386 | -118.409779 | 9 |
| Analyzer Skid | OP10, P5 | UV-DOAS and FTIR Analyzers<br>$H_2S$, BC, and PM Monitors [b] | 33.902461 | -118.415343 | 9 (open-path)<br>8 (point) |
| Retroreflectors | OP11 | UV-DOAS and FTIR Retroreflectors | 33.902366 | -118.417347 | 15 |
| Analyzer Skid | OP11, P6 | UV-DOAS and FTIR Analyzers<br>$H_2S$, BC, and PM Monitor [b] | 33.906151 | -118.419062 | 11 (open-path)<br>8 (point) |
| Met Station | Met, Vis | Wind Speed and Direction Sensor | 33.913330 | -118.424950 | 30 |
| Met Station | Met, Vis | Wind Speed and Direction Sensor | 33.914510 | -118.398240 | 30 |

[a] Point monitor locations are listed with the closet corresponding open-path skid location.

[b] This site includes proposed additional monitoring, which is outlined in Section 1.2.2.

The physical lengths for each sampling path are listed in Table 2. In a monostatic configuration, the beam traverses this path twice from the emitter to the retroreflector and then back to the detector. The resulting optical path lengths are twice as long as the physical paths lengths, which allow lower detection limits.

Table 2. Physical length of each sampling path.

| Path | Physical Path Length (m) |
|---|---|
| OP1 | 200 |
| OP1.5 | 336 |
| OP2 | 500 |
| OP3 | 327 |
| OP4 | 351 |
| OP5 | 263 |
| OP6 | 336 |
| OP7 | 377 |
| OP8 | 284 |
| OP9 | 579 |
| OP10 | 515 |
| OP11 | 449 |

All instruments are operated following the manufacturer's specifications, including necessary bump tests, which challenge instruments with known gas concentrations to confirm accurate response. Data completeness is calculated during quarterly reporting and removes time periods when low-visibility conditions beyond the control of the refinery resulted in invalid open-path data.

Raw measurements from open-path analyzers, point monitors, and meteorological sensors are averaged to 5-min resolution by the data acquisition system at each site and then transmitted to a cloud-based data management system (DMS) in real time. Data undergo automated quality control (AutoQC) and are made available on a public website within 10–15 minutes of collection. The website also calculates a rolling hourly concentration to enable comparisons with hourly notification thresholds. Additional details on the public website and notification system are in Section 4.

Data are reviewed daily, and final data sets are provided to South Coast AQMD no later than 60 days after the end of each calendar quarter. Furthermore, to meet the new Rule 1180 requirement for data accessibility, the most recent five calendar years of hourly data following adoption of the amended Rule will be made available for public download in an easily downloadable, accessible, and interpretable electronic format. Additional details regarding data analysis and reporting are provided in the Quality Assurance Project Plan (QAPP), which is included as Appendix B in this document.

### 1.2.2 Additional Monitoring under Amended Rule 1180

At the El Segundo Refinery, naphthalene will be monitored with existing UV-DOAS analyzers and additional monitors will be collocated with the six existing point monitor sites for particulate matter (PM) smaller than 10 microns in diameter ($PM_{10}$) and smaller than 2.5 microns in diameter ($PM_{2.5}$). One metals monitor will be installed near the Fluid Catalytic Cracking Unit (FCCU) along the facility fenceline, in accordance with the Guidelines. Concentrations of metals are expected to remain well below notification thresholds during routine operations, and possible elevated concentrations would be adequately captured by a single monitor placed near the FCCU along the fenceline in case of a potential upset event at the facility. This FAMP will be revised to address monitoring of polycyclic aromatic hydrocarbons (PAHs) after the South Coast AQMD Executive Officer provides written notice that real-time monitoring of PAHs is feasible, in accordance with Rule 1180.

In accordance with the amended Rule, modification of the existing fenceline monitoring system will be completed no later than 15 calendar months following approval of this FAMP by the South Coast AQMD Executive Officer. Furthermore, Rule 1180 exempts the refinery from operating the fenceline monitoring system for 96 hours in a calendar year provided that the operation of the existing fenceline monitoring system is disrupted by the required installation of new fenceline air monitoring equipment and the refinery complies with downtime notifications requirements (Section 3.3).

### 1.2.3 Exemption Criteria

Rule 1180 provides a list of compounds that must be monitored unless facilities meet exemption criteria for specific compounds. The El Segundo Refinery is exempt from monitoring hydrogen fluoride because this compound is not used or stored at the facility, so these monitors are not installed in accordance with the Rule.

# 2. Fenceline Monitoring System

This FAMP was developed by considering the following elements:

- Amended Rule 1180 and the Guidelines.
- Monitoring objectives, which were established by amended Rule 1180 and the Guidelines.
- Assessment of potential source areas, target compounds, annual and seasonal meteorology, and overall fenceline monitoring coverage requirements.
- Technical and engineering feasibility related to available monitoring technologies and instrument siting.
- Data management and QA and Quality Control (QC) requirements.

## 2.1 Key Elements of Rule 1180 and the Guidelines

According to South Coast AQMD Rule 1180 and the Guidelines, a FAMP shall include details of the following:

- An evaluation of routine emission sources at the facility (e.g., health risk assessment modeling);
- An analysis of the distribution of operations and processes within the facility to determine potential emission sources and their locations
- An assessment of potential air pollutant distribution in surrounding communities (e.g., health risk assessment modeling);
- A technical justification for not including real-time monitoring for any of the air pollutants specified in Table 1 of Rule 1180, consistent with the criteria of the Guidelines;
- A summary of fenceline air monitoring instruments and ancillary equipment that are proposed to continuously measure, monitor, record, and report air pollutant levels, wind speed, and wind direction in real-time near the facility perimeter;
- A summary of instrument specifications, detectable pollutants, and minimum and maximum detection limits for all air monitoring instruments;
- Proposed monitoring equipment siting and selected pathways (when applicable) for fenceline instruments, including the justification for selecting specific locations based on the assessments noted above;
- Operation and maintenance requirements for the proposed monitoring systems;
- An implementation schedule consistent with the requirements of Rule 1180;

- Procedures for implementing data QA and QC;
- A web-based system for disseminating information collected by the fenceline air monitoring system;
- Methods for making the most recent five calendar years of electronic historical data available for public download and electronic transmission to the Executive Officer within 60 calendar days of the conclusion of each quarter in an approved format(s);
- Details of the public notification system; and
- Independent audits.

South Coast AQMD provided a checklist for key elements to be included in the FAMP as part of the Guidelines. This completed checklist, along with references to where in this document the element is addressed, is included in **Appendix A**.

## 2.2 Facility Location

### 2.2.1 Topography and Meteorology

The El Segundo Refinery is characterized by undulating hills approximately 0 to 160 feet above sea level. Due to the coastal siting of the refinery, wind patterns are dominated by the sea breeze-land breeze pattern. To assess wind climatology, meteorological data from the Los Angeles International Airport (LAX) Hastings site from 2007 to 2011 and the Chevron El Segundo East meteorological site from 2020 to 2025 were used to generate the wind roses shown in **Figures 2 and 3**. Note that the petals of a wind rose show the direction from which the wind is blowing. The LAX Hastings site is located only 3 miles north of the refinery and is 1 mile from the coast; thus, the meteorological data from this site are highly representative of the conditions at the El Segundo Refinery. These meteorological surface wind data were also used in Chevron's 2017 Voluntary Risk Reduction Plan (VRRP)[3] for this facility.

**Onshore Winds.** Winds most frequently blow from the southwest toward the northeast and move across the refinery and into the residential and commercial areas to the northeast of the facility. These winds are referred to as "onshore winds." Onshore winds are associated with the sea breeze phenomenon and are strongest during the daytime, early evening, and summer.

**Offshore Winds.** Winds also blow from the east/northeast and toward the southwest and out to the ocean. These "offshore winds" are associated with the land breeze phenomenon and tend to be stronger during the nighttime, early morning hours, and winter.

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[3] ERM (2017) 2015 voluntary risk reduction plan for the Chevron El Segundo Refinery. Prepared for Chevron USA, Inc., March.

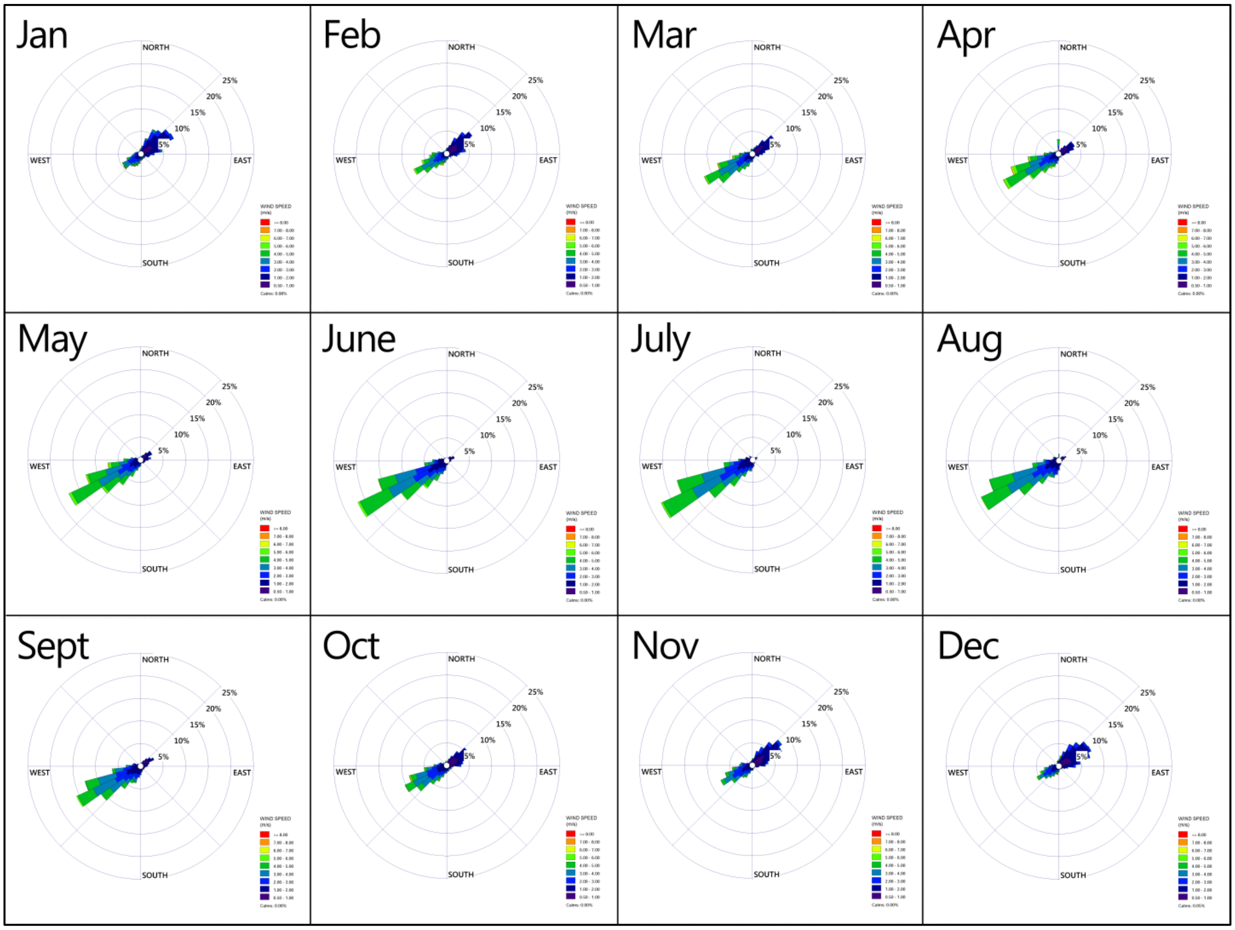

**Figure 2.** Average monthly wind roses from data collected at the LAX Hastings site from 2007 to 2011. The color scale runs from low windspeed (purple, 0.5 – 1 m/s) to high windspeed (red, greater than or equal to 8 m/s).

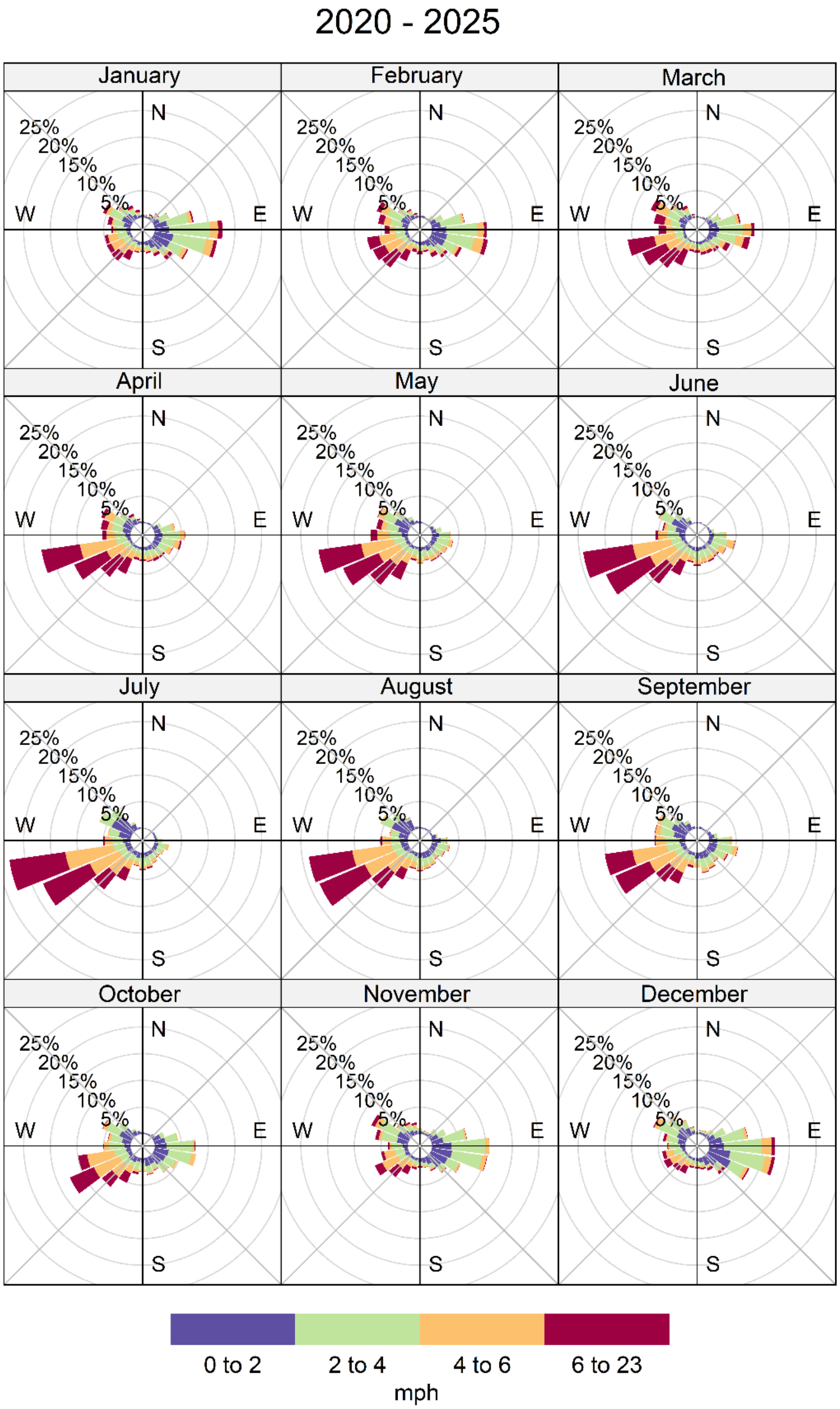

**Figure 3.** Average monthly wind roses from data collected at the East meteorological site at Chevron El Segundo.

In the winter, offshore wind patterns are most prevalent because of the cooler land temperatures. In the early spring and late fall, both onshore and offshore winds occur with roughly equal frequency. From late spring through summer and early fall, onshore wind patterns are the most frequent. In general, there is little deviation from the southwesterly onshore or northeasterly offshore flow throughout the year.

### 2.2.2 Nearby Sources

The El Segundo Refinery is directly adjacent to multiple potential off-site sources, as shown in **Figure 4**:

- The NRG El Segundo Power Plant to the west
- The Hyperion Water Treatment Plant to the north
- The Scattergood Generating Station to the north
- LAX to the north and northeast

Because the refinery is located in a densely populated area, typical urban emissions of pollutants are expected. The NRG El Segundo Power Plant and the Scattergood Generating Station generate electricity via the combustion of natural gas. They are therefore expected to be significant sources of nitrogen oxides ($NO_x$). LAX contributes to $NO_x$ pollution due to heavy traffic loads and air traffic emissions; Interstate 405 is another major source of $NO_x$ pollution due to heavy traffic. Interstate 405 is also a major source of diesel PM due to its large volume of heavy-duty vehicle traffic. The Hyperion Water Treatment Plant is one of the largest such plants in the area and is likely a significant source of hydrogen sulfide ($H_2S$) and sulfur oxides ($SO_x$).

These sources may affect background concentrations in the region. The Chevron El Segundo fenceline monitoring system may detect emissions originating from outside the facilities depending on pollutant concentration and meteorological conditions.

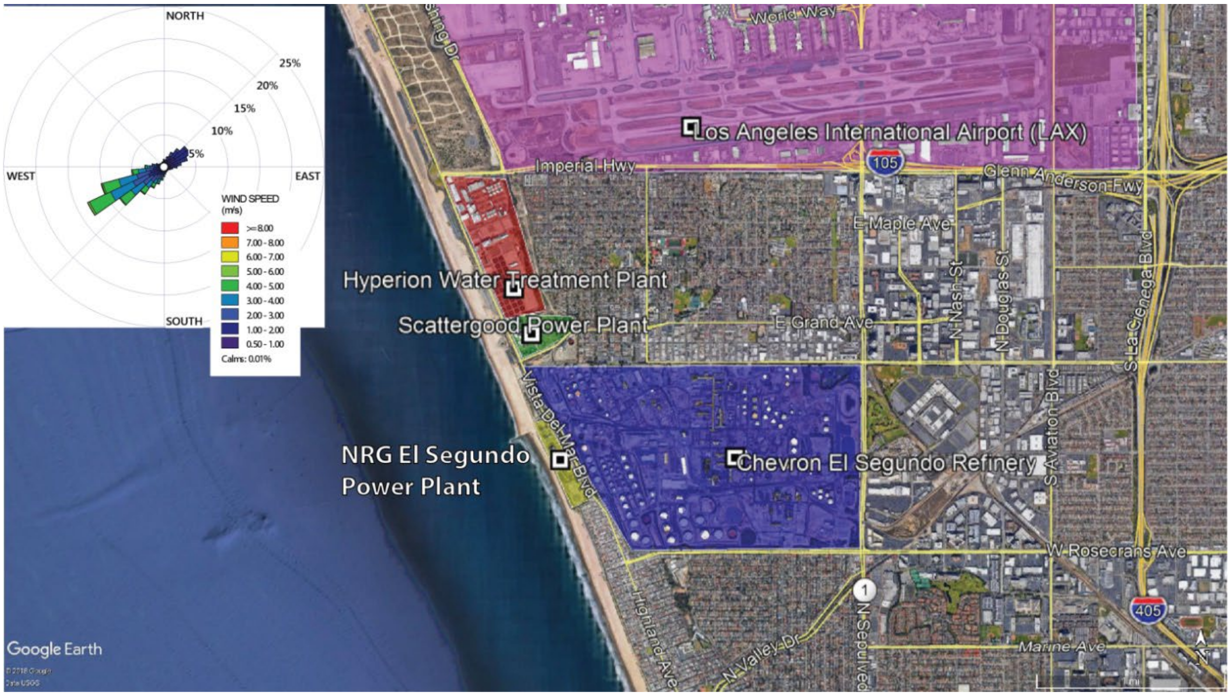

**Figure 4.** Satellite view of the Chevron El Segundo Refinery and nearby off-site sources. The inlaid wind rose was generated from hourly data from the LAX Hastings site from 2007 to 2011.

## 2.2.3 Sensitive Receptors

Residential areas near the refinery include El Segundo to the north and east and Manhattan Beach to the south and southwest. **Figure 5** shows nearby sensitive receptors, including schools and childcare facilities, adult-health facilities, recreation areas, and residential areas. At least one of each type of receptor is located within a mile of the refinery's fenceline. The combination of winds and proximity of sensitive receptors helps guide the placement of fenceline monitoring systems.

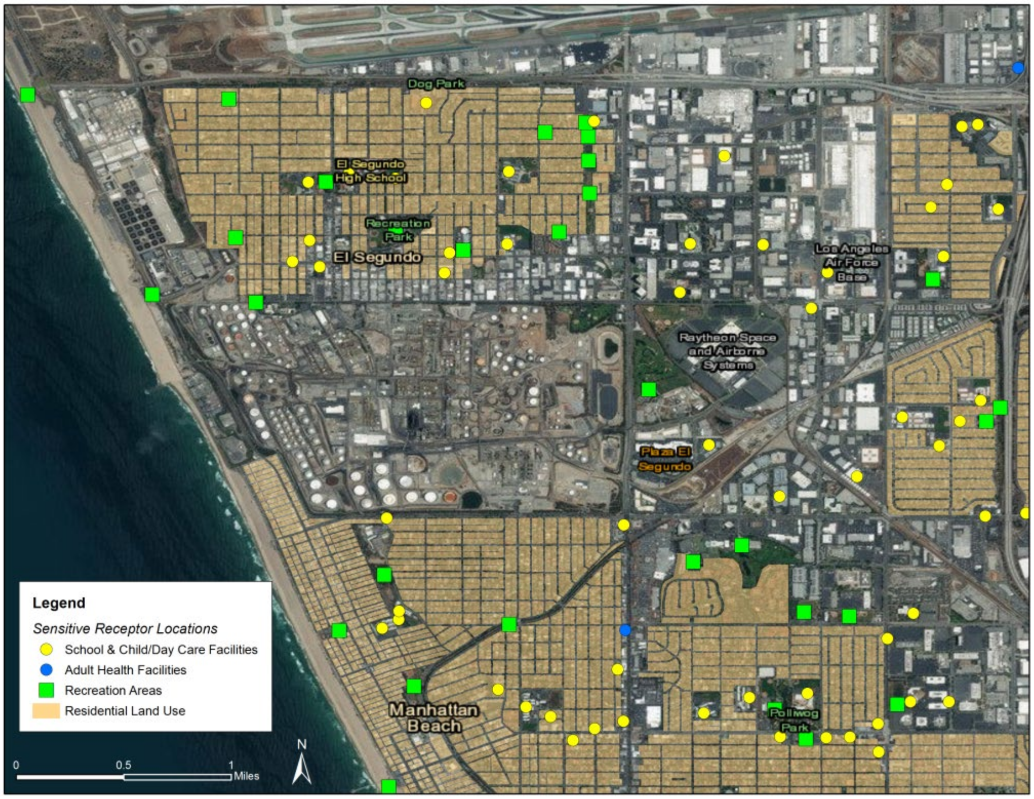

**Figure 5.** Map of sensitive receptors near the Chevron El Segundo Refinery.

There are also several recreation areas along the fencelines that include small community parks, beaches (El Segundo, Manhattan Beach, and Los Angeles County), and a golf course/driving range (to the east). There are schools located close to the northern fenceline in the city of El Segundo; these include nursery schools, preschools, and elementary, middle, and high schools. There are slightly fewer schools to the south in the city of Manhattan Beach. Daycare facilities are present in both the residential and commercial neighborhoods. Based on the dominant wind directions and the location of sensitive receptors in residential areas, the residential areas along the northeast and southwest fencelines are the most important areas to monitor.

## 2.3 Historical Emissions and Hotspots

### 2.3.1 Facility Operations and Processes

The El Segundo Refinery is a petroleum refinery producing fuel products such as liquefied petroleum gas, gasoline, jet fuels, diesel fuels, residual fuel oils, and coke via the distillation of crude oil, coking, cracking, alkylation, and reforming. Crude oil, which is used to produce gasoline and other refinery products, is delivered by ship to the marine terminal or received via pipeline directly to the refinery. The crude oil is then processed in the crude units, where it is heated and distilled into multiple feedstock components that are later processed elsewhere in the refinery. The heavy residual oil leaving the crude units is further distilled in the vacuum units to yield additional, lighter hydrocarbon products and vacuum residuum. The vacuum residuum is processed in the Coker Unit, and the lighter hydrocarbon components from the crude units and vacuum units are fed to other refinery units for further processing. Some of the major downstream processes are cracking in the FCCU and ISOMAX Unit, processing to recover sulfur in the hydrotreating units such as the Vacuum Residuum Desulfurization Unit, synthesizing in the Alkylation Unit, and reforming in the Continuous Catalytic Reforming Unit. Auxiliary systems are also necessary to support refinery operations. These systems include hydrogen plants to produce hydrogen needed for certain refinery reactions, boilers to produce steam, cogeneration plants to produce electricity and steam, and wastewater-treatment systems.

### 2.3.2 On-Site Emission Sources

In 2017, Chevron submitted a VRRP to South Coast AQMD. As part of this plan, an extensive emissions inventory was generated under South Coast AQMD Rule 1402 for the 2015 reporting year.[4] The emissions information presented here is a result of that effort. **Table 3** lists the annual emissions of the chemical species listed under South Coast AQMD Rule 1180.

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[4] ERM (2017) 2015 voluntary risk reduction plan for the Chevron El Segundo refinery. Prepared for Chevron USA, Inc., March.

**Table 3.** Emissions of species listed in Rule 1180 at the Chevron El Segundo Refinery. $NO_x$ and $SO_x$ were not part of the VRRP and are therefore not included in this table.

| Pollutant Name | Emissions (kg/yr) |
|---|---|
| 1,3-Butadiene | 10 |
| Acetaldehyde | 202 |
| Acrolein | 276 |
| Ammonia | 69,841 |
| Benzene | 432 |
| Cadmium | 17 |
| Carbonyl Sulfide | 594 |
| DieselExhPM[a] | 267 |
| Ethylbenzene | 658 |
| Formaldehyde | 1,728 |
| Hexane | 1,805 |
| Hydrogen Sulfide | 13,061 |
| Manganese | 30 |
| Naphthalene | 122 |
| Nickel | 59 |
| Styrene | 2 |
| Toluene | 1,596 |
| Xylenes | 2,385 |

[a] BC is a surrogate for diesel exhaust particulate matter.

For the purposes of dispersion modeling (Section 2.3.3), 326 sources were developed: 80 point sources, 155 volume sources, 79 area sources, and 12 poly-area sources. For both current and proposed facility risk configurations, all sources were included in the risk impacts. All stationary sources where the emissions passed through a stack or vent were modeled as point sources, including all stationary combustion sources.

All above-ground tanks were modeled as volume sources. The tank height and diameter were taken into consideration when determining the initial vertical and horizontal dimensions, in accordance with U.S. Environmental Protection Agency (EPA) guidelines. Since emissions from tanks are generally released at the top of the tank, the release height was assumed to be at the roof height for each volume source.

Many of the fugitive emissions associated with specific common regions were modeled as area sources. A total of 79 specific area sources were identified for a wide variety of rectangular regions, and the release heights were based upon each source's release geometry noted in the VRRP.

Other fugitive emissions that could not be identified with a specific location were assumed to occur within a plant region and were modeled as poly-area sources; specific fugitive emissions releases were identified with the plant region. A poly-area source configuration was used for these releases because of the unusual footprint of each of the nine plant regions. Welding emissions occurred across eight of the nine plant areas, and the emissions were equally spread over the eight plant area sources, excluding the maintenance plant area. The release height for each plant area was assumed to be at the ground. Because of operations occurring in these areas, it was assumed that emissions would initially be dispersed evenly throughout a 10-meter height. Portable diesel and gasoline internal combustion engine emissions could occur anywhere within the facility.

Figures 6 through 10 show emissions of key Rule 1180 species gridded on a map of the facility. Reported facility toxics emissions in 2015, along with coordinate and dimension information, were obtained from the 2015 VRRP modeling data. Emissions were gridded in a geographic information system (GIS) by location and source type in order to locate sources within the facility fenceline that had the highest emissions, on a per-pollutant basis.

Ammonia is emitted at several locations throughout the refinery, including the FCCU, process heaters and furnaces, and a number of other areas. Ammonia emissions are primarily related to uses in pollution-control devices.

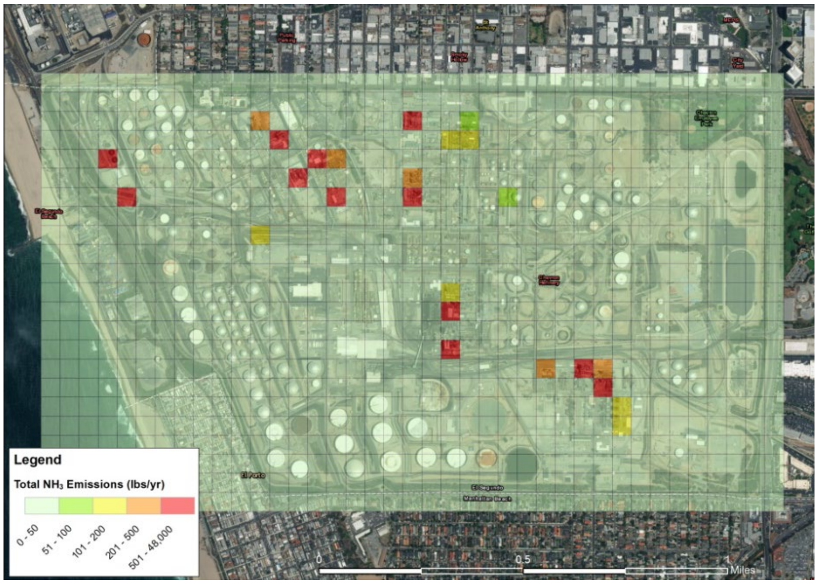

**Figure 6.** Gridded emissions of ammonia.

$H_2S$ emissions are primarily due to processes involved with sulfur removal ($H_2S$ plant, vacuum residual desulfurization, etc.). As expected, the spatial distribution of $H_2S$ (**Figure 7**) and carbonyl sulfide match closely.

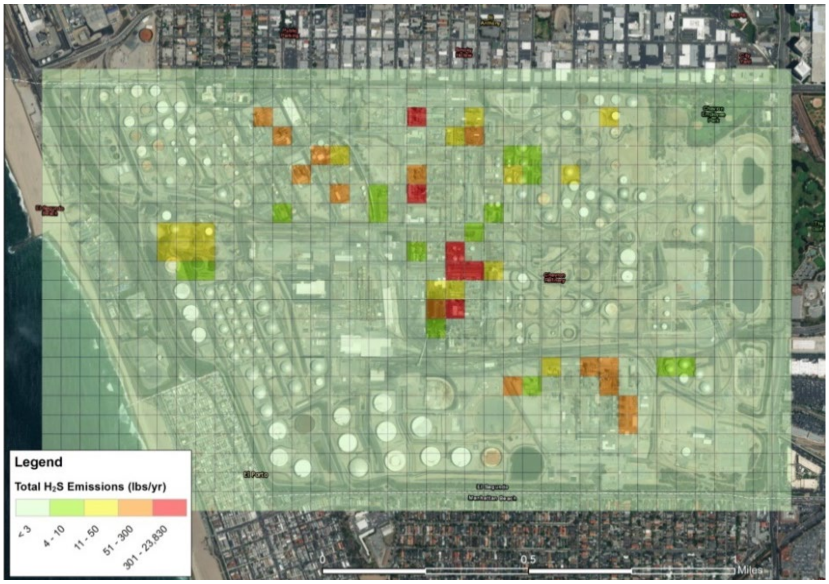

**Figure 7.** Gridded emissions of hydrogen sulfide.

The emission locations of BTEX are shown in **Figure 8**. Emissions of these hydrocarbons are widely distributed around the refinery property. Emissions maps of the individual BTEX compounds are similar to one another because these compounds are typically emitted in the same process streams.

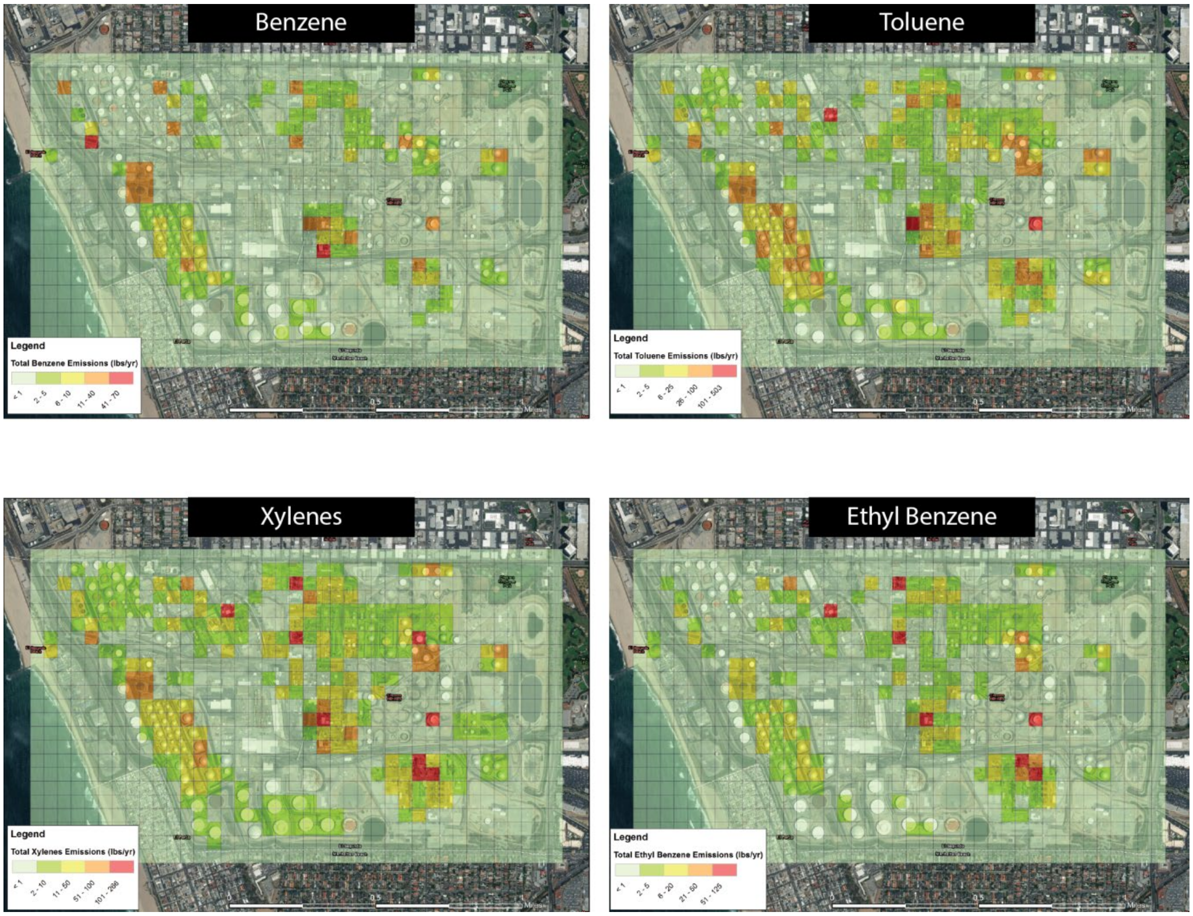

**Figure 8.** Gridded emissions of BTEX compounds.

The gridded emissions of 1,3-butadiene are shown in Figure 9.

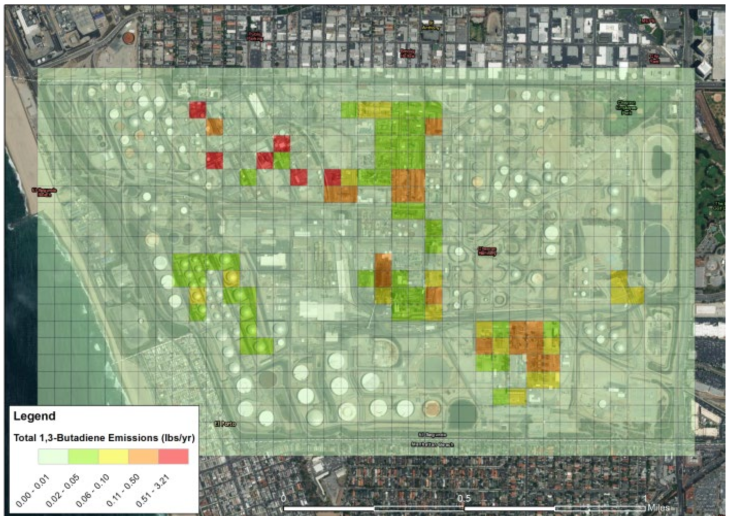

**Figure 9.** Gridded emissions of 1,3-butadiene.

Acrolein and acetaldehyde gridded emissions are highly spatially correlated and are shown in Figure 10. Both compounds are simple aldehydes that are expected to be emitted by similar processes.

**Figure 10.** Gridded emissions of acrolein and acetaldehyde.

## 2.3.3 Dispersion Modeling

Based on the emission source areas, receptors, and wind patterns, the most important areas for fenceline monitoring include the majority of the northern fenceline, the northern portion of the eastern fenceline, and the southwest fencelines. Additional evidence is provided by dispersion modeling.

Emissions data, topographic features, and meteorological measurements were used to model the spatial distribution of species that impact the community. To facilitate the combination of emissions and wind patterns, a modeling study was conducted as part of the 2015 VRRP.[5] The current facility could not be fully evaluated with the emissions inventory module (EIM), as the EIM only provides emission source strengths and locations at the facility. Therefore, modeled facility concentrations using Air Dispersion Modeling and Risk Tool results from the Hotspots Analysis and Reporting Program model were plotted. Annual average unit concentrations were calculated using South Coast AQMD 5-yr hourly AERMOD-ready meteorological data set for LAX Hastings. Concentrations were calculated at each of 3,298 receptors that represented fenceline, commercial, and residential/sensitive receptors out to a distance of 2,800 m from the north and south boundaries, 1,700 m from the eastern boundary, and to the ocean on the west. The EPA's regulatory default parameters were used in the modeling, along with a single urban area, defined as the city of Los Angeles with a population of 9,862,049.

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[5] ERM (2017) 2015 voluntary risk reduction plan for the Chevron El Segundo Refinery. Prepared for Chevron USA, Inc., March.

The model results showing the 5-yr average concentration for each species are shown in **Figures 11 through 14**. Key points are as follows:

- Modeled benzene concentrations (Figure 11) show significant concentrations along the northern fenceline and the southwest corner of the refinery.
- Modeled 1,3-butadiene concentrations (Figure 12) show a similar trend compared with benzene.
- Modeled $H_2S$ and ammonia concentrations (Figures 13 and 14) reinforce the importance of covering the north/northwest and southwest fencelines.
- There are virtually no pollution impacts for the southeast corner of the refinery because the winds rarely blow in this direction and there are no emission sources there.

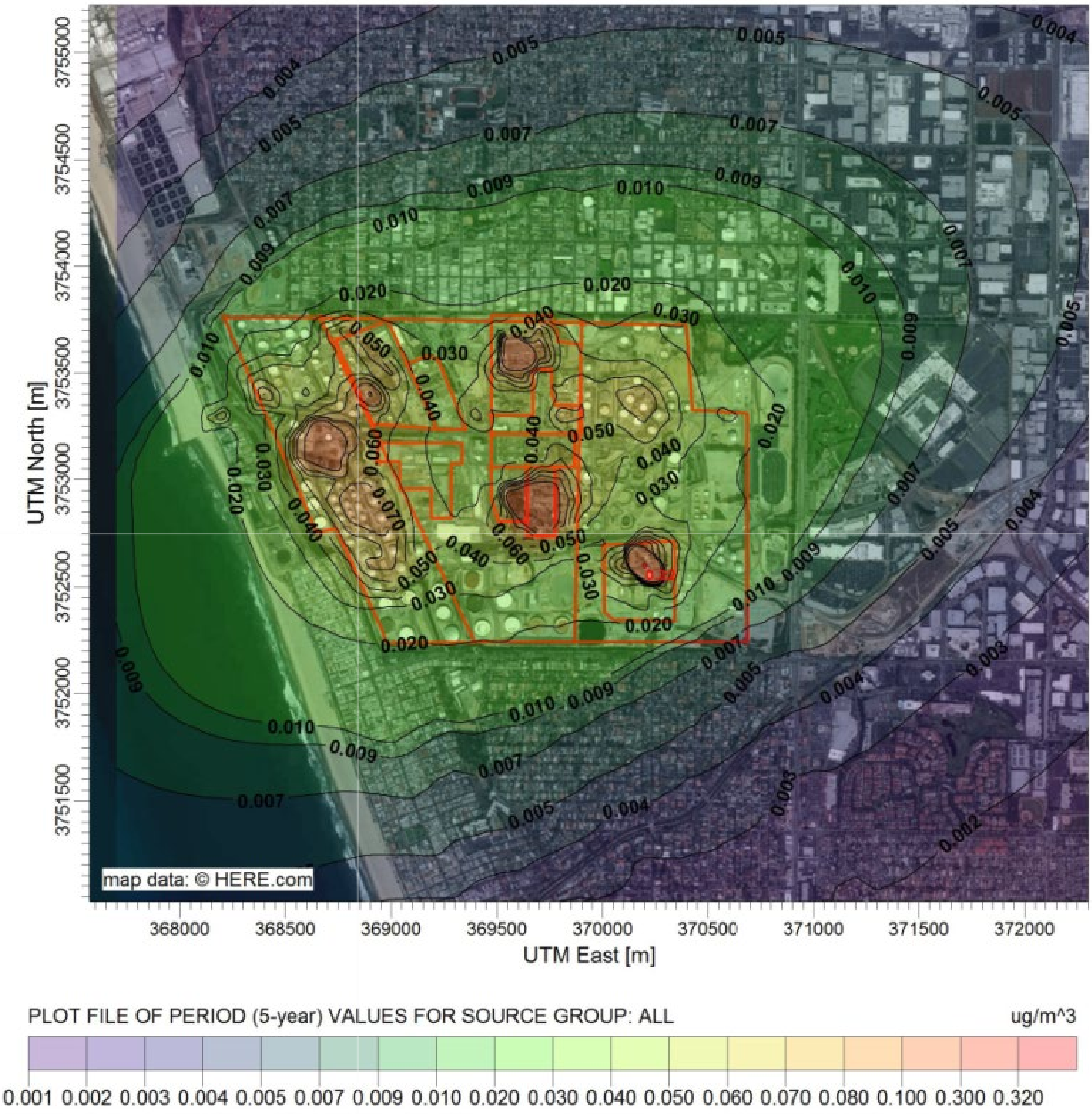


**Figure 11.** Benzene annual average concentrations from 2007 to 2011, using LAX Hastings surface meteorological data. The axes correspond to Universal Transverse Mercator (UTM) coordinates.

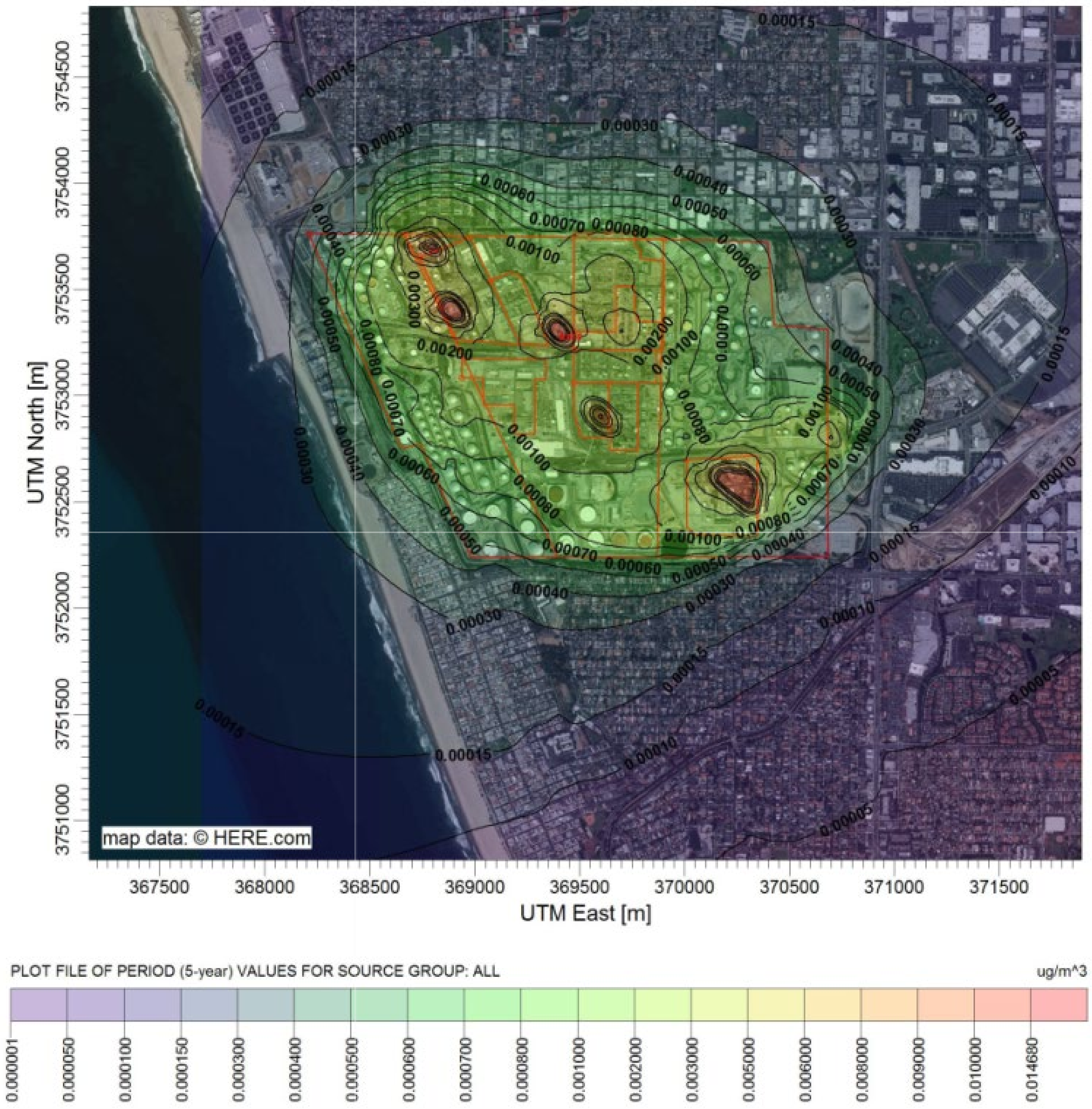


**Figure 12.** 1,3-butadiene annual average concentrations from 2007 to 2011, using LAX Hastings surface meteorological data.

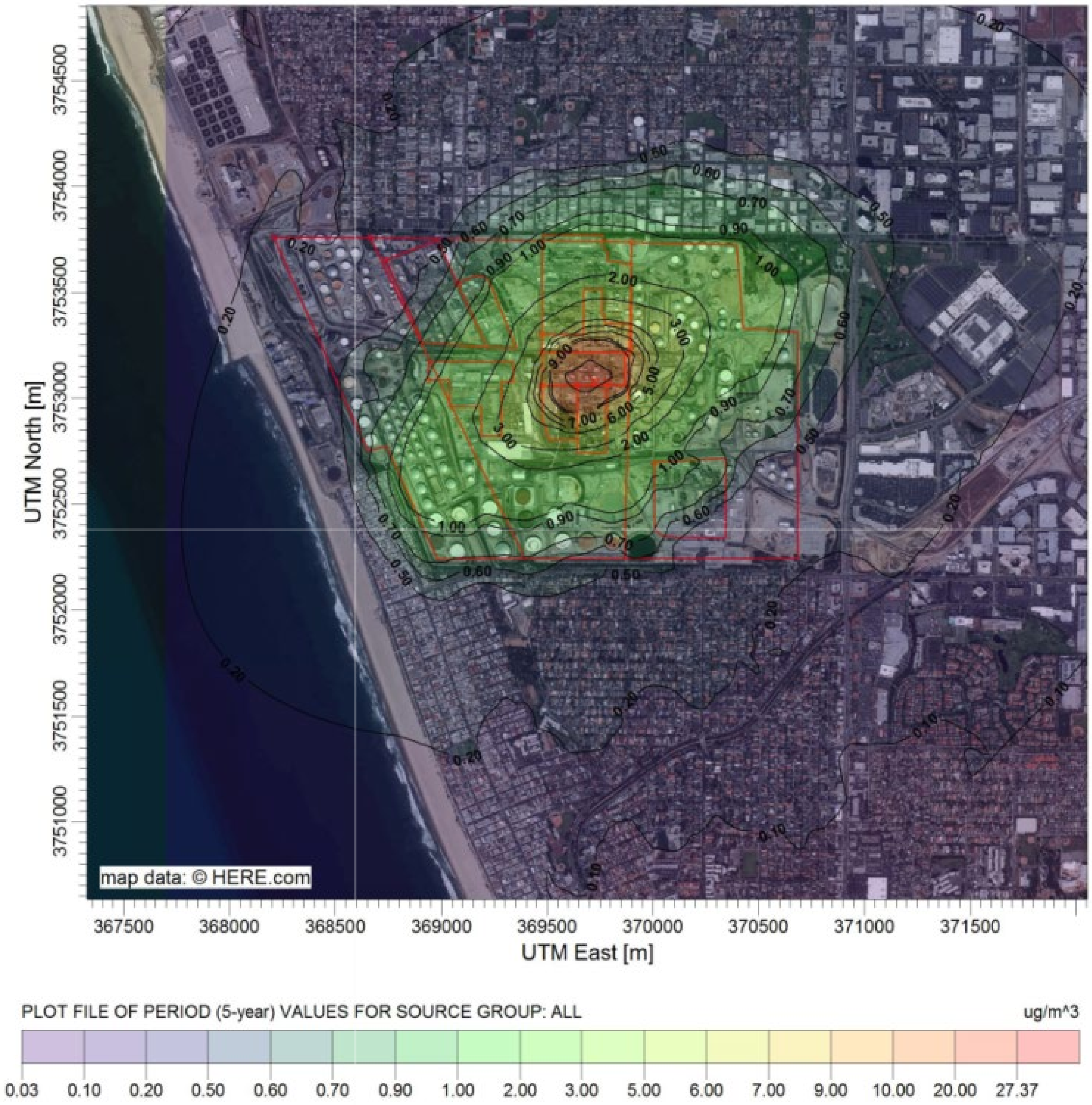


**Figure 13.** Hydrogen sulfide annual average concentrations from 2007 to 2011, using LAX Hastings surface meteorological data.

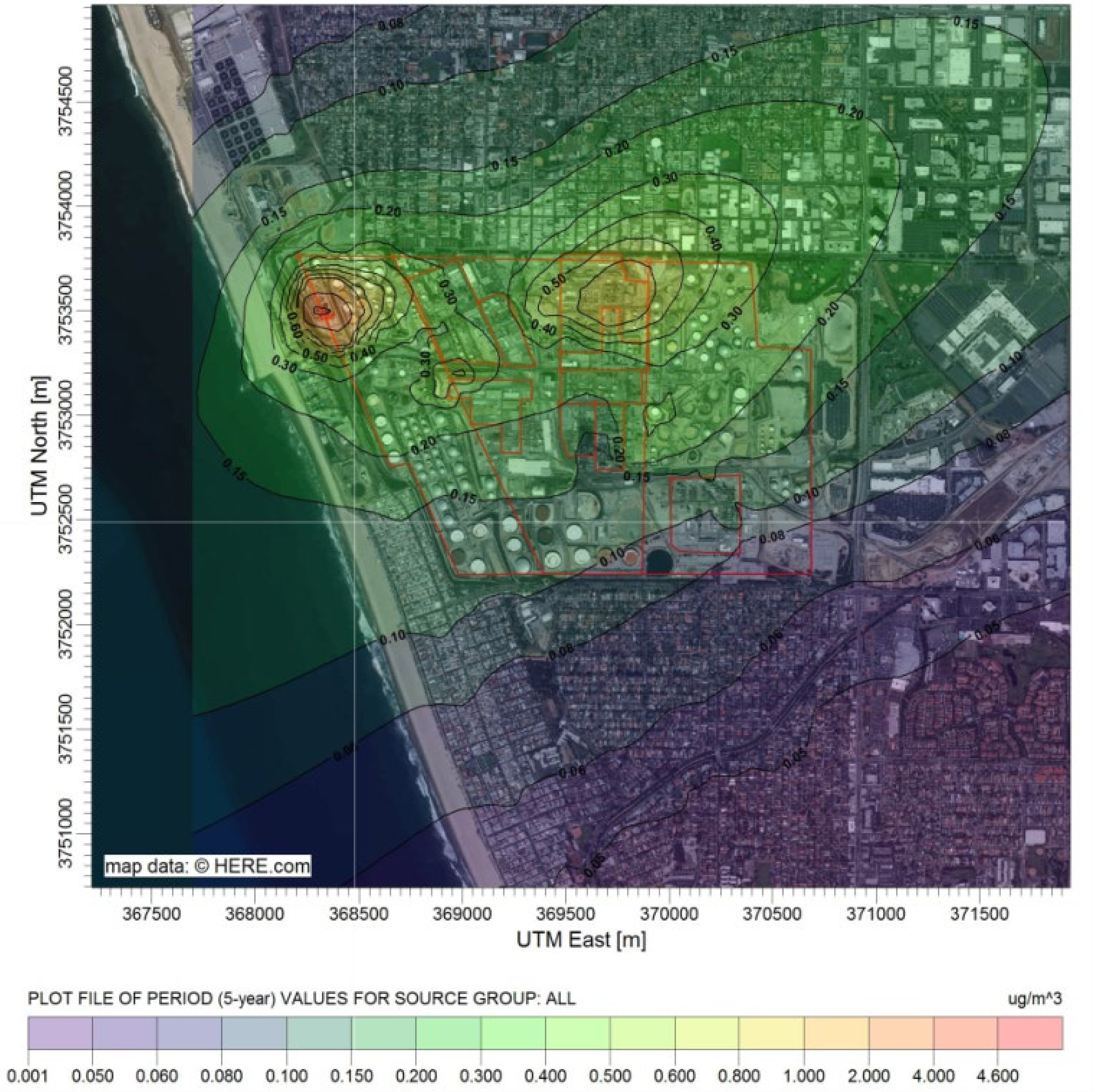


**Figure 14.** Ammonia annual average concentrations from 2007 to 2011, using LAX Hastings surface meteorological data.

## 2.4 Siting Justification

Chevron is actively monitoring all sides of the El Segundo Refinery via open-path analyzers for most compounds and point monitors for $H_2S$ and BC. Per the amended Rule 1180, additional point monitors will be installed for $PM_{10}$ and $PM_{2.5}$, as described in Section 1.2.2.

The following is Chevron's rationale for determining the placement of current (previously approved by South Coast AQMD) monitoring sites:

- The 12 monitoring paths provide ample coverage of areas of concern based on the results presented in Sections 2.2 and 2.3; areas where the impact potential is very low are also included.
- Path 1 is positioned between one of the refinery's tank farms and the community of El Segundo. $H_2S$ and BC are not a concern for this path because this area is not downwind of any major sources of these species.
- Path 1.5 and P1 (point monitors) were added to provide coverage between the laboratory and crude unit areas of the refinery and the community of El Segundo.
- Paths 2-7, P2, and P3 provide coverage during the most frequent (onshore) wind patterns between the refinery's process block and tank farms and nearby commercial areas, residential neighborhoods, and other sensitive receptors.
- Path 8 is located between the refinery and areas to the southeast. While the analysis shows that this path is very unlikely to be impacted by refinery emissions, it has been included to ensure a robust monitoring network.
- Paths 9-11 and P4-P6 provide coverage during the less frequent (offshore) wind patterns between the refinery's process block and tank farms and the Manhattan Beach neighborhood toward the southwest.
- The eastern meteorological site is free of major obstructions and provides the best siting opportunity for measuring meteorological parameters.
- The western meteorological site was selected because of the coastal siting of the refinery.
- No monitors are necessary on the western fenceline between Path 1 and Path 11 because there are no downwind sensitive receptors in this area. In addition, any aloft emissions generated by upwind offsite sources to the west would pass over any monitors located at the ground level.

The following is Chevron's rationale for selecting new monitoring sites:

- $PM_{10}$ and $PM_{2.5}$ will be collocated with BC monitors to achieve total facility coverage by point monitors.
- Metals analyzers measuring cadmium, manganese, and nickel will be located at sites downwind of the most frequent wind direction along the facility fenceline and near the FCCU, which is the only potential source of emissions of these compounds that could be detected at the fenceline. Concentrations of metals are expected to remain well below notification thresholds during routine operations, and possible elevated concentrations due to an upset event would be adequately captured by these monitoring locations.

## 2.5 Monitoring Technology and Equipment

Literature reviews, site surveys, and interviews with instrument manufacturers all informed the analyzer selection process for the fenceline monitoring system. Both open-path analyzers and point monitor instruments were investigated, but the required sampling distances (hundreds of meters), measurement time resolution (5 minutes), and current state of measurement technology resulted in the selection of open-path analyzers for most compounds. Point monitors were selected for BC, $H_2S$, metals (cadmium, manganese, and nickel), and PM ($PM_{10}$ and $PM_{2.5}$), and standard technologies were selected for meteorological measurements, including wind speed, wind direction, and visibility.

Table 4 summarizes the compounds monitored, as well as the sites and technologies used, for the fenceline monitoring system. The principles of operation for each measurement technology are provided in Sections 2.5.1 through 2.5.3.

**Table 4.** Summary of compounds, sites, and technologies used by the Chevron El Segundo fenceline monitoring system.

| Compound | Sampling Sites | Monitoring Technology | Comments |
|---|---|---|---|
| 1,3-Butadiene | OP1–OP11 | OP FTIR | Required |
| Acetaldehyde | OP1–OP11 | OP FTIR | Required |
| Acrolein | OP1–OP11 | OP FTIR | Required |
| Ammonia | OP1–OP11 | OP FTIR | Required |
| BC | P1–P6 | Aethalometer | BC is a surrogate for diesel PM. |
| Benzene | OP1–OP11 | OP UV-DOAS with Xenon | Required |
| Cadmium | P1, P2, P3, and P4.5 | Energy Dispersive X-Ray Fluorescence (EDXRF) | Metals monitoring will occur near the FCCU, in accordance with the Guidelines. |
| Carbonyl Sulfide | OP1–OP11 | OP FTIR | Required |
| Ethylbenzene | OP1–OP11 | OP UV-DOAS with Xenon | Required |
| Formaldehyde | OP1–OP11 | OP FTIR | Required |
| $H_2S$ | P1–P6 | Point $H_2S$ | Required |
| HCN | OP1–OP11 | OP FTIR | Required |
| HF | -- | -- | Chevron El Segundo Refinery does not use HF in any major processes, so it is not monitored. |
| Manganese | P1, P2, P3, and P4.5 | EDXRF | Metals monitoring will occur near the FCCU, in accordance with the Guidelines. |
| Naphthalene | OP1–OP11 | OP UV-DOAS with Xenon | Required |
| Nickel | P1, P2, P3, and P4.5 | EDXRF | Metals monitoring will occur downwind of the FCCU, in accordance with the Guidelines. |
| $NO_x$ | OP1–OP11 | OP UV-DOAS with Xenon | Measures $NO_2$ only; however, most $NO_x$ in the refinery is emitted from elevated sources and therefore not expected to be measured by fenceline monitors. |
| PAHs | -- | -- | PAH monitoring will occur after the South Coast AQMD Executive Officer provides written notice that real-time monitoring of PAHs is feasible, in accordance with Rule 1180. |
| $PM_{10}$ | P1–P6 | Light scattering spectrometry | Required |
| $PM_{2.5}$ | P1–P6 | Light scattering spectrometry | Required |
| $SO_2$ | OP1–OP11 | OP UV-DOAS with Xenon | Required |
| Styrene | OP1–OP11 | OP FTIR | Required |
| Toluene | OP1–OP11 | OP UV-DOAS with Xenon | Required |
| Total VOCs (Non-Methane Hydrocarbons) | OP1–OP11 | OP FTIR | Will report "total hydrocarbons" as a sum of ethane, propane, butane, and pentane concentrations, each normalized to the molecular weight of propane. |
| Xylenes | OP1–OP11 | OP UV-DOAS with Xenon | Required |

### 2.5.1 Open-Path Analyzers

Open-path analyzers send a beam of light across the open air and receive it at a detector. In a monostatic configuration, a mirror (retroreflector) is positioned at the opposite end of the pathway that reflects the beam of light back to a detector positioned with the open-path instrument (Figure 15). When gases are present in the beam, some of that light is absorbed. The detector can distinguish between a beam received in clean air versus a beam in which gases are present. Based on their composition, gases absorb light in a specific way. These gas-specific absorption characteristics serve as a unique fingerprint for each gas. By comparing known reference standards with the results from field measurements, the system can identify the gas based on which wavelength absorption patterns are present. Likewise, the quantity of light that is absorbed is a direct function of the concentration of the gas in the air. By analyzing the amount of light lost due to gas absorption, the system can quantify the average concentration of various compounds along the beam path. A single open-path analyzer can continuously monitor paths several hundred meters in length. Open-path analyzers are therefore ideal for use as a fenceline monitoring system when it is necessary to cover a significant linear distance.

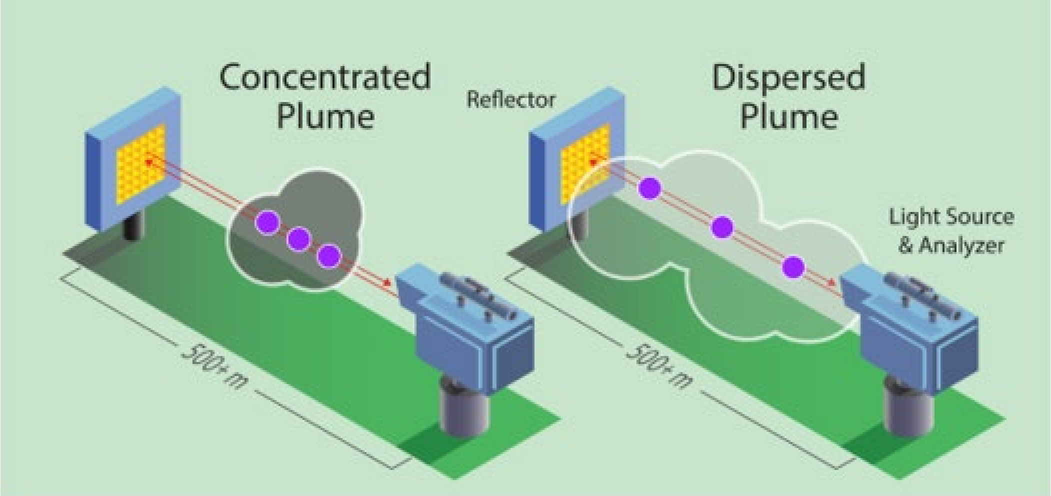


**Figure 15**. Basic operating principle of open-path analyzers.

Open-path analyzers detect average concentrations across the entire distance from the transmitter to the detector (transmitter to retroreflector and back to detector). Periods of poor visibility due to weather-related conditions (e.g., fog) are known to interfere with open-path measurements. Rule 1180 allows for such data to be excluded from counting against the facility if supported by visibility measurements. Accordingly, visibility sensors are located as shown in Figure 1 (Section 1.2.1).

Monostatic open-path instruments were selected to reduce the need for substantial power at the retroreflector sites and improve minimum detection limits (MDLs) by increasing optical path lengths. Only the light-source/detector end of the monitoring path requires substantial power, communications equipment, and a large shelter. Limited power is needed at the retroreflectors, but each retroreflector must be aligned correctly for maximum performance and must be cleaned regularly. Figure 16 shows example installations of an open-path shelter and equipment, a point monitor installation, and a representative retroreflector installation.

Figure 16. Examples of an open-path shelter (top), retroreflector (bottom left), and point monitor (bottom right) installations.

The analyzers installed at the Chevron El Segundo fenceline monitoring system measure in real time: the FTIR analyzers record a data point every 2.5 min and the UV-DOAS analyzers record a data point every 30 sec. Furthermore, these analyzers record and store measured spectra, background and reference spectra, additional data used for concentration retrievals, and associated average concentrations of measured pollutants for retrospective investigations.

### 2.5.2 Point Monitors

At the refinery, BC is measured using an aethalometer. In this tape-based accumulation and optical absorption technique, a sample is deposited onto a filter tape that is illuminated. The transmitted light is then compared between the accumulation spot (i.e., the sample) and the clean tape (i.e., the reference). The amount of light absorbed and the flow rate through the tape are converted to concentrations of BC.

$H_2S$ is also measured using a tape-based accumulation and optical absorption technique. A sample is deposited onto a lead acetate filter tape that is illuminated. $H_2S$ and lead acetate undergo a chemical reaction that changes the optical absorbance properties of the tape, and the transmitted light is compared between the accumulation spot (i.e., the sample) and the clean tape (i.e., the reference). The amount of light absorbed and the flow rate through the tape are converted to concentrations of $H_2S$.

Metals (cadmium, manganese, and nickel) are measured using Energy Dispersive X-Ray Fluorescence (EDXRF). This technique exposes a filter tape deposited sample to high-energy X-rays, thereby adding energy to the system in a process known as excitation. This energy is subsequently released via the emission of secondary, lower-energy X-rays in a process known as fluorescence. The energy levels associated with this fluorescence are specific to individual elements, which allows EDXRF to directly measure concentrations of metals. A sampling frequency of 30 min is used for the fenceline monitoring system, which is sufficient for the 1-hr and 8-hr public notification thresholds required by the amended Rule 1180.

PM will be measured by light scattering spectrometry, which converts optical measurements to particle mass. This technique draws in ambient air with different-sized particles and dries them before measuring the scattered light impulse of each particle. The amplitude of the scattered light is directly related to the particle size diameter, which is subsequently converted into particle mass, and both $PM_{10}$ and $PM_{2.5}$ are measured simultaneously. A sampling frequency of at least one sample per hour will be reported for the fenceline monitoring system, which is sufficient for the 24-hr public notification thresholds required by the amended Rule.

### 2.5.3 Meteorological Sensors

Meteorological stations measure wind speed and direction. These supporting data are helpful for determining from where potential detections by the fenceline monitoring system may have originated.

A visibility sensor is used to assess low-visibility conditions that can cause invalid or missing measurements from open-path analyzers. Heavy fog may entirely block the signal from an open-path instrument and prevent data collection, but even light fog can absorb the signal partially and interfere with monitoring. Measurements are generally impacted when visibility is fewer than 2.5 miles; this situation results in marginal operating conditions for the analyzer (e.g., decreased signal strength or increased integration time). If data from open-path analyzers are invalid due to low signal return and visibility is also low, the data are flagged as invalid due to low visibility.

### 2.5.4 Minimum Detection Limits

Table 5 summarizes the MDLs for compounds measured with open-path analyzers by the fenceline monitoring system for two representative path lengths and compares them with public notification thresholds. Minimum Detection Limits must be sufficiently below notification thresholds for the monitoring technology to be considered appropriate for this application.

These theoretical MDLs are provided by instrument manufacturers and are based on both spectroscopic specifications and estimated sampling path lengths. In reality, MDLs of open-path systems are dynamic and depend on atmospheric conditions (e.g., the MDL will increase as atmospheric visibility decreases), the presence of interfering or unknown compounds, the unique characteristics of each spectroscopic system, the atmospheric path length, and equipment performance. Actual MDLs can be higher or lower than theoretical values and can also change with time, so they will be calculated during routine operations with ambient data. MDLs are for the average concentration along a sampling path, so narrow plumes that only cover a portion of the path would need to have a higher concentration than the MDL to be detected.

**Table 5.** Theoretical open-path analyzer MDLs for two representative path lengths compared with public notification thresholds.

| | Compound | MDL at 579 meters (ppb) | MDL at 200 meters (ppb) | 1-hr Concentration Notification Threshold (ppb) |
|---|---|---|---|---|
| FTIR | 1,3–Butadiene | 3.5 | 10.0 | 297 |
| | Acrolein | 13.0 | 37.5 | 1.1[a] |
| | Acetaldehyde | 5.2 | 15.0 | 260 |
| | Ammonia | 2.6 | 7.5 | 4,507 |
| | Carbonyl Sulfide | 7.6 | 22.0 | 270 |
| | Formaldehyde | 3.5 | 10.0 | 44 |
| | Total VOCs | 2.6 | 7.5 | 730[b] |
| | HCN | 8.6 | 25.0 | 309 |
| | Styrene | 6.9 | 20.0 | 5,000 |
| UV-DOAS | Benzene | 0.2 | 0.7 | 8 |
| | Ethylbenzene | 0.3 | 0.8 | --[c] |
| | Naphthalene | 0.2 | 0.5 | --[c] |
| | $NO_2$ | 2.6 | 7.6 | 100 |
| | m-Xylene | 0.3 | 0.9 | 5,000 |
| | o-Xylene | 3.3 | 9.4 | 5,000 |
| | p-Xylene | 0.2 | 0.6 | 5,000 |
| | $SO_2$ | 0.6 | 1.7 | 75 |
| | Toluene | 0.7 | 2.1 | 1,300 |

[a] The notification threshold for acrolein is lower than the MDL of available open-path technology, so public alerts are not sent for this compound.

[b] This notification threshold for Total VOCs is an information-based value prescribed by Rule 1180.

[c] No notification threshold is defined for this compound.

Table 6 summarizes MDLs for compounds measured with point monitors and compares them with public notification thresholds. As in the case of the open-path analyzers, MDLs measured with point monitors must be sufficiently below notification thresholds for the monitoring technology to be considered appropriate for this application. Minimum Detection Limits for point monitors are provided by the manufacturer of the analyzer. The MDL values presented for cadmium, manganese, and nickel are based on a 30-min sampling frequency.

**Table 6.** Theoretical point monitor MDLs compared with public notification thresholds.

| Compound | MDL | Notification Threshold | Time Resolution for Notification Threshold (hr) |
|---|---|---|---|
| BC | 0.1 µg/m$^3$ | --[a] | -- |
| Cadmium | 0.0072 µg/m$^3$ | --[a] | -- |
| $H_2S$ | 5 ppb | 30 ppb | 1 |
| Manganese | 0.00041 µg/m$^3$ | 0.17 µg/m$^3$ | 8 |
| Nickel | 0.00027 µg/m$^3$ | 0.2 µg/m$^3$ | 1 |
| $PM_{10}$ | 0.1 µg/m$^3$ | 50 µg/m$^3$ | 24 |
| $PM_{2.5}$ | 0.1 µg/m$^3$ | 35 µg/m$^3$ | 24 |

[a] No notification threshold is defined for this compound.

# 3. Routine Operations

Instrument operations and maintenance includes daily data checks to ensure data are flowing from all instruments, as well as monthly, quarterly, and annual maintenance activities. Additional details are provided in the QAPP and individual instrument standard operating procedures (SOPs) (Attachments 1–7).

## 3.1 System Maintenance

Automated system status indicators will alert data reviewers to operational issues on an ongoing basis. Sonoma Technology’s after-hours on-call staff additionally respond to alerts for operational issues 24 hours per day, 7 days per week. Routine maintenance activities, including planned schedules and estimated downtime for completion, are detailed in the QAPP and individual instrument SOPs.

## 3.2 Backup Air Monitoring

Back-up air monitoring measures are described in the QAPP.

## 3.3 Fenceline Downtime or Malfunction

According to Rule 1180, downtime for the fenceline monitoring system will be reported as follows:

- A call will be made to 1-800-CUT-SMOG at least 48 hr prior to planned maintenance or modification of the fenceline monitoring system;
- A call will be made to 1-800-CUT-SMOG within 2 hr of discovering, and no more than 8 hr after the start of downtime, that the fenceline monitoring system failed to provide continuous, real-time data for more than 1 hr;
- Written notification will be submitted to the South Coast AQMD Executive Officer within 24 hr of discovering, and no more than 30 hr after the start of downtime, that the fenceline monitoring system failed to provide continuous, real-time data for more than 24 hr.; and
- The public website will be updated to indicate that continuous, real-time data are unavailable when the fenceline monitoring system is experiencing known downtime.

# 4. Public Website and Notification System

## 4.1 Real-Time Data Dissemination

Raw measurements from open-path analyzers, point monitors, and meteorological sensors are averaged to 5-min resolution (30-min for metals).

monitoring and 1-hr for PM) by the data acquisition system at each site and then transmitted to a cloud-based DMS in real time. The data undergo AutoQC before being made available on the public website within 10-15 minutes of collection. Additional details regarding data flow and QC processes are described in the QAPP.

### 4.1.1 Data Quality Assurance and Control

Data generated by the fenceline monitoring equipment undergo review throughout the measurement and reporting process. The QA/QC plan ensures that data produced by the fenceline monitoring system are representative and defensible. Clear definitions and procedures for QA/QC are also necessary to inform the public on why data may be missing, suspect/questionable, or invalid. Data review processes are detailed in the QAPP.

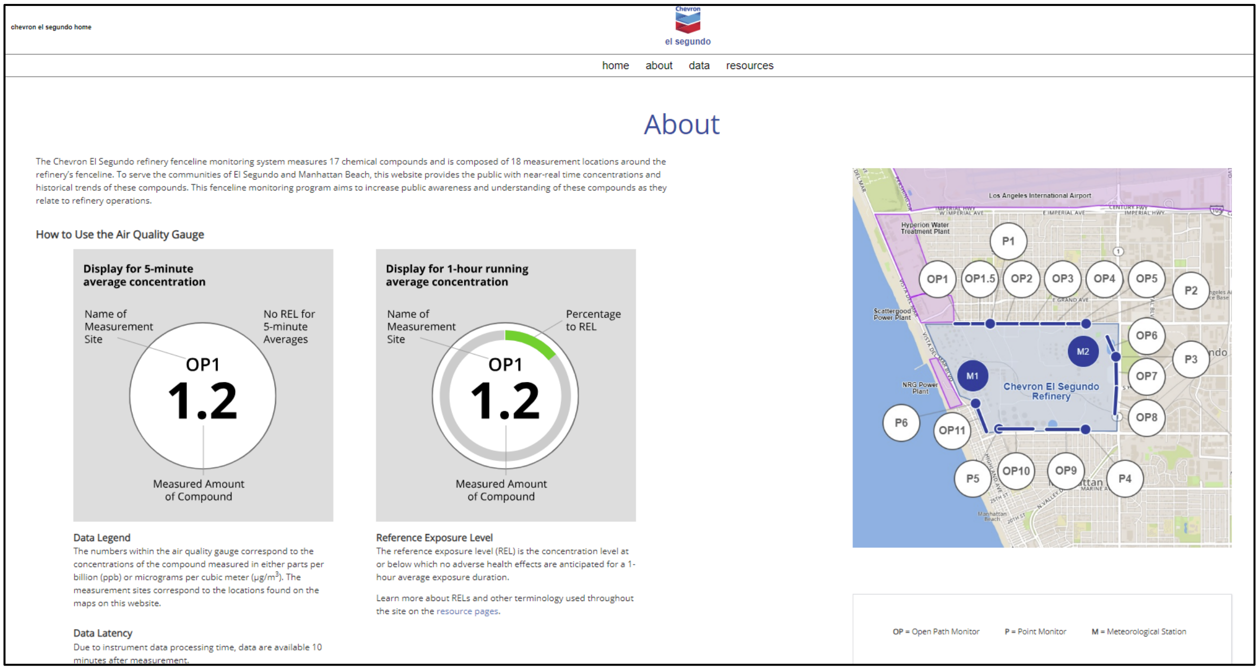
### 4.1.2 Public Website

As required by Rule 1180, a public website displays and stores at least 5 calendar years' worth of the most recent data collected from the fenceline air monitoring system. In addition, the following information will be made publicly available on the fenceline air monitoring website:

- A description of the air pollutants monitored by the fenceline monitoring system, including their general health impacts, and a link to the OEHHA Air Chemical database website;
- A description of measurement techniques;
- A description of notification thresholds;
- A mechanism for the public to opt-in and opt-out of fenceline notifications, select separate email and/or text message notification options, and provide feedback to the facility;
- Access to view all instances when an air pollutant was measured above a notification threshold;
- Real-time and historic concentrations of all air pollutants and wind speed and direction measured by the fenceline monitoring system with corresponding data quality flags;

  - 5 years' worth of the most recent historic data will be accessible via a calendar date picker, which will allow the public to select a range of dates for data display. Data will be returned in a time series format with an option to download the data in a text file (e.g., comma separated value [csv] format).
- Definitions of data quality flags; and
- Documentation for the fenceline monitoring system, including the most recently approved (or partially approved) FAMP, report(s) generated from independent audits, specific-cause analysis (SCAs), quarterly reports, and corrective action plans (CAPs).

The public website for the Chevron El Segundo fenceline monitoring system can be found at https://www.elsegundo1180.com, and a representative screen capture is shown in Figure 17.



About

The Chevron El Segundo refinery fenceline monitoring system measures 17 chemical compounds and is composed of 18 measurement locations around the refinery's fenceline. To serve the communities of El Segundo and Manhattan Beach, this website provides the public with near-real time concentrations and historical trends of these compounds. This fenceline monitoring program aims to increase public awareness and understanding of these compounds as they relate to refinery operations.

How to Use the Air Quality Gauge

**Display for 5-minute average concentration**

**Display for 1-hour running average concentration**

**Data Legend**
The numbers within the air quality gauge correspond to the concentrations of the compound measured in either parts per billion (ppb) or micrograms per cubic meter ($\mu g/m^3$). The measurement sites correspond to the locations found on the maps on this website.

**Data Latency**
Due to instrument data processing time, data are available 10 minutes after measurement.

**Reference Exposure Level**
The reference exposure level (REL) is the concentration level at or below which no adverse health effects are anticipated for a 1-hour average exposure duration.

Learn more about RELs and other terminology used throughout the site on the resource pages.

**OP** = Open Path Monitor **P** = Point Monitor **M** = Meteorological Station

Figure 17. A screen capture of the public website for the Chevron El Segundo fenceline monitoring system.

## Real-Time Data

Data are displayed using real-time, 5-min data points and rolling hourly averages. The website also includes functionality to notify the public with custom messaging about instrument maintenance activities, potential issues with the monitoring network, or any other relevant information affecting the use of data. Preliminary, quality-controlled data are presented as a time series, color-coded by sampling site and annotated for quality (i.e., valid, invalid, suspect, missing).

## Historical Data

Historical data are made available on the public website as time series plots of 5-min and rolling hourly concentrations and can be viewed with a date selector. Furthermore, and as required by amended Rule 1180, the most recent five calendar years of hourly data will be made available for public download in an easily downloadable, accessible, and interpretable electronic format.

## Learning Center

For the public website, key components include visual display of data in real time, context for the public to better understand the concentrations displayed, and a mechanism for feedback. All feedback is reviewed by the facility, and responses may be issued via email.

The collected data are high time resolution, spatially variable, and chemically complex. To provide context for this complex data set, the following information is included through a combination of links, graphics, and captions:

- Information about the species measured and the measurement techniques
- Context of what fenceline measurements represent compared with other regional air quality measurements
- Health data provided on the web page sourced from official OEHHA information
- Discussion of sources outside the refinery that could affect the measured concentrations
- Definitions of abbreviations
- Discussion of data below detection
- Definition of data QC flags and their meaning
- Frequently asked questions (FAQs)
- Quality procedures

Information is written at a public-friendly level, with clarity and thoroughness reducing the number of questions that arise. To facilitate public feedback, a feedback button is provided on the web page. When a user clicks on the button, an email form pops up for the user to submit comments about the website. Those forms are reviewed by refinery personnel and/or a designated contractor and archived. Although not all comments need to be addressed, all comments will be made available to South Coast AQMD upon request. Some of the comments may aid in the creation of future FAQs.

## Documentation

The most recently approved FAMP and QAPP are available on the public website and will be updated whenever there are new approvals.

Quarterly reports are available on the public website. Additional information regarding quarterly reports is provided in Section 4.2.1.

Specific-cause analyses, independent audit reports, and CAPs are available on the public website. Additional information on these documents is provided in Sections 4.2.2 through 4.2.4.

### 4.1.3 Public Notification System

As required by Rule 1180, the publicly accessible website includes a web-based notification program that automatically generates and sends a notification whenever:

- The concentration of any pollutant exceeds the applicable notification threshold, along with the following information:
    - A unique identification number for each notification generated;
    - Refinery name;
    - Location, site, date, and time of the exceedance;
    - Air pollutant name, concentration measured, and the notification threshold; and
    - A link to the OEHHA Air Chemical database website to the specific air pollutant detected above the threshold, where applicable.
- The concentration of any pollutant exceeds 2, 4, 8, 16, and 256 times the initial applicable notification thresholds, as defined by Rule 1180, along with the following information:
    - The corresponding unique identification number;
    - Refinery name;
    - Location, site, date, and time of the exceedance;
    - Air pollutant name, concentration measured, and the notification threshold; and
    - A link to the OEHHA Air Chemical database website to the specific air pollutant detected above the threshold, where applicable.
- An exceedance event has concluded. This is after an exceedance notification was generated for a given compound and that the concentration has been continuously detected at a level below the applicable notification threshold for a minimum of 30 min. This notification will contain the following information:
    - The corresponding unique identification number;
    - The maximum concentration of the air pollutant, detected during the period the notification threshold was exceeded, using the same averaging time as the notification threshold; and
    - The duration for which the notification threshold was exceeded; or, if the exceedance notification was sent in error, the follow-up notification will include an explanation as to the cause of the erroneous notification.

Notifications are sent as soon as technically feasible, up to 15 minutes after the exceedance or follow-up event occurs. The web-based notification program includes a mechanism for the public to (1) opt-in to receive notifications, (2) opt-out of fenceline notifications, (3) select separate email and/or text message notification options, and (4) provide comments or feedback to the Refinery, as well as a mechanism for the Refinery to respond to these comments. Notification thresholds are listed in Tables 5 and 6 and discussed in Section 2.5.4.

## 4.2 Reports, Audits, and Corrective Actions

### 4.2.1 Quarterly Reports

Quarterly reports are submitted to the South Coast AQMD Executive Officer and made available on the public website within 60 calendar days after the conclusion of each quarter. The reports include the following information:

- A summary of the air pollutant concentrations indicating the concentration trend for each air pollutant;
- Data processing calculations, such as conversion calculations of instrument signal to pollutant concentration;
- A summary of the calibration data;
- A description of data completeness, accuracy, and precision;
- QA/QC measures;
- Instrument maintenance and performance checks;
- Any instance when an air pollutant was measured above a notification threshold;
- Any instance when a fenceline air monitoring system downtime or malfunction required a notification to the South Coast AQMD Executive Officer or corrective action(s); and
- Review and resolution of any data quality flags, including finalization of the data.

### 4.2.2 Specific-Cause Analyses

When the concentration of one or more compounds is measured above an applicable notification threshold, an SCA will be initiated no later than 24 hr after discovery to determine the source(s) of the compound(s). Multiple threshold exceedances of one or more compounds within 7 calendar days attributable to the same cause will be addressed in a single SCA.

If the specific cause was determined to be from an on-site source, corrective action(s) will be initiated no later than 24 hr after determination to stop the exceedance or prevent a similar exceedance. An SCA report will be submitted to South Coast AQMD and made available on the public website within 14 calendar days of determination. If corrective action was required, a reinspection of the source will be conducted within 14 calendar days of completion and an updated SCA will be submitted to South Coast AQMD and made available on the public website within 28 calendar days of completion.

If the specific cause was determined to be from an off-site source, South Coast AQMD will be notified no later than 24 hr after determination with the basis of determination and the suspected off-site source. Specific-cause analyses will also be initiated within 24 hr of being notified by the South Coast AQMD Executive Officer that the refinery is the off-site source of an air pollutant measurement that exceeds the notification threshold.

If three SCA events occur for the same pollutant and fenceline monitor within a given calendar year and indicate either the same cause or that the cause cannot be determined, the refinery requires that a qualified independent party with relevant technical expertise in refinery operations or fenceline monitoring systems initiate an SCA within 14 calendar days of the most recent event. The qualified independent party will produce an SCA report, which will be submitted to South Coast AQMD and made available on the public website in accordance with Rule 1180. Corrective actions and CAPs will be completed as detailed in Section 4.2.4.

### 4.2.3 Independent Audits

In accordance with amended Rule 1180, an independent audit will be completed by January 1, 2029, and once every 36 calendar months thereafter. These audits will include a systematic review of the entire fenceline air monitoring network and ensure that the collected facility data meet the stringent QA criteria outlined in the QAPP.

Based on the results of a recent Request for Proposals, South Coast AQMD selected a qualified contractor to develop an auditing protocol and implement the first independent audit of all fenceline air monitoring systems subject to Rule 1180. South Coast AQMD anticipates that this initial audit will be completed by 2026 and, as part of this first independent audit, a protocol will be developed and used as the basis for future audits.

The independent audits will be performed by a qualified independent party and identify any deficiencies in the fenceline air monitoring system and quality assurance procedures. The audit reports will be signed by the qualified independent party, submitted to South Coast AQMD and made available to the public via the public website within 90 days after the audit has been performed.

If corrective actions (Section 4.2.4) are required following an independent audit, a follow-up independent audit will be completed within 3 calendar months of the completion of corrective actions. Follow-up audits will determine whether all corrective actions were completed and whether they successfully resolved the deficiencies identified in the independent audit. Follow-up audit reports will be signed by the qualified independent party, submitted to South Coast AQMD, and made available to the public via the public website within 90 days after the follow-up audit has been performed.

### 4.2.4 Corrective Action Plans

If the independent audit report identifies deficiencies in a fenceline monitoring system, a CAP will be developed within 3 calendar months of the audit report. The CAP will describe actions to address all deficiencies, as well as any proposed exemptions from corrective action that will negatively affect safety. The CAP will be submitted to the South Coast AQMD Executive Officer for review and made available on the public website within one business day of approval.

All corrective action(s) will be completed pursuant to the schedule in the approved CAP, and records indicating when the corrective action(s) have been completed will be kept.

### 4.2.5 Recordkeeping

Chevron El Segundo maintains records of all information required under Rule 1180 for at least five calendar years and will make that information available to South Coast AQMD upon request. Records for at least the two most recent calendar years are kept on site.

# Appendix A. FAMP Checklist

South Coast AQMD provided a checklist for key elements to be included in the FAMP as part of the Guidelines. This completed checklist (Table A-1), along with references to where in this document each element is addressed, is included below.

**Table A-1.** FAMP checklist provided by South Coast AQMD in the Guidelines and applicable section in this FAMP.

| Fenceline Air Monitoring Plan Checklist | | Applicable Section in the FAMP |
|---|---|---|
| **Fenceline Air Monitoring Coverage (or Spatial Coverage)** | | |
| ☒ | Identify the facility's proximity to sensitive receptors affected by the refinery operation and provide the information below. | Sections 2.2 and 2.3 |
| | • Distance from facility to closest sensitive receptor(s)<br>• Location of downwind and upwind communities<br>• Significant sources of non-refinery emissions surrounding the facility (e.g., non-refinery industrial facilities)<br>• Dispersion modeling† | |
| ☒ | Describe historical facility emission patterns and pollutant hotspots based on the following: | Section 2.3 and Appendix B |
| | • On-site location of operations and processes within the facility's perimeter<br>• On-site location of emissions sources and level of emissions<br>• Facility plot plans and topography<br>• Dispersion modeling† | |
| ☒ | Select sampling locations along the perimeter of the facility based on the information above. Also, provide the following: | Sections 1.2 and 2.4 |
| | • Locations where equipment is sited (e.g., GIS coordinates) and measurement pathways<br>• Elevations of equipment and pathways<br>• A description of how the monitoring system will provide adequate coverage, especially for all nearby downwind communities | |

| Fenceline Air Monitoring Plan Checklist | | Applicable Section in the FAMP |
|---|---|---|
| **Fenceline Air Monitoring Equipment Description** | | |
| ☒ | Select fenceline air monitoring equipment that is capable of continuously monitoring air pollutants in real-time and provide the following: | Section 2.5 and Appendix D (QAPP) |
| | • Specifications for the fenceline instruments (e.g., detection limits, time resolution)<br>• Explanation of the operation and maintenance requirements for selected equipment<br>• Justification to use alternative technologies | |
| ☒ | Monitor for the pollutants listed in Table 1 of Rule 1180 and include the following: | Sections 1.2 and 2.5 |
| | • Pollutant detection limits for all instruments and the defining factors, such as paths measured for open-path systems<br>• Justification of any exclusion of chemical compounds listed in Table 1 of Rule 1180 or measurement of a surrogate compound | |
| **Quality Assurance** | | |
| ☒ | Develop a QAPP that describes the following: | Sections 3 and 4, and Appendix D (QAPP) |
| | • Quality assurance procedures for data generated by the fenceline air monitoring system (e.g., procedures for assessment, verification, and validation of data)<br>• Standard operating procedures for all measurement equipment<br>• Routine equipment and data audits | |

| Fenceline Air Monitoring Plan Checklist | | Applicable Section in the FAMP |
|---|---|---|
| **Data Presentation to the Public** | | |
| ☒ | Design a data-display website that includes the following: | Sections 4.1 and 4.2 |
| | • Educational material that describes the objectives and capabilities of the fenceline air monitoring system<br>• A description of all pollutants measured and measurement techniques<br>• A description of background levels for all pollutants measured and provide context for the levels measured at the fenceline<br>• The most recently approved, or partially approved, FAMP and QAPP<br>• Definition of each data quality flag<br>• Reports generated from independent audit(s), including corrective action plan(s) or revised corrective action plan(s), if applicable<br>• Specific-cause analysis<br>• Hyperlinks to relevant sources of information<br>• A means for the public to provide comments and feedback; procedures to respond<br>• Real-time and at least 5 years of historic concentration data of all air pollutants measured on the fenceline air monitoring system, including data quality flags, quarterly reports, and audits<br>• Real-time and at least 5 years of historic wind speed and wind direction data<br>• Quarterly data summary reports, including relationship to notification thresholds, data completeness, instrument issues, and QC efforts | |

| Fenceline Air Monitoring Plan Checklist | | Applicable Section in the FAMP |
|---|---|---|
| **Notification System** | | |
| ☒ | Design a notification system for the public to voluntarily participate in that includes the following: | Section 4.1 |
| | • Notifications for activities that could affect the fenceline air monitoring system (e.g., planned maintenance activities or equipment downtime)<br>• Notifications for the availability of periodic reports that inform the community about air quality<br>• Notifications for exceedances of thresholds<br>• Communication methods for notifications, such as automated emails, text messages, and other approved communication methods | |

† The dispersion modeling will be conducted using U.S. EPA's Preferred and Recommended Air Quality Dispersion Model (e.g., the Health Risk Assessment).

# Appendix B. Quality Assurance Project Plan

The QAPP for the Chevron El Segundo fenceline monitoring system is included as Appendix B to this document.

# Quality Assurance Project Plan

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## Prepared for

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October 17, 2025
Revision 5

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This document contains blank pages to accommodate double-sided printing.

# Contents

# Figures

# Tables

# Review and Revision History

| Revision Number | Date | Responsible Party | Description of Change |
|---|---|---|---|
| 0 | November 28, 2018 | Chevron | Issue to South Coast AQMD for review, Initial Draft, SOPs not included |
| 1 | October 1, 2019 | Chevron | Issue to South Coast AQMD for review, SOPs included |
| 2 | October 13, 2020 | Chevron | Issue to South Coast AQMD for review, Revised Draft to address comments and updated guidance provided by South Coast AQMD |
| 3 | May 25, 2021 | Chevron | Issue to South Coast AQMD for review, Revised Draft to address comments from South Coast AQMD |
| 4 | August 5, 2024 | Chevron | Changes to address amendments to Rule 1180 passed on January 5, 2024 |
| 5 | October 17, 2025 | Chevron | Updated in response to comments received by South Coast AQMD |

This QAPP is a living document that undergoes annual review and will be revised and updated as necessary when the system is modified. The official version of this QAPP is maintained by Chevron in El Segundo. This QAPP contains all critical documents used by this program, including standard operating procedures (SOPs) and blank data entry forms.

# Definitions, Acronyms, Units, and Abbreviations

| Term | Definition |
|---|---|
| $\mu g/m^3$ | micrograms per cubic meter |
| BC | black carbon |
| BTEX | benzene, toluene, ethylbenzene, and (o-, m-, p-) xylenes |
| Bump Test | Test for accuracy and precision using a certified concentration of analyte |
| Chevron | Chevron Products Company, El Segundo Refinery |
| cm | centimeter |
| $cm^{-1}$ | inverse centimeters (wavenumber) |
| CV | coefficient of variation |
| DAS | data acquisition system |
| DMS | data management system |
| DQI | data quality indicators |
| DQO | data quality objectives |
| EPA | U.S. Environmental Protection Agency |
| FTIR | Fourier transform infrared (open-path instrument) |
| $H_2S$ | hydrogen sulfide |
| IR | infrared |
| m/s | meters per second |
| MDL | minimum detection limit |
| MQO | measurement quality objectives |
| ms | milliseconds |
| NA | Not available |
| NAAQS | National Ambient Air Quality Standards |
| ND | Neutral density |
| $ng/m^3$ | nanograms per cubic meter |
| NIST | National Institute of Standards and Technology |
| nm | nanometer |
| OP | operational codes |

| Term | Definition |
|---|---|
| PM | project manager |
| $PM_{10}$ | Particulate matter mass less than 10 micrometers in diameter |
| $PM_{2.5}$ | Particulate matter mass less than 2.5 micrometers in diameter |
| ppb | parts per billion |
| ppm | parts per million |
| ppm-m | parts per million per meter |
| QA | quality assurance |
| QAPP | quality assurance project plan |
| QC | quality control |
| $R^2$ | coefficient of determination |
| Real-time data | Data delivered within 10 minutes of collection |
| Refinery | Facility that refines crude oil into products |
| REL | Reference Exposure Level |
| RH | relative humidity |
| RPU | remote processing unit |
| SOP | standard operating procedure |
| South Coast AQMD | South Coast Air Quality Management District |
| TBD | to be determined |
| Total VOCs | C2 – C5 straight chain alkanes |
| UDL | upper detection limit |
| UV | ultraviolet |
| UV-DOAS | ultraviolet differential optical absorption spectroscopy (open-path instrument) |
| VICI | Valco Instruments Co., Inc. |
| VOCs | volatile organic compounds |
| XRF | X-ray fluorescence |

# 1. Project Background and Management

## 1.1 Background

### 1.1.1 Purpose

Chevron Corporation conducts air quality monitoring at its El Segundo, California, refinery in compliance with the South Coast Air Quality Management District's (South Coast AQMD) Rule 1180.[1] The monitoring program follows a facility-specific air monitoring plan consistent with the South Coast AQMD's Refinery Fenceline Air Monitoring Plan Guidelines.[2] Rule 1180 requires routine monitoring for specific air compounds near the fencelines of all South Coast refineries, and that the collected data are reported to the public.[3] These systems are intended to measure air pollutant concentrations and provide the public with real-time information about air quality near refineries.

### 1.1.2 Rationale

Rule 1180 requires fenceline monitoring of stated target compounds to "provide air quality information to the public about levels of various criteria air pollutants, volatile organic compounds, particulate matter, and other compounds, at or near the property boundaries of petroleum refineries and in nearby communities."[1] In accordance with its monitoring plan, Chevron conducts open-path and point pollutant monitoring and collects meteorological measurements to meet the rule's requirements.

This quality assurance project plan (QAPP) describes the quality assurance (QA) processes associated with operations, maintenance, and data management of the fenceline monitoring system, and identifies key project team members and associated responsibilities. This document is reviewed annually and updated as needed.

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[1] Rule 1180: Fenceline and Community Air Monitoring for Petroleum Refineries and Related Facilities (South Coast AQMD). Adopted December 1, 2017, and amended January 5, 2024.

[2] Rule 1180 and Rule 1180.1 Fenceline Air Monitoring Plan Guidelines (South Coast AQMD). January 2024.

[3] Fenceline monitoring began on January 1, 2020.

## 1.2 Roles and Responsibilities

This project involves refinery staff; contractors; and QA, field, and website personnel. **Figure 1** shows an organization chart for the project.

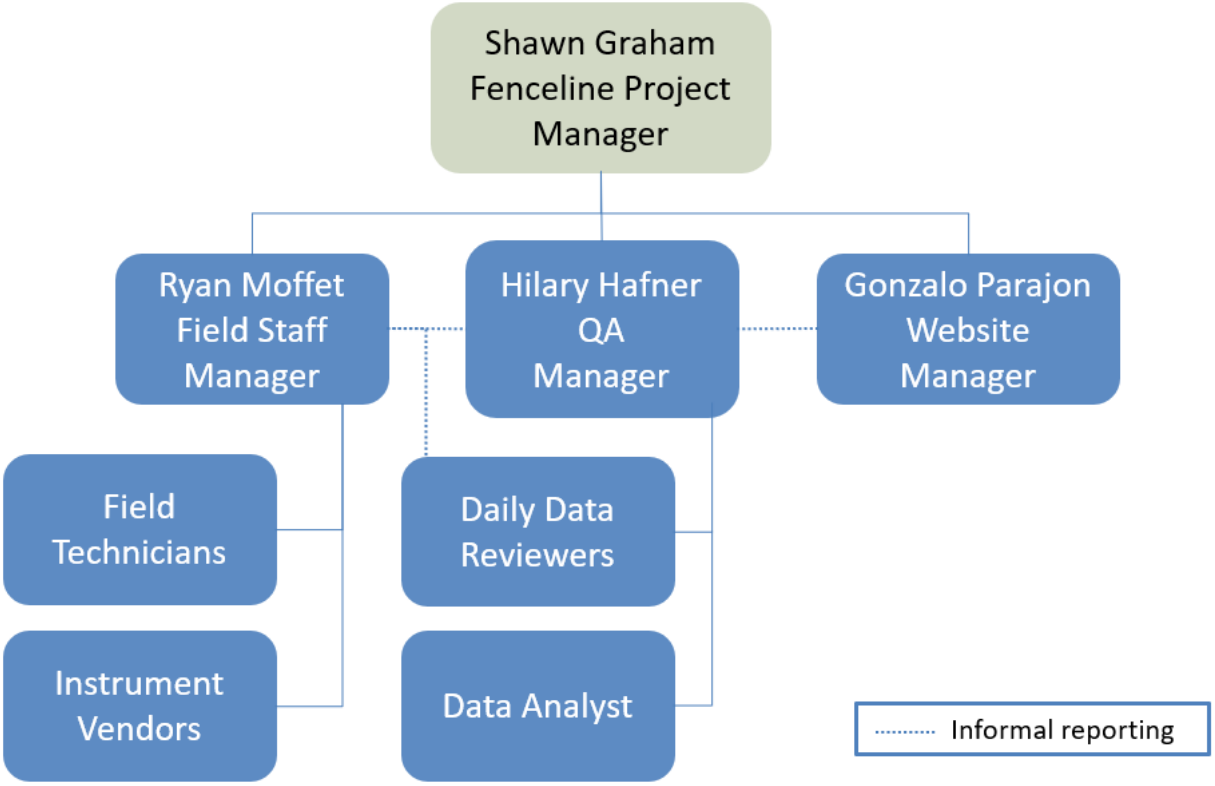

**Figure 1.** Organizational chart for the Chevron El Segundo refinery monitoring project.

The overall project is run by a **Fenceline Project Manager** appointed by the refinery. This project manager (PM) acts as the central point of contact for the South Coast AQMD and the QA Manager, Field Staff Manager, and Website Manager. The PM is responsible for overseeing the project and reporting directly to the South Coast AQMD. If a change to the monitoring system (i.e., method change, site/monitor shutdown, installation, replacement, etc.) is warranted for safety, construction, or technological change reasons, the Fenceline Project Manager is responsible for initiating these changes. The Fenceline Project Manager communicates these system changes to the South Coast AQMD by revising the Air Monitoring Plan and the QAPP.

The **QA Manager** is responsible for ensuring data collected under this project is of sufficient quality to be scientifically defensible and satisfies its intended use. The QA Manager oversees data collection and review, provides QA oversight, and oversees and reports on QA activities to the Fenceline Project Manager and South Coast AQMD QA Officer. The QA Manager oversees daily data review and data management, works with the Field Staff Manager to ensure that any data issues are addressed promptly by the field technicians, and works with the Website Manager to ensure that data provided to the public are accurate and satisfy data quality objectives (DQOs). The QA Manager works with the Field Staff Manager to oversee training of both Field Technicians and Data Reviewers. The QA Manager is primarily responsible for developing the QAPP (including document updates and future revisions, as the QAPP is a living document).

The **Field Staff Manager** ensures that Field Technicians (site operators) are meeting the requirements of the project as outlined in this QAPP. The Field Staff Manager coordinates staff coverage and serves as a technical resource for site measurements. For example, the Field Technicians, under direction from the Field Staff Manager, perform maintenance according to the schedules and SOPs included in this QAPP. The Field Staff Manager ensures that all maintenance and service calls are appropriately documented, sufficient supplies and consumables are available to the field staff, and the Field Technicians have the necessary training and documentation required to carry out this work. The Field Staff Manager, with input and support from the Field Technicians, is responsible for coordinating SOP revisions with the QA Manager and Fenceline Project Manager.

The **Website Manager** is responsible for ensuring the real-time data is properly displayed on the website and available per Rule 1180 requirements and managing inquiries from the public. Automated alerts notify the Website Manager when the real-time data are not available on the website. The Website Manager is responsible for assessing and fixing data communication and other information technology-related issues concerning the website and data system.

**Field Technicians/Site Operators** perform instrument maintenance. The technicians ensure that all measurements are collected in accordance with the SOPs, standard methods, and regulations, where applicable. Technicians perform the required performance audits and quality checks on instruments and document all work in site logs.

The **Instrument Vendors** provide related technical support for the instruments deployed in the field.

Daily data review and data validation are conducted by experienced air quality analysts. The **Data Reviewers** communicate with the QA Manager, Field Staff Manager, and Field Technicians when they notice an issue that needs to be addressed.

The **Data Analyst** is responsible for ensuring that data that fail the auto-screening process are inspected, and that data validation follows the proper schedule and procedures. The Data Analyst is also responsible for delivering the validated data to the PM and developing and approving the quarterly reports. Quarterly reports are equivalent to a data quality assessment as defined in the U.S. Environmental Protection Agency's (EPA) Guidance for Quality Assurance Project Plans.[4]

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[4] U.S. Environmental Protection Agency (2002) EPA guidance for quality assurance project plans, EPA QA/G-5. Report by the Office of Environmental Information, Washington, DC, EPA/240/R-02/009, December. Available at www.epa.gov/quality/guidance-quality-assurance-project-plans-epa-qag-5.

# 2. Measurements

## 2.1 Instrument Selection and Descriptions

The required list of compounds to be measured by the fenceline monitoring system is presented in **Table 1**. These compounds are measured at a 5-min resolution, except for (1) metals, which will be measured on a 30-min basis, and (2) particulate matter, which will be measured on an hourly basis. Chemical species are measured using open-path optical analyzers, and point monitors are used where open-path monitoring is not feasible. Because of the distances that need to be covered by measurements (hundreds of meters), the data time-resolution requirements (5 minutes), and the current state of measurement technology, open-path instruments (Ultra Violet-Differential Optical Absorption Spectroscopy [UV-DOAS] and Fourier Transform Infrared spectroscopy [FTIR] instruments) were selected for measuring all compounds, except for black carbon (BC), hydrogen sulfide ($H_2S$), particulate matter, and metals.

**Table 1.** Pollutants listed in Table 1 of Rule 1180 that are measured by the Chevron El Segundo Fenceline Monitoring System.

| **Air Pollutants** |
|---|
| **Criteria Air Pollutants** |
| Nitrogen Oxides |
| Particulate matter mass less than 2.5 micrometers in diameter ($PM_{2.5}$) |
| Particulate matter mass less than 10 micrometers in diameter ($PM_{10}$) |
| Sulfur Dioxide ($SO_2$) |
| **Volatile Organic Compounds (VOCs)** |
| Total VOCs (C2 – C5 linear alkanes) |
| Formaldehyde |
| Acetaldehyde |
| Acrolein |
| 1,3-Butadiene |
| Naphthalene |
| Styrene |
| BTEX Compounds (Benzene, Toluene, Ethylbenzene, Xylenes) |
| **Metals** |
| Cadmium |
| Manganese |
| Nickel |
| **Other Compounds** |
| Hydrogen Sulfide ($H_2S$) |
| Carbonyl Sulfide |
| Ammonia ($NH_3$) |
| Black Carbon (BC) |
| Hydrogen Cyanide |

Along all measurement paths (see Section 2.2), benzene, toluene, ethylbenzene, xylenes (BTEX), naphthalene, and $SO_2$ are measured by a **CEREX ultraviolet Sentry monostatic UV-DOAS** instrument with a xenon light source. The xenon light is required to collect measurements over paths that are about 200 to 600 meters long and to achieve the necessary minimum detection limits (MDL) for BTEX. The UV-DOAS operates in the monostatic configuration using silvered quartz corner-cube retroreflectors. The analyzer records the intensity of light at discrete wavelengths. Any UV-absorbing gas that is present in the beam absorbs at a specific wavelength of light. Each species of gas has a unique absorbance fingerprint (i.e., absorbance at several different wavelengths are unique to that gas). The analyzer compares regions within the sample absorbance spectra to the same regions within the reference absorbance spectra. The analyzer uses a classical Least Squares Regression analysis to compare the measured absorption spectrum to a standardized reference spectrum. Beer's Law is used to convert absorbance to gas concentrations. The approach is analogous to that used in the EPA TO-16 document.[5] Closeness of fit is indicated by the coefficient of determination ($R^2$), a measure of agreement between the measured spectra and the reference spectra. The $R^2$ is provided with each concentration so that interference can be detected if it is present. Selection of regions of analysis that are free of absorbance from other gases within the sample is the primary means of avoiding cross-interference. Spectral subtraction is used in cases with overlapping absorbance features; the subtraction technique is proprietary to the instrument manufacturer.

Total VOCs, formaldehyde, acetaldehyde, acrolein, styrene, carbonyl sulfide, hydrogen cyanide, $NH_3$, and 1,3-Butadiene are measured with a **CEREX AirSentry FTIR** instrument. The FTIR operates by sending a beam of infrared light through the open air. The IR beam is reflected back to the analyzer by a retro-reflector array (monostatic configuration using thin gold film coated corner-cube retroreflectors), where the absorption due to the target gases is measured and recorded. Like the UVDOAS, the FTIR uses a classical Least Squares Regression analysis to compare the measured absorption spectrum to calibrated reference absorption spectra consistent with EPA's TO-16 methodology. Beer's Law is used to convert absorbance to gas concentration. The FTIR operates on the same principal as the UV-DOAS through the use of reference spectra. There are a variety of standard and/or proprietary methods to minimize interference from water vapor and other interfering gases, including spectral subtraction and selecting isolated absorbance peaks for the gases of interest.

Any fog impacting the monitoring sites can absorb the signals from an open-path instrument and interfere with measurements, and heavy fog may entirely block signals and impact valid data collection. Given the coastal location of the refinery, marine fog events are expected during the nighttime and early morning hours. Visibility measurements are collected using Campbell Scientific CS120A visibility sensors at two representative locations along the fenceline to provide operational verification of invalid open-path data resulting from low atmospheric visibility conditions.

$H_2S$ is measured by **Galvanic Applied Sciences ProTech 903W $H_2S$ analyzer** instruments. The 903W operates by collecting $H_2S$ on a lead acetate tape, and measures concentrations by sensing a color change as $H_2S$ reacts with the tape.

BC is measured using **Magee Scientific AE33 Aethalometers**. The Aethalometer monitors BC concentrations by measuring the increased darkness on a filter tape caused by BC particulates.

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[5] Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. Compendium Method TO-16. Long-Path Open-Path Fourier Transform Infrared Monitoring Of Atmospheric Gases (1999) EPA/625/R-96/010b.

Particulate matter with a mass of less than 10 µm ($PM_{10}$) and 2.5 µm ($PM_{2.5}$) will be measured using a Teledyne T640X instrument. The T640X derives particulate mass concentrations by measuring the scattered light from particles as they pass through a light beam.

Lastly, metals will be measured using **Cooper Environmental Xact** instruments. The Xact operates by first depositing the particulate matter on Teflon tape, and then subsequently analyzing the deposit using X-ray fluorescence (XRF).

Table 2 summarizes the estimated range of the MDL and upper detection limits (UDL) for each species measured by open-path instruments. The MDL is the lowest path-average concentration that can be measured at the path length, and the UDL is the highest path-average concentration that can be measured at the path length. Detection limits are approximate and are based on the theoretical capabilities of the instruments; however, they are supported by their manufacturers' lab tests and real-world applications. Actual detection limits depend on atmospheric conditions and on the specific instruments used. The detection limits are reported as average concentrations along a path; narrow plumes that cover only a portion of the path would only be detected at a concentration higher than the MDL.

The 903W instrument's MDL for $H_2S$ is listed as 5 parts per billion (ppb) by the manufacturer. The Magee Scientific Aethalometer's MDL for BC is less than 0.5 µg/m$^3$. For 30-min sampling times, the Xact instruments' MDL is 0.58 ng/m$^3$ for chromium, 0.71 ng/m$^3$ for manganese, and 0.47 ng/m$^3$ for nickel. The Teledyne PM monitor has a MDL of less than 0.1 µg/m$^3$ for both $PM_{2.5}$ and $PM_{10}$.

**Table 2.** Range of approximate open-path instrument minimum detection limits (MDL) and upper detection limits (UDL) in parts per billion (ppb) by technology, species, and path length. Actual detection limits depend on atmospheric conditions.

| | 1180 Compound | Shortest Path (200 m) | | Longest Path (579 m) | |
|---|---|---|---|---|---|
| | | MDL | UDL | MDL | UDL |
| FTIR | 1,3-Butadiene | 10 | 24,000 | 4 | 8,300 |
| | Acetaldehyde | 15 | 500,000 | 5 | 170,000 |
| | Acrolein | 38 | 230,000 | 13 | 78,000 |
| | Ammonia ($NH_3$) | 8 | 140,000 | 3 | 48,000 |
| | Carbonyl Sulfide | 22 | NA | 8 | NA |
| | Formaldehyde | 10 | 63,000 | 4 | 22,000 |
| | Total VOCs | 8 | 15,000 | 3 | 5,000 |
| | Hydrogen Cyanide | 25 | 50,000 | 9 | 17,000 |
| | Styrene | 20 | 29,000 | 7 | 10,000 |
| UV-DOAS | Benzene | 0.7 | 80,000 | 0.2 | 27,000 |
| | Ethylbenzene | 0.8 | 7,000 | 0.3 | 2,500 |
| | Naphthalene | 0.5 | 400 | 0.2 | 150 |
| | Nitrogen Dioxide | 8 | 11,000 | 3 | 4,000 |
| | Sulfur Dioxide ($SO_2$) | 2 | 5,000 | 0.6 | 2,000 |
| | Toluene | 1 | 7,000 | 0.7 | 2,500 |
| | o-Xylene | 9 | 6,000 | 3 | 2,000 |
| | m-Xylene | 0.9 | 5,000 | 0.3 | 2,000 |
| | p-Xylene | 0.6 | 2,600 | 0.2 | 1,000 |

## 2.2 Monitor Siting Overview

A map of the fenceline monitoring system is shown in **Figure 2** and indicates the type of measurements collected at each location. The open-path monitoring sites are indicated by the “A” and “R” circles, and their pathways are indicated by the orange lines connecting the sites. Transmitter-detectors/analyzers are located within permanent shelters at the sites labeled “A”, and retroreflectors are placed at the sites labeled “R”.

The 903W instruments (which monitor $H_2S$) and Magee Scientific Aethalometers (which monitor BC) are located in separate cabinets at six locations near the open-path monitoring sites. The T640X instruments (which monitor $PM_{10}$ and $PM_{2.5}$) will be added to all cabinets containing the 903W and Aethalometer instruments. Metals will be measured at point monitor sites P1, P2, P3, and P4.5; the Xact instruments will be placed in their own cabinets separate from the other instruments.

Two meteorological stations at the west and east ends of the refinery include visibility sensors, as well as wind, temperature, and relative humidity sensors. Chevron selected these locations after considering the dominant wind patterns for the area, sources of potential air emissions on the refinery property, and nearby local receptors.

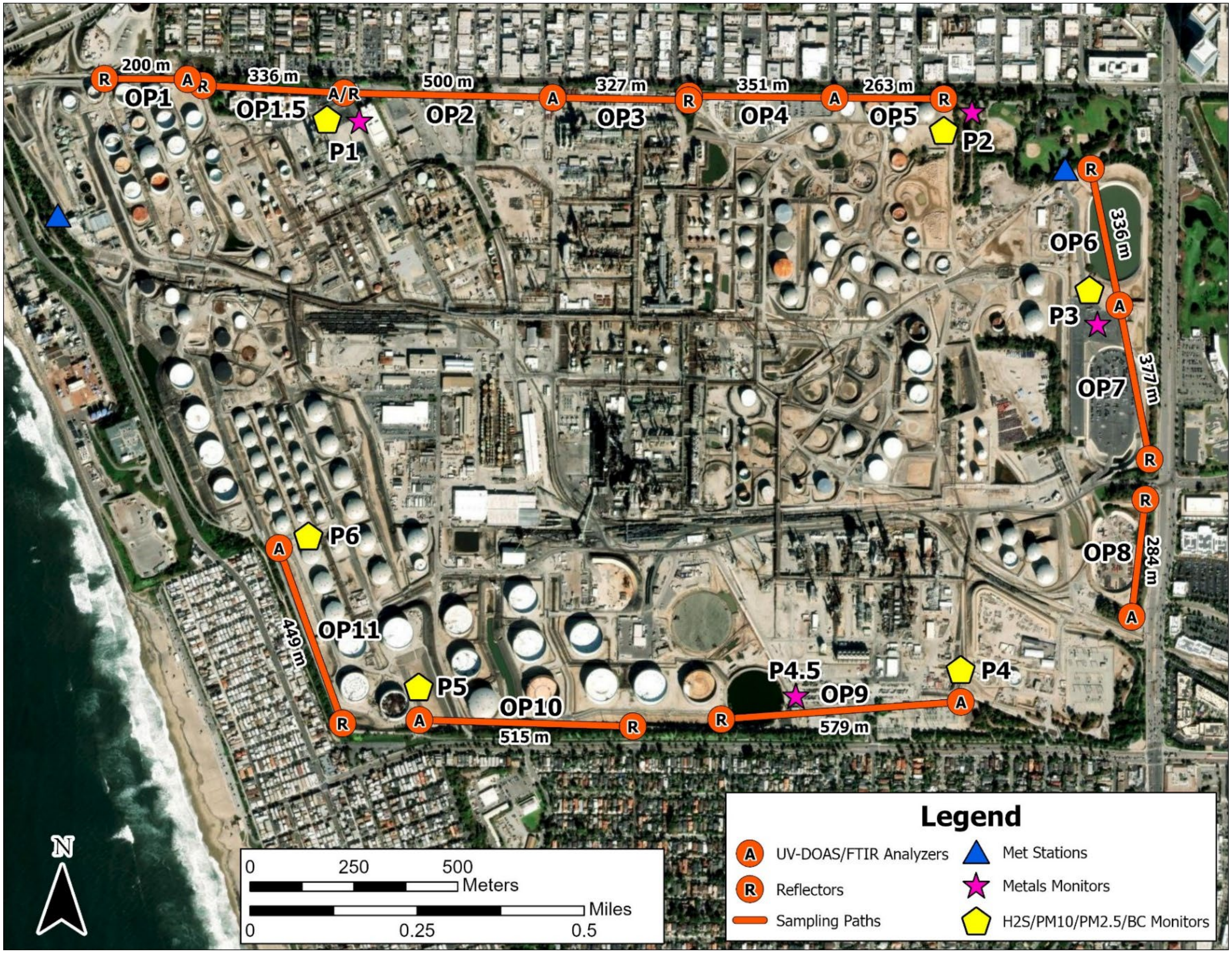

Figure 2. Location of sensors and measurement paths. Each path consists of a transmitter-detector (A) and a retroreflector (R)

## 2.3 Instrument Operations and Maintenance

Seven instrument systems are included in this project: UV-DOAS, FTIR, 903W, Aethalometer, T640X, Xact, and the combination of meteorological instruments that include visibility sensors. This project has built QA processes into the operation and maintenance work to ensure that data collected under this project is of sufficient quality to be scientifically defensible, is collected with high temporal completeness, and satisfies its intended use. **Section 4** of this document describes the data management, quality control, and verification processes for this project.

This section describes maintenance actions that are designed to ensure high-quality data are collected. For example, as part of the maintenance visits, technicians will verify instrument response by performing bump tests. Equipment is not placed into service until it meets all measurement criteria. Missing data are minimized by following the preventative maintenance schedules described in this section.

Spare parts are maintained for all analyzers; examples of these spare parts include bulbs, cryocoolers, and filters. Scheduled maintenance occurs for all instruments on respective monthly, quarterly, and/or annual bases. Emergency maintenance will occur as needed when problems are identified during daily data review and auto-screening of real-time data. For extensive outages, alternative methods of data collection are considered, including installing replacement analyzers or using alternative sampling methods (e.g., summa cans) to cover periods when instruments are not in service.

New analyzers purchased for the fenceline monitoring system are put through a site acceptance test (SAT) before data go live to the public. A detailed SAT procedure was created for the implementation phase of the fenceline monitoring system and has been maintained by the refinery. The procedure includes an initial gas test (or similar performance test) of each analyzer to ensure adequate analyzer response, as well as checks on the flow and optical response. Finally, the SAT procedure verifies that the data from the analyzer are being properly logged by the DAS, ingested into the data management system (DMS), and displayed correctly on the public website.

If a spare or new analyzer does not meet the specifications outlined in the SAT documentation, the analyzer will not be commissioned on site. The issues will be documented and the field staff will work with the manufacturer until the issue has been resolved and the SAT acceptance criteria are met.

To gauge the precision and accuracy of the UV-DOAS and FTIR open-path systems, bump tests are performed monthly using flow-through cells. These bump tests are used to verify that each system can reliably detect concentrations near the level of concern. Traceable gases that meet the National Institute of Standards and Technology's standards are passed through these cells continuously. Concentrations of these gases are selected such that they are well above the level of quantitation (LOQ = 5xMDL), but near or below the alert thresholds for the selected species. The exhaust of the cell is scrubbed with activated carbon that is appropriate to the gas being used. For both systems, during a normal measurement (and also during bump testing), the light beam passes from the source, through the cell, and across the entire atmospheric path length to the retroreflector. After bouncing off the retroreflector, the light beam again passes through the atmosphere and cell to reach the detector. Since the light beam travels through the ambient atmosphere that includes other gases and particles (as it would during a normal measurement), these bump tests are realistic assessments of the instrument capabilities. Effective path-average concentrations for benzene and ammonia during bump tests are targeted to be about 1 to 20 ppb. The quantitative DQOs are evaluated by calculating the coefficient of variation (CV, precision) and percent accuracy during the bump tests, as shown in **Equation 4** in Section 3.2.1.

As part of normal operations, temperature control and ventilation systems must be maintained to ensure optimal performance. The instrument enclosures for UV-DOAS and FTIR instruments include temperature control systems. The shelter housing the UV-DOAS and FTIR is ventilated and is not required to be temperature controlled. The retroreflector housings have a heater fan system designed to reduce the impact from condensation and particulates on the surface of the retroreflectors.

### 2.3.1 UV-DOAS

The UV-DOAS system is designed to require only modest service and maintenance. **Table 3** summarizes typical UV-DOAS maintenance activities as recommended by the manufacturer, and additional information is provided in the instrument SOP (**Attachment 1**). These actions help ensure data integrity and maximize uptime. **Table 13** (see Section 3.2.2) lists the performance criteria related to the maintenance activities.

**Table 3.** Schedule of maintenance activities for the CEREX UV Sentry UV-DOAS.

| Activity | Monthly | Quarterly | Annually |
|---|---|---|---|
| Visually inspect the system. | ✓ | | |
| Inspect optics on detector and retro-reflector; clean if necessary. | ✓ | | |
| Inspect system filters. | ✓ | | |
| Confirm the alignment to verify there has not been significant physical movement. Note: this is automatically monitored as well. | ✓ | | |
| Download data from detector hard drive and delete old files to free space, if needed. Ensure data are backed up on external drive. | ✓ | | |
| Ensure there are no obstructions between the detector and the retro-reflector (such as equipment, vegetation, vehicles). | ✓ | | |
| Change out the UV source. | | ✓ | |
| Replace ventilation exit and intake filters. | | ✓ | |
| Realign system after service. | ✓ | | |
| Check system performance indicators. | ✓ | | |
| 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. | | | ✓ |

### 2.3.2 FTIR

The CEREX AirSentry FTIR system is also designed to require only modest service and maintenance, and the maintenance activities required are similar to those for the UV-DOAS system. Table 4 summarizes these maintenance activities, as recommended by the manufacturer, and additional information is provided in the instrument SOP (Attachment 2). The frequency of the preventative maintenance depends on the operating environment and may need to be adjusted. On an as-needed basis, system status alarms may alert operators to specific issues that need to be addressed. Bump tests are performed on site.

**Table 4.** Schedule of maintenance activities for the CEREX AirSentry FTIR.

| Activity | Monthly | Quarterly | Semi-Annually | Annually | Two Years | Three Years |
|---|---|---|---|---|---|---|
| Visually inspect the system. | ✓ | | | | | |
| Inspect and clean AC system exterior heat sink. | | | ✓ | | | |
| Inspect the optics on the analyzer and retroreflector; clean if necessary. | | | | ✓ | | |
| Confirm the alignment to verify there has been no significant physical movement.[a] | ✓ | | | | | |
| Ensure data are backed up on external drive. Download data from detector hard drive and delete old files to free space, if needed. | ✓ | | | | | |
| Ensure there are no obstructions between the detector and the retro-reflector (such as equipment, vegetation, vehicles). | ✓ | | | | | |
| Change out the IR source. | | | | | | ✓ |
| Realign system after service. | ✓ | | | | | |
| Check system performance indicators. | ✓ | | | | | |
| Perform bump test. | ✓ | | | | | |
| Review and test light and signal levels. Check average light intensity to establish baseline for IR Source change frequency and retro-reflector wear. | | | | ✓ | | |
| Verify system software settings. | | ✓ | | | | |
| Replace air conditioner fans. | | | | | ✓ | |
| Replace cryocooler. | | | | | ✓ | |

[a] This is monitored both manually and automatically.

### 2.3.3 $H_2S$ Analyzer

**Table 5** describes maintenance actions for the Galvanic ProTech 903W $H_2S$ analyzer, including cleaning, inspections, and gas testing, and additional information is provided in the instrument SOP (**Attachment 4**). On an as-needed basis, system status alarms may alert operators to specific issues that need to be addressed.

Compressed gas cylinders are used for the calibration of the 903W instrument. Bump checks are performed using $H_2S$ concentrations between 30 and 100 ppb. Zero gas is prepared by running ambient air through an $H_2S$ gas scrubber.

The $H_2S$ monitors are located with the Aethalometer and particulate matter mass analyzers at each site in a cabinet that is separate from the open-path instrument shelter. Temperature stability for this point-monitor shelter is achieved using an air conditioner and heater. Bump tests and calibrations are to be performed with the shelter door closed to ensure the enclosed equipment is at optimal stability.

**Table 5.** Schedule of maintenance activities for Galvanic Applied Sciences ProTech 903W $H_2S$ instrument.

| Activity | Daily | Monthly | Quarterly | Semiannually |
|---|---|---|---|---|
| Check data validity | ✓ | | | |
| Inspect sample line tubing | | ✓ | | |
| Visually inspect the tape | | ✓ | | |
| Install new filter tape roll* | | ✓ | | |
| Add 5% acetic acid to the humidifier | | ✓ | | |
| Inspect the sample chamber | | ✓ | | |
| Replace inlet filter | | ✓ | | |
| Check and empty water trap | | ✓ | | |
| Perform Bump Test | | ✓ | | |
| Calibrate system | | | | ✓ |
| Inspect and clean the sampling system | | | ✓ | |

* The used lead acetate tape shall be disposed of as hazardous waste in accordance with manufacturer's recommendations and local regulations.

## 2.3.4 Aethalometer

Table 6 summarizes typical maintenance activities for the Magee Scientific AE33 Aethalometers, as recommended by the manufacturer. The frequency of the preventive maintenance depends on the operating environment and may need to be adjusted beyond the manufacturers' recommendations based on actual performance and environmental conditions. On an as-needed basis, system status alarms may alert operators to specific issues that need to be addressed.

To ensure the integrity of the sampling system, the Aethalometer is subjected to both a leak check and a flow rate check once per month. Flow rate checks are carried out using a NIST-traceable flow meter with a valid calibration. Acceptance criteria (see Table 13 in Section 3.2.2) for a flow rate check is ±10%; if the sample flow is outside of this range, a flow calibration is performed. To test the optical system, a series of neutral density filters are inserted into the sample block of the instrument; the instrument must reproduce these known values, within 10%.

Additional performance checks recommended by the manufacturer are performed as listed in Table 6 and in the AE33 Aethalometer SOP (Attachment 3). The Aethalometer is located together with the $H_2S$ and particulate matter mass analyzers at each site in a cabinet that is separate from the open-path instrument shelter. Temperature stability for this point-monitor shelter is achieved using an air conditioner and heater.

**Table 6.** 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 | ✓ | | |
| Inspect optical chamber and clean as necessary | | ✓ | |
| Calibrate flow | ✓ | | |
| Change bypass cartridge filter | | | ✓ |
| Install new tape roll | ✓ | | |
| Calibrate tape sensor | | ✓ | |
| Clean air test | | ✓ | |
| Stability test | | ✓ | |
| Neutral density filter test | | | ✓ |
| Grease optical chamber sliders | | | ✓ |
| Inlet leakage test | | | ✓ |

### 2.3.5 Particulate Matter

Table 7 describes maintenance actions for the Teledyne T640X particulate mass monitor, including cleaning, inspections, adjustments, and calibrations. These maintenance actions are described in in Teledyne T640X SOP (Attachment 6).

Quality control processes for the Teledyne T640X monitor includes flow checks for the pneumatic system and a SpanDust™ check for the optical system. The monthly flow check consists of three separate flow checks using a NIST-traceable flow meter; all three checks have an acceptance criteria of ±5%. The process for adjusting the optical system's photomultiplier tube (PMT) uses SpanDust™, a dust with a specific refractive index and a known optical response. All T640X PMT detectors have a very specific response to this span dust, which allows for the sensor to be checked and adjusted in the field to account for drift caused by contamination of the optics.

Table 7. 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) | ✓ | | |
| Leak check | ✓ | | |
| Inspect and clean optical chamber and RH/T sensor | | ✓ | |
| Change disposable filter for 5-LPM flow and bypass flow (if installed) | | | ✓ |
| Inspect inner and outer sample tubes | ✓ | | |

### 2.3.6 Metals

Table 8 describes the maintenance actions for the Cooper Environmental Xact particulate metals monitor. The Xact instrument automatically measures test material on a daily basis to track instrument performance, which is referred to as an "upscale" measurement. These upscale checks are automatically performed using a rod of constant composition, which is irradiated with X-rays from the X-ray source. Upon irradiation, this rod emits characteristic fluorescent X-rays, which are measured by the detector. These upscale readings will be evaluated monthly for any abrupt changes in response. Leak checks and a flow rate check using a NIST-traceable flow meter are also performed monthly. On a quarterly basis, NIST-traceable thin film with a known concentration of particulate metals are analyzed to check the element-specific calibrations. On an annual basis, a blank check and flow calibration are performed. These maintenance actions are described in the Xact SOP (Attachment 7).

**Table 8.** Schedule of maintenance activities for the Cooper Xact.

| Activity | Monthly | Quarterly | Annual |
|---|---|---|---|
| QA upscale measurements | ✓ | | |
| Tape change | ✓ | | |
| Leak check | | ✓ | |
| Flow check | | ✓ | |
| XRF calibration check | | ✓ | |
| Flow calibration | | | ✓ |
| Blank check | | | ✓ |
| General cleanup; examine tubing, enclosure, and components for particle build-up, rust or damage; replace parts as needed | | | ✓ |
| Xact recalibration | | | ✓ |

### 2.3.7 Visibility and Other Meteorological Sensors

**Table 9** lists the maintenance activities that are performed during each quarterly site visit to ensure that all visibility and meteorological instruments are performing correctly, and additional information is provided in the instrument SOPs (**Attachments 5 and 8**). The visibility sensors are checked and cleaned monthly. The quantitative response of the sensors is audited by field technicians semiannually. The meteorological instrumentation calibrations are conducted with reference to the recommendations in the EPA's *Quality Assurance Handbook for Air Pollution Measurement Systems (QA Handbook), Volumes I, II, and IV.*[6,7,8]

As part of the calibration process, each instrument is first tested to determine whether it is operating within the prescribed operational limits (see Table 11 in Section 3.2.2) 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, the instrument may be repaired, calibrated, or replaced. A standard form is used to document the performance of each sensor before and after any adjustments or instrument replacement.

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[6] 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.

[7] 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.

[8] 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.

## Wind Speed

An anemometer drive is used to simulate known wind speeds. The propeller torque disc is used to determine the anemometer's starting threshold. The sensor's starting threshold is a shaft-bearing efficiency measurement.

The wind speed propeller and tail assembly are visually inspected to ensure that they are not cracked or damaged. The propeller is removed and the sensor shaft is immobilized to simulate zero wind speed. The anemometer drive is connected to the sensor shaft to simulate wind speeds between 0 and 44.1 m/s. The wind speed is determined from wind speed coefficients provided by the manufacturer. The remote processing unit (RPU) responses are then compared to the calculated values.

## Wind Direction

A vane angle fixture is used to set the weather vane to known directions at 45-degree intervals, moving clockwise and then counterclockwise through the full 360-degree range of the monitor. A pocket transit mounted on a tripod is used in conjunction with a vane alignment rod to determine the orientation of the wind monitor on the tower mast. A vane torque gauge is used to determine the vane's starting threshold.

## Ambient Temperature

The ambient temperature sensor is tested by comparing the current ambient temperature measured by an NIST-traceable digital thermometer to the temperature reading from the RPU. The digital thermometer is placed near the temperature probe in a shaded location. Both sensors are allowed to reach equilibration before the responses of the respective sensors are recorded.

## Relative Humidity

The relative humidity (RH) sensor is tested by comparing the current RH measured by an NIST-traceable psychrometer to the RH reading from the RPU. The psychrometer is placed near the RH probe in a shaded location. Both sensors are allowed to reach equilibrium before their responses are recorded.

## Visibility Sensors

An appropriate manufacturer-specific calibration kit is used to test the visibility sensors. Generally, a calibration kit consists of a blocking plate or block for checking the sensor zero, and a scatter plate for checking the sensor span. The calibration fixture is assigned a factory-traceable extinction coefficient used to calculate the expected values during calibrations.

**Table 9.** Routine maintenance checklist for the meteorological sensor sites.

| 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 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/ 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. Clean the glass windows on a monthly basis. |
| | Check that the cable connections are secure. |
| | Inspect the hardware holding the sensors to the tower and tighten the bolts if necessary. |
| Data Logger Enclosure<br>Cables | 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 from the data logger to the sensors. |
| Data Logger Enclosure<br>Guy Wires | Check that the sensor cables are attached to the tower. |
| | Where guy wires are used, check that they are taut and that the attachment points are tight. Verify that the cables are not frayed, and that the integrity has not been compromised in any other way. If the attachment points are loose, call STI for instructions. |

### 2.3.8 Instrument or Standards Certifications

For factory calibrations, a certification of the standard gases used is requested from the manufacturer. Where possible, NIST-traceable gas standards are used. Standards will not be used past their expiration date. If an expired standard is used, it is required to be recertified by the manufacturer. The spectral file numbers generated during the calibration tests are documented and archived.

### 2.3.9 Overview of Data Flow, Spectrum Generation, and Quality Control Parameters for Open-Path Instruments

This section provides context for some of the parameters used in the QA/ quality control (QC) procedures for open-path systems. Most open-path monitors generate an absorption spectrum, and concentrations are derived from these spectra. The processes for generating spectra are distinctly different depending on the system (UV-DOAS and FTIR) and manufacturer, but always result in a spectral file containing absorbance as a function of wavelength. To generate absorbance using the FTIR and UV-DOAS systems, the logarithm of the ratio of two "single beam" transmission spectra is calculated (one being the sample, and the other being the "background"). For ambient open-path measurements, one single beam must be measured or estimated using a spectrum that does not contain the analyte of interest; this is the background sample. Different manufacturers have different methods for determining the appropriate background concentrations. In practice, the single gas MDL for one analyte in an otherwise clean air sample is lower than that in an air sample that contains interfering species (species that absorb in the same spectral region as the analyte). MDLs are also effected by the total averaging time of the collected data.; the greater the number of scans that are averaged, the lower the MDL will be due to the reduction of noise. Several other parameters obtained during the collection of spectra may be used to QC the data.

For UV-DOAS measurements, light is collected for a period (called the "integration time"). The instrument software determines the integration time based on the minimum amount of light needed for a valid measurement. Long integration times can indicate low light levels, and can be used to flag data as questionable (due to the presence of fog or an object blocking the beam); each instrument manufacturer specifies a range of acceptable integration times for the system. A related metric that is applicable to all open-path measurements is the overall intensity of the light received at the analyzer, which is termed "signal strength." For Cerex UV-DOAS measurements, signal strengths greater than 92% are generally acceptable; below this value, the data are flagged as questionable. For FTIR measurements, light levels are affected by absorption from atmospheric gases (carbon dioxide, water, etc.). The acceptable values for a manufacturer's FTIR system may be between 3% and 100%.

To derive concentrations, spectra must be fit using a Least Squares procedure. A "library" spectrum of known compounds is used to best fit the measured spectra collected at the monitoring site. The goodness of fit is quantified using the well-known $R^2$ value, which is equal to 1 for a perfect fit and zero for a measurement that is not correlated to the library spectra. Some instrument manufacturers use the term "percent match," which is $100*R^2$. Therefore, a positive detection of an analyte must satisfy an $R^2$ threshold value.

## 2.4 System Emergency Maintenance Actions

When issues arise, corrective actions are taken to ensure DQOs are met. Table 10 lists the types of issues that require corrective actions. (This table is not all-inclusive; additional checks may be added as the project progresses.) Most of the corrective actions listed in Table 10 are encountered during the course of normal operations. Formal corrective actions are required by Rule 1180 following independent audits (described in Section 4.2.3 of the Fenceline Air Monitoring Plan [FAMP]).

Data Reviewers review data on a daily basis, identify issues as they occur, and work with the Field Technicians, Field Staff Manager, QA Manager, and instrument contractors to resolve issues that need to be addressed on site. Under the direction of the Fenceline Project Manager, the Field Site Manager implements these corrective actions, including equipment repair and replacement as necessary. Like-for-like equipment exchanges are made as necessary. This QAPP will be updated if different equipment exchanges are necessary.

**Table 10.** Potential sampling and data reporting problems and corrective actions.

| Item | Problem | Action | Notification | Person Responsible |
|---|---|---|---|---|
| Failed acceptance criterion | Instrument malfunction | Conduct root cause analysis, flag data | Field Staff Manager, Fenceline Manager, Project Manager, QA Manager | Field Staff Manager |
| Erratic data | Possible instrument malfunction | Contact Field Staff Manager and Instrument Vendor to investigate, correct, and implement changes to minimize re-occurrence | Document in logbook, notify Field Staff Manager | Field Technician |
| Power | Power interruptions | Check line voltage, reset or restart instruments | Document in logbook, notify Field Staff Manager | Field Technician |
| Data downloading | Data will not transfer to the DMS | Contact Field Staff Manager and Instrument Vendor to investigate and correct the issue, and implement changes to minimize re-occurrence | Document in logbook, notify Field Staff Manager and Website Manager | Field Technician |
| Supplies and consumables | Essential supplies run low | Contact Field Staff Manager | Document in logbook, notify Field Staff Manager | Field Technician |
| Access to sites | Technician cannot access the sites | Contact Fenceline Project Manager to resolve access issues | Document in logbook, notify Fenceline Project Manager | Field Technician |

| Item | Problem | Action | Notification | Person Responsible |
|---|---|---|---|---|
| Instrument light level | A low light level alert is observed | Site visit for realignment or source replacement – contact Instrument Vendor if support is needed | Document in logbook, notify Field Staff Manager | Field Technician |
| Website | Website is down | Contact Website Manager to investigate and correct the issue, and implement changes to minimize re-occurrence | Notify Fenceline Project Manager | Website Manager |

In accordance with Rule 1180, Chevron has committed to the response actions listed in **Table 11**.

**Table 11.** Summary of outage response actions and timelines for open-path and point monitors.

| Event | Response Time | Action |
|---|---|---|
| Routine maintenance | 48 hours prior | Notify South Coast AQMD by calling 1-800-CUT-SMOG |
| Unplanned outage that lasts more than 1 hour | Within 2 hrs after discovering the outage, and no more than 8 hours after the start of downtime | Notify South Coast AQMD by calling 1-800-CUT-SMOG |
| Outage lasting more than 24 hours | Within 24 hours after discovery | Written notification to the South Coast AQMD |
| Widespread outage lasting more than 48 hours at Paths 5, 6, 10, and 11 | Within 48 hours after discovery | For gaseous compound monitors, deploy summa polished canister samplers at upwind and downwind locations.<br>For metals and particulate matter monitors, deploy filter samplers at upwind and downwind locations. |

Routine, scheduled maintenance for the open-path instruments occurs at least once per month. Chevron will notify the South Coast AQMD Executive Officer 48 hours before any planned maintenance by calling 1-800-CUT-SMOG. During those maintenance visits, the field technician will carry normal repair parts to the site. It is expected that routine maintenance may take about 2 hours, and the sensors might not report data during these periods.

If monitors fail to report data or appear to be reporting erroneous data due to a malfunction between routine visits, remote diagnosis and, if necessary, a site visit will be conducted. Chevron will call 1-800-CUT-SMOG to notify the South Coast AQMD Executive Officer within two hours of discovering the issue, and no more than eight hours after the start of the downtime or the discovery of a malfunction causing a failure to accurately provide real-time air monitoring information. Chevron will also provide the name of the facility, the impacted systems, the impacted data, the date and time of the occurrence, and the reason for the lapse in collecting and/or reporting the real-time air monitoring data. If the problem cannot be resolved with the equipment or parts on hand, Chevron will obtain replacement parts from the vendor.

If both the FTIR and UV-DOAS fail on a given path, monitors on the adjacent paths will provide backup data. In the event of a prolonged power outage or another issue affecting multiple monitors, passive sampling—conducted to comply with the EPA benzene rule—will provide backup data. In addition, in the event of a widespread outage lasting longer than 48 hours that includes Paths 5, 6, 10, and 11, integrated 12-hr canister samples of VOCs will be taken twice per day on the southwest and northeast sides of the refinery (the predominant upwind/downwind directions).

Chevron will submit required written notification to the South Coast AQMD Executive Officer for any equipment failure that results in a failure to accurately provide continuous, real-time air monitoring information for 24 hours or longer. The written notification will be submitted to the Executive Officer within 24 hours of discovering the equipment failure, and will include the following:

- An explanation of activities currently being pursued or taken to remedy the equipment failure;
- Estimated time needed to restore the fenceline air monitoring equipment to normal operating conditions that comply with the approved fenceline and community air monitoring plan; and
- Temporary air monitoring measures to be implemented until the fenceline air monitoring system is restored to normal operating conditions

When the fenceline air monitoring system is experiencing a known downtime or malfunction, Chevron will indicate that the data are unavailable for the missed or inaccurate time periods on the web-based fenceline data display and notification program.

Troubleshooting and corrective actions will be carried out by Field Technicians, with assistance from the Field Staff Manager and Instrument Vendors as needed. If the problem cannot be resolved with the equipment or parts on hand, spare parts and analyzers may be used to replace the faulty equipment to minimize downtime and data loss. The decision to install a replacement instrument must be authorized by the Fenceline Project Manager. Corrective actions taken are documented in a log that contains the following information: date and time of issue, instrument impacted, monitoring site location, a description of the problem and root cause analysis, the recommended corrective action, estimated downtime, and the personnel involved.

### 2.4.1 Backup Equipment

Spare parts, analyzers, and expendables are kept on hand to ensure high data completeness and that project objectives are met. Chevron's contractor has spare parts, including major components, available for emergency repairs. This inventory is kept either at the refinery warehouse or by the contractor. The following is a summary of these items.

Major spare parts on hand:

- FTIR source, expected lifetime of 2-3 years
- UV source (2-24 at any one time), expected lifetime of 3-6 months
- FTIR cryocooler (replace as a complete detector module), expected lifetime of 24 months
- FTIR retroreflector cubes
- UV-DOAS retroreflector cubes
- Interferometer control board
- UV-DOAS lamp power supply
- Backup modem and switch
- Backup datalogger

Examples of expendables on hand:

- Equipment filters
- Instrument tape (Aethalometer, 903W, and Xact)
- Certified calibration gases
- Activated carbon
- Backup drives

It is expected that, with these measures, instrumentation problems can be resolved by the next business day; if downtime exceeds 24 hours, Chevron will respond with the required written notification to the South Coast AQMD.

# 3. Quality Objectives and Criteria

## 3.1 Data and Measurement Quality Objectives

The EPA provides a seven-step process to establish DQOs that ensure collected data are of sufficient quality to support project objectives.

1. **Problem Statement:** The goal of this monitoring program is to meet the requirements of Rule 1180, which was established to provide the public with information regarding air pollutants at the fenceline of petroleum refining facilities.
2. **Program Goals:** The Chevron El Segundo Refinery provides information to the public regarding concentrations of specific compounds specified in Table 1 in Section 2.1. Real-time data are provided as 5-minute and/or 1-hour rolling averages. Notifications are distributed based on the thresholds established by the South Coast AQMD.
3. **Information Inputs:** Concentration data from open-path monitors and point monitors are provided as 5-minute, 30-minute, and/or 1-hr rolling averages. These data are compared with established thresholds published by recognized authorities on the health effects of the pollutants. As part of the data quality assessment, data are reviewed with respect to representativeness and comparability; other measurements from similar geographic locations serve as a basis of comparison.
4. **Study Boundaries:** Measurements covering the refinery fenceline are deployed to provide real-time data to the public. The Air Monitoring Plan was established in collaboration with South Coast AQMD to meet the program goals and meet the requirements of Rule 1180.
5. **Analytic Approach:** Instrumentation was selected in conjunction with South Coast AQMD to provide sufficient coverage of the refinery fenceline. Most of the chemical species are measured using open-path technology whereas point monitors were selected based on available technology. All data are subjected to automated and human QC processes to ensure they meet the data-use objectives.
6. **Performance Criteria:** Performance criteria are specified in Section 3.2.1. These criteria set out the measurement quality objectives (MQOs) needed to satisfy the goals of the study. Quantitative measures of completeness (**Table 12**) and accuracy and precision (**Table 13**) are provided in Section 3.2.1. Qualitative measures of representativeness and comparability are provided in Section 4.3.
7. **Data Acquisition:** Both the sampling (Section 2) and analysis (Section 4) approaches for this project have been laid out to satisfy the requirements of Rule 1180. Section 2 describes the rationale for instrument and site selection. Collected data are handled according to the data management, QC, and verification procedures established in Section 4.

## 3.2 Performance Criteria

As part of the DQO process, measurement performance criteria are established during monitoring design. These criteria, referred to as data quality indicators (DQIs) and MQOs, specify the data quality needed to minimize decision errors based on the data. DQOs herein are defined in terms of the degree of precision, accuracy, representativeness, comparability, and completeness needed for the monitoring. Of these objectives, precision and accuracy are quantitative MQOs; representativeness and comparability are qualitative measures; and completeness is a combination of quantitative and qualitative measures. Representativeness objectives were partially addressed through the selection of fenceline sampling sites and establishing the height of the collected samples. Representativeness and comparability are further addressed through the data review process, as discussed in Section 4.

The MQOs for the data collected by the fenceline measurement system is provided here. The principal quantitative indicators of data quality are data completeness, precision, and accuracy.

### 3.2.1 Precision and Accuracy

Gaseous measurements outlined in this document are subjected to precision and accuracy tests ("bump tests"). During these tests, a number (N) of replicated measurements ($x_i$) of a standard reference material of known magnitude ($x_{std}$) are measured. Here, an acceptable number of trials is defined as 7≤N≤15. The average value of these measurements is calculated as

$$\bar{x} = \frac{\sum_i x_i}{N} \tag{1}$$

and the standard deviation (σ) as:

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

From these definitions, %Accuracy is defined as:

$$\%Accuracy = \frac{\bar{x} - x_{std}}{x_{std}} \times 100\% \tag{3}$$

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

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

### 3.2.2 Data Completeness

Data completeness is assessed by reviewing the data quality control (QC) and operational (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 DMS during the quarter.

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

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

- Missing = Possible – Captured

**% Missing:** The percentage of Missing data points relative to Possible during the quarter.
- % Missing = (Missing / Possible) * 100

**Invalid-Weather:** The number of data points that are invalid due to weather during the quarter.
- These data are designated as QC = 9 – "invalid", OP = 73 – "Low Visibility Conditions"

**Planned Maintenance:** The number of data points that are invalid due to planned instrument maintenance during the quarter.
- These data are designated as QC = 9 – "invalid", OP = 28 – "Planned Instrument Maintenance"

**Unplanned Maintenance:** The number of data points that are invalid due to unplanned instrument maintenance during the quarter.
- These data are designated as QC = 9 – "invalid", OP = 29 – "Unplanned Instrument Maintenance"

**Expected:** The number of Possible data points corrected for periods of low visibility conditions and planned instrument maintenance during the quarter.
- Expected = Possible – Invalid-Weather – Planned Maintenance

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

**% Invalid:** The percentage of Invalid data points relative to Possible during the quarter.
- % Invalid = (Invalid / Possible) * 100

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

**% Suspect/Questionable:** The percentage of suspect/questionable data points relative to Possible during the quarter.
- % Suspect = (Suspect / Possible) * 100

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

**% Valid:** The percentage of Valid data points relative to Possible during the quarter.
- % Valid = (Valid / Possible) * 100

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

**% Complete:** The percentage of Public Recorded data points relative to Expected during the quarter.
- % Complete = (Public Recorded / Expected) * 100

Table 12 shows the data completeness objectives for all collected data. For communication purposes, the Percent Data Valid—which is the percentage of data values that are valid divided by the number of captured data values, corrected for low-visibility conditions and scheduled maintenance and calibrations—are also computed. Quarterly completeness averages are calculated using 1-hr averages from the top of each hour in 3-month increments. Annual averages are updated quarterly and are the average of measurements from the four most recent quarters.

**Table 12.** Data completeness objectives.

| Monitoring Equipment | Objective | Period |
|---|---|---|
| Open-path FTIR and UV-DOAS | 90% | Annual |
| Meteorological | 90% | Annual |
| Sensors monitoring $H_2S$, BC, $PM_{2.5}$, $PM_{10}$, and particulate metals | 90% | Annual |

Other factors that affect data availability include instrument tests, routine maintenance, and other scheduled maintenance (e.g., replacement of UV bulbs for the UV-DOAS after every 2,000 hours of use [roughly quarterly] and replacement of the FTIR cryocoolers every 2 years). Regular maintenance and careful, responsive operation minimize instrument downtime. Table 13 shows performance criteria for the fenceline monitoring system, which were partially guided by the EPA QA Handbook.[5,9]

**Table 13.** Performance criteria for the fenceline monitoring systems.

| Sensor | Test | Acceptance Criteria for Precision and Accuracy |
|---|---|---|
| UV-DOAS | 5 ppm-m benzene sample (5 ppb path average for a 500 m one-way path) bump test | ±25%* |
| FTIR | 15 ppm-m $NH_3$ sample (15 ppb path average for a 500 m one-way path) | ±25%* |
| 903W $H_2S$ analyzer | 50 ppb bump test | ±20% |
| | Zero test | ±2.5 ppb |
| | Multipoint calibration at 0, 25, 50, 74 ppb | ±2.5 ppb for zero<br>±20 % of expected value for each nonzero point |
| AE33 Aethalometer | Flow check | ±10% |
| T640 | Flow checks | ±5% |
| | Span dust check | ±0.5 channel tolerance |
| Xact | Flow check | ±5% |
| | Calibration check | ±10% |
| Temperature | Two-point test | ±0.5ºC |
| RH | Hygrometer | ±7% |
| Wind speed | Starting threshold test; transfer function test | ±0.25 m/s below 5 m/s and ±5% above 5 m/s |
| Wind direction | Angle verification | ±5 degrees |
| Visibility | Extinction | ±10% |

*Based on flow-through calibration system.

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[9] 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. https://www3.epa.gov/ttn/amtic/qalist.html.

## 3.3 Training and Certifications

Education and training are critical for building an effective monitoring system. All activities conducted under this QAPP are performed by individuals with appropriate training, including:

1. Safety (through the Occupational Safety Councils of America [OSCA])
2. Instrument-specific training from vendors
3. Data validation training from experienced analysts
4. Routine operations and maintenance training, including QAPP and SOP review, led by experienced field technicians

All personnel assigned to operation, maintenance, QA, and data handling are properly trained in the operation of the fenceline monitoring system. This includes field technicians, individuals performing data validation, and all other staff responsible for operating the fenceline monitoring system. This training is conducted by other operational staff with at least one year of experience operating refinery fenceline monitoring systems, as well as by analyzer manufacturers (whether through in-person instruction or online training materials). Personnel are provided with copies of this QAPP and SOPs. Staff are trained on the operation and maintenance of the system prior to and during start-up. Annual refresher training is performed for existing staff, as well as subsequent training for new staff hired later in the project or if changes are made to the system. The QA Manager determines the specific training requirements for operation and maintenance of the system and determines if trainees are qualified to work independently. Training is provided by the QA Manager or a designated representative, and a training record is maintained by the Field Staff Manager.

## 3.4 Documentation and Records

Proper documentation and records are kept of all activities related to the operation and maintenance of fenceline monitoring systems and data management processes. This QAPP is the major guiding document for maintaining the fenceline monitoring system. The official copy of the QAPP is kept by the Fenceline Project Manager. It is reviewed at least annually, and is updated if any significant changes are made to the fenceline monitoring systems.

The SOPs attached to this QAPP (Attachments 1-8) were developed with input from vendors and experienced field technicians. They are intended to be ‘living documents’ and are updated to reflect operational improvements and site-specific changes. All staff involved in the fenceline monitoring program have been provided with electronic copies of the SOPs. Revised versions of the QAPP and SOPs are distributed to both refinery and contractor staff via email, and are stored on a shared drive. Additionally, hard copies of the SOPs and the analyzer user manuals are kept in the analyzer shelters and are replaced with each revision. By updating both the digital and hard copies of the QAPP, SOPs, and other QC documents, we are working to ensure that staff only use the most recent version so measurement and data quality objectives are met.

The analyzer shelters also contain logbooks where all onsite activities related to components of the fenceline monitoring system are recorded. This includes planned maintenance activities and emergency site visits. The field logbooks are scanned monthly to generate electronic copies; these are stored on a shared drive for access by the data validation team.

Any corrections that are made to hard-copy documents are indicated by a cross out of the previous entry and addition of a new entry, along with the date of correction and the initials/name of the individual making the correction. Electronic documents (reports and data) of current and previous versions of the FAMP, QAPP, and SOPs are stored on a password-protected server at Sonoma Technology. Table 14 shows the retention policy for fenceline air monitoring system documentation.

**Table 14.** Retention policy for fenceline air monitoring system documentation.

| Document | Retention Policy |
|---|---|
| FAMP | Fenceline Project Manager to retain all versions for 5 years |
| QAPP | Fenceline Project Manager to retain all versions for the duration of the air monitoring program |
| Maintenance forms | QA Manager to retain all documents for 5 years |
| Audit forms | QA Manager to retain all documents for 5 years |
| Corrective action reports | QA Manager to retain all documents for 5 years |
| Calibration standard certifications | QA Manager to retain all documents for 5 years |
| Logbooks | Field Staff Manager to retain all versions for 5 years at Chevron (or electronically) |
| Training documents | QA Manager to retain all documents for 5 years |

## 3.5 Independent Audits

Rule 1180 specifically calls for QA reviews by a qualified independent party, including QC and audits of the fenceline air monitoring systems.[10] Section 4.2.3 of the FAMP provides additional details regarding the requirements, scope, and timelines of these audits.

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[10] South Coast Air Quality Management District (2024) Rule 1180: Refinery fenceline and community air monitoring. Final rule adopted December 1, 2017, amended January 5, 2024. Available at https://www.aqmd.gov/docs/default-source/rule-book/reg-xi/r1180.pdf.

# 4. Data Management, Quality Control, and Verification

Data quality criteria are evaluated through (1) automatic data checks conducted through the DMS, and (2) data reviews by trained analysts (daily data reviews and periodic, more-thorough validation).

## 4.1 Overview of the Data Management Process

Raw data management occurs on a real-time, daily, monthly, quarterly, and annual basis. The data flow for this Fenceline monitoring system is shown in **Figure 3**. In near-real time, data are transferred from infield instruments through a data acquisition system (DAS, a Campbell Scientific Datalogger) to a DMS using a cellular modem. The DAS transmits data from the monitoring sites to the DMS every 5 minutes. Data are also stored onsite on instrument computers in case of cell modem failure. The DMS uses a Microsoft SQL relational database with stored procedures. Raw data directly from the DAS are not intended for the public website. Only after the data undergoes automated QC processes (described in Section 4.2) and aggregation to 1-hr values are the data displayed on the website. Certain metadata pertaining to site visits is also recorded in the site logbooks. Every site visit is recorded in the site logbook. Site logbooks are stored in the instrument cabinets and shelters, which are locked. Electronic copies of the logbooks are scanned on a monthly basis on a secure, password-protected network, along with this QAPP and the associated SOPs.

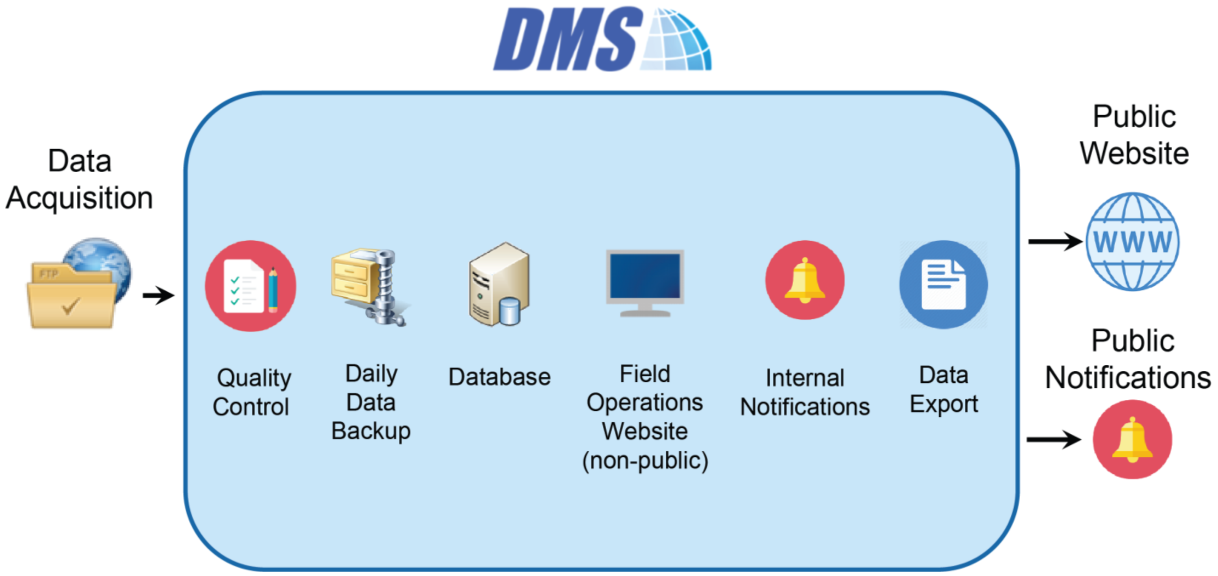

**Figure 3.** Data flow diagram indicating key processes of the data management system.

### 4.1.1 QC and QA Processes

All data produced by instruments are considered **Level 0**. All **Level 0** data values that are not associated with bump tests, other instrument maintenance, or instrument problems are displayed to the public in near-real time (within 10 minutes). If data are subsequently found to be invalid, they will be removed from the public display. As data reach higher levels of QA/QC, they are automatically updated on the public website.

As described in Section 4.2, the DMS automatically quality-controls data, detects outliers and problems, generates reports, and creates alerts. The auto-screening capabilities of the DAS and the DMS are used for continuous examination of data quality. The DAS assigns initial QC codes and operational (OP) codes to each data value, based on operating characteristics information collected from the analyzers at the same time as the data values. These QC codes and OP codes can be modified within the password-protected DMS, and by trained analysts with proper access credentials later during the validation process, which does not happen in real time. The DMS keeps track of QC and OP code changes. All of this information is stored in the DMS, which uses a Microsoft SQL relational database with stored procedures. As part of the auto-screening process, QC codes are assigned as follows:

- **Valid (QC code 0)** – data are within normal operating parameters.
- **Invalid (QC code 9)** – data do not meet quality control criteria.
- **Missing (QC code 8)** – data have not been received by the DMS for a time period greater than 10 minutes since the last data were received.
- **Suspect (QC code 5)** – operating parameters are marginal and should be reviewed further.

The automatically QCed air quality data are displayed on the public website within 10 minutes after collection. At this point, these data are considered **Level 0.5**.

Further routine verification of the data is described in Section 4.3. The DMS serves a non-public operations website that is used for daily graphical review of the data by experienced analysts. The DMS also has a notification system to inform/alert project and facility staff of problems. After this routine data review is complete, data are considered **Level 1.0**.

During the last phase of data verification, data from longer time periods are validated by executing various QA procedures (described in Section 4.4) and instrument QC checks (described in Section 4.5). After these in-depth checks are complete and the data are annotated appropriately, the resulting data are considered **Level 2.0**. At this point, the data are considered final for reporting to the South Coast AQMD. Data from all stages of validation are retained in the DMS.

### 4.1.2 Data Storage and Processing

The DMS data are backed up daily. Backup media are moved weekly to a secure offsite facility. The data and hardcopy records are stored for a period of five years after sampling.

The Website Manager oversees the maintenance of the DMS, which is conducted monthly. Testing is performed on a separate staging system. Maintenance includes improvements to the system, updates to AutoQC or data flagging processes (as outlined by the QA Manager), or any other fixes to ensure that DMS matches the most recent version of the QAPP. Version control software is used to track changes made to the various programs deployed in the DAS and DMS.

### 4.1.3 Data Delivery

A method will be made available to South Coast AQMD and the public to download hourly data, reported at the top of the hour, within 60 calendar days after the conclusion of each quarter in comma separated value (.csv) format. Hourly data from the equipment described in this QAPP will be provided for each parameter being monitored.

Data graphs are stored and available on the website for five years, starting from January 1, 2024, the date that Rule 1180 was amended to include this requirement. Chevron maintains an electronic copy of the data for five years, consistent with Rule 1180.

## 4.2 Automated Quality Control

Automated data screening is conducted within the DMS upon data ingest. Automated screening checks of data feeds are used to screen out invalid data from public display and are helpful to focus the data reviewer's efforts on data that need the most attention. Initial screening checks, along with actions to be taken, are summarized in **Table 15**. The screening check concentration criteria are based on an analysis of expected instrument performance, concentration levels of concern by compound, and typical ambient concentrations by compound. All screening criteria (flags and rates of change) are preliminary and are refined during the project based on actual observations. Unlike data flags, screening criteria are not displayed on the public website, but are stored in the DMS. The DMS auto-screening checks that are used include:

- **Range.** These checks verify that the instrument is not reporting values outside of reasonable minimum and maximum concentrations.
- **Sticking.** If values are repeated for a number of sampling intervals, data are reviewed for validity. Typically, four or more intervals of sticking values are a reasonable time span to indicate that investigation is needed. Sticking checks are not applied to data below the instrument detection limit.

- **Rate of Change.** Values that change rapidly without reasonable cause are flagged and reviewed.
- **Missing.** If data are missing, data during those time periods are coded as missing.
- **Sensor OP codes and alarms**. If the instrument assigns operation (OP) codes to data automatically (e.g., for bump tests or internal flow rate checks), the data are reviewed, codes confirmed, and data flags checked.
- **Visibility impairment.** While the exact relationship between visibility and open-path measurements is not established, the expectation is that there would be no measurements when visibility is less than 2.5 miles.

Additional parameters that are monitored as indicators of data quality include a data quality value for each concentration as reported by the instrument (i.e., correlation between measured and reference spectra) and signal strength.

Data flags identified through auto-screening are graphically reviewed during data validation (i.e., not in real time), and QC flags are updated with daily and quarterly actions. The DMS keeps track of data changes in its chain-of-custody feature—i.e., raw data are preserved, as well as all changes.

**Table 15.** Initial screening checks for 5-minute data. All valid and suspect data values are displayed to the public in real time. If data are invalid, they will not be included in the public display. All screening values below (flags and rates of change) continue to be refined during the project. During data validation, flagged data are further investigated.

| Measurement Species (units) | Checks | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Minimum Detection Limit (MDL):** If concentration is below MDL, flag as below MDL> Data will still be displayed. | **Range:** If concentration is above value listed, flag as suspect and conduct investigation | **Sticking:** If same value observed for four or more intervals, flag as suspect and conduct investigation | **Rate of Change Between Intervals:** If concentration changes by more than value listed, flag as suspect and conduct investigation | **Missing:** If data are missing, flag as missing and investigate cause | **Sensor OP Code/Alarm:** If sensor indicates malfunction or bump test data, flag as appropriate | **Visibility:** If visibility is less than 1,000 m and data are missing, flag as appropriate |
| $SO_2$ (ppb) | SAME FOR ALL POLLUTANTS | 750 | SAME FOR ALL POLLUTANTS | 250 | SAME FOR ALL POLLUTANTS | SAME FOR ALL POLLUTANTS | SAME FOR ALL POLLUTANTS |
| Nitrogen Dioxide (ppb) | | 750 | | 250 | | | |
| Total VOCs (non-methane hydrocarbons) (ppb) | | TBD | | TBD | | | |
| Formaldehyde (ppb) | | 135 | | 45 | | | |
| Acetaldehyde (ppb) | | 780 | | 260 | | | |
| Acrolein (ppb) | | 3.3 | | 1.1 | | | |
| 1,3-Butadiene (ppb) | | 900 | | 300 | | | |
| Styrene (ppb) | | 14,700 | | 4,900 | | | |
| Benzene (ppb) | | 27 | | 9 | | | |
| Toluene (ppb) | | 29,400 | | 9,800 | | | |
| Ethylbenzene (ppb) | | 1,380 | | 460 | | | |
| Total Xylenes (ppb) | | 15,000 | | 5,000 | | | |
| $H_2S$ (ppb) | | 90 | | 30 | | | |
| Carbonyl Sulfide (ppb) | | | | 270 | | | |
| $NH_3$ (ppb) | | 1,380 | | 460 | | | |
| Black Carbon ($\mu g/m^3$) | | 30 | | 10 | | | |
| Visibility (meters) | If value is <0, flag as suspect | 1,000 | Not applicable | Not applicable | | | Not applicable |

## 4.3 Routine Data Verification

### 4.3.1 Confirm Daily Operation

Operationally, data are reviewed daily by a data reviewer to assess instrument operation. This process leads to Level 1.0 data. This initial review, typically of a three- to five-day time-series plot of selected parameters for each instrument, allows reviewers to verify that instruments are operating within specification. If it appears that an instrument is not operating, or the data are missing, the field operator is notified and further investigation and corrective action, if needed, is taken.

In addition to daily checks of the field website, an automated alerting system lets technicians and managers know when data have been missing for a specified period of time. Missing data may indicate a power issue, an instrument problem, or a data communication problem. The time allowed for missing data will likely be adjusted as the project proceeds to reduce false or excessive alerting. The alerting is currently set to 6 missing 5-minute values (i.e., 30 minutes).

### 4.3.2 Assess Data Reasonableness

The data reviewer assesses whether the pollutant concentrations are reasonable with respect to the time of day, season, meteorology, and concentrations expected and observed along other paths. Analysts typically review data in the form of time series plots and correlations between species. As noted in EPA's TO-16 document, the analyst should look for trends in data where none should exist. For example, ozone and $NO_2$ come from area sources and follow well-characterized diurnal trends; if these trends are not observed or there are outliers, it is indicative of problems. For an FTIR instrument, correlations with water vapor should be noted, as water vapor may interfere with several compounds quantified here. Gases that come from the same source (BTEX, for example) should be correlated. The real-time instrument MDL may give an indication of excessive baseline noise and underlying instrument issues. Measurements of BC concentrations should have two daily peaks related to urban vehicle traffic, therefore, the monitors located around the facility should have similar trends (with the exception of, for example, elevated concentrations due to local sources, such as nearby diesel engines). If anomalies are observed, additional analysis is conducted to determine whether there is an instrument malfunction, or the data are truly anomalous but explainable. Data reasonableness is also assessed more thoroughly during the data validation process.

## 4.4 Data QA Procedures

On a quarterly schedule, an experienced air quality analyst validates data by building on the processes leading to Level 1.0 data. This validation starts with an in-depth review of the data, which includes a graphical review of time series data and statistical tests to ensure the data are valid for the intended end use. The QA Manager evaluates QA/QC procedures and ensure the methods for meeting the DQOs are followed. Data validation activities are reviewed and approved by the QA Manager.

Quarterly data validation activities include:

- Looking for statistical anomalies and outliers in the data and investigating them.
- Ensuring there are not several continuous 5-minute averages of the same number.
- Evaluating monthly summaries of the minimum, maximum, and average values.
- Ensuring the data are not biased by exceptional conditions or events occurring off refinery property.
- Ensuring data reasonableness by comparing the data to remote background concentrations and average urban concentrations.
- Ensuring the data or measurements are realistically achievable and not outside the limits of what can be measured.[11]
- Inspecting several sampling intervals before and after data issues or instrument bump tests or repairs to ensure all affected data have been properly flagged.
- Referring to site and operator logbooks to see if some values may be unusual or questionable based on observations by site operator.
- Assessing instrument meta-data to confirm reasonableness.
- Assessing visibility measurements to ensure adequate signal was obtained to quantify pollutant concentrations.
- Confirming that bump tests were conducted and were within specifications.

On a quarterly basis, to ensure all the daily QC tasks are complete, analysts will:

- Review any instrument bump test results.
- Verify that the daily instrument checks were within tolerances.
- Review manual changes to operations/data and verify that the changes were logged and appropriately flagged; ensure that logged information is complete and understandable.
- Ensure that instrument checks have the appropriate QC codes applied.

On a quarterly basis, analysts finalize the data by filling in missing records with null values and adding Null Codes. Analysts will:

- Assign invalid data a Null Code and provide a reason why the data are invalid.
- If a record is not created for a particular site/date/time/parameter combination, create a null record for data completeness.

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[11] Measurements below the method detection limit will be flagged in the DMS for review by an analyst.

- Inspect data consistency.
- Review collected data ranges for consistency – ranges should remain within the expected values over months of monitoring.
- Check bump-test values for completeness; ensure they meet the acceptance criteria.
- Review quarterly data completeness.

General criteria for suspecting or invalidating data include:

- Monitor appears to have malfunctioned (acting erratic, spiking, or showing other evidence of questionable operation).
- Data are outside of plausible values (indicating a calculation error, averaging error, or instrument malfunction).

Common reasons for data invalidation include instrument malfunctions, power failures, and bump test data that were not identified as such. As the measurements progress, we will update and refine the screening checks. Screening checks are typically specific to the site, instrument, time of day, and season, and are adjusted over time as more data are collected.

Data are invalidated only if a reason can be found for the anomaly or automated screening check failure. If the data are anomalous or fail screening but no reason can be found to invalidate the data, the data are flagged. Additional analysis may be needed to deem data valid or invalid. Voided data are flagged as invalid in the database. A summary of issues leading to invalidated data is documented in the data file.

All actions are documented in the DMS, which retains raw data and traceability of all actions that result in the final data. At the conclusion of activities covered in this section, the data are considered Level 2.0 data. Level 2.0 data are summarized in quarterly reports, which describe data completeness, quarterly and monthly statistics, and outliers and anomalies. The data are also put in context in relation to health thresholds. The quarterly reports are written at a public-friendly level, but still reflect a high level of data validation and quality control. These reports are posted to the public website approximately 60 days following the end of each quarter.

## 4.5 Instrument QC Checks

Additional QC checks for the instruments are summarized in **Table 16**. Data that fail the QC checks are flagged in the DMS and brought to the attention of the reviewer by color coding in the graphic summaries.

On a quarterly basis, the refinery or its designated contractor review the performance of the network by (1) reviewing the data completeness by monitoring path, instrument, and chemical species; (2) reviewing results of bump tests; (3) analyzing the reported values in context of refinery operations; and (4) analyzing the data in context of the meteorological conditions. The contractor also uses analyses like those used to support the network design to evaluate the overall network performance and ensure it is meeting overall objectives. The results are summarized in a quarterly report and provided to the South Coast AQMD.

**Table 16.** Typical instrument QA/QC checks.

| QA/QC Checks | Frequency | Acceptance Criteria |
|---|---|---|
| **UV-DOAS** | | |
| Bump test (accuracy) | Monthly and after major service | ±25%* |
| Goodness of Fit ($R^2$) | Continuous | 0.8 to 1.0 |
| Integration time | Continuous | ≤250 ms |
| Signal intensity | Continuous | ≥70%<br>(if integration time >250 ms) |
| **Aethalometer** | | |
| Flow rate | | ±10% |
| Span check (ND filter check) | | ±10% |
| Zero check (Clean air test) | | <550 ng/m$^3$ for Channel 6 |
| **FTIR** | | |
| Bump test | Monthly and after major service | ±25%* |
| Goodness of Fit ($R^2$) | Continuous | 0.7 to 1.0 |
| Signal intensity | Continuous | ≥2% |
| **903W $H_2S$ Analyzer** | | |
| Bump test | Monthly | ±20% |
| Zero | Monthly | ±2.5 ppb |
| Multipoint calibration at approximately 0, 25, 50, 74 ppb | Initially and then a minimum twice per year at least 4 calendar months apart. Additional calibrations following major repair. | ±2.5 ppb for zero<br>±20 % of expected value |
| **T640X Particulate Mass Monitor** | | |
| Span dust check | Monthly | ±0.5 channel tolerance |
| Flow rate | Monthly | ±5% |
| Leak/blank check | Monthly | PM readings zero with filter |
| **Xact Metals Monitor** | | |
| Upscale | Monthly | <10% deviation from factory value |
| Leak check | Quarterly | < 150 mmHg/min leak rate |
| Flow check | Quarterly | ±5% |
| Calibration check | Quarterly | ±10% |
| Blank check | Annually | Monitor for systematic changes |

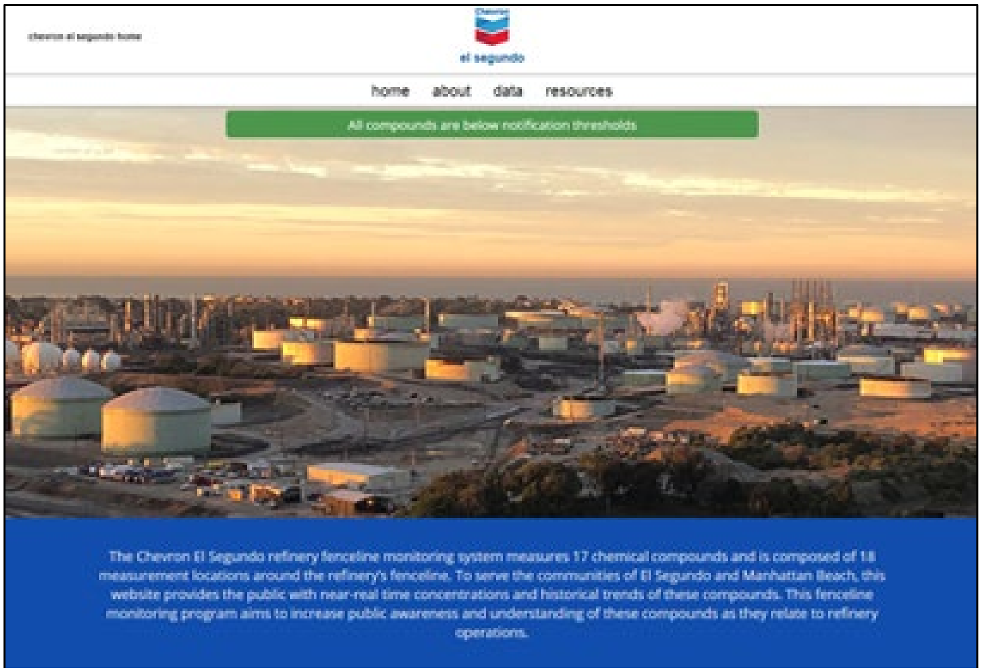
| QA/QC Checks | Frequency | Acceptance Criteria |
|---|---|---|
| **Meteorology** | | |
| Two-point temperature test | Quarterly | ±0.5°C |
| RH | Quarterly | ±7% |
| Wind speed starting threshold and transfer function | Quarterly | ±0.25 m/s below 5 m/s and ±5% above 5 m/s |
| Wind direction angle verification | Quarterly | ±5 degrees |
| Visibility – extinction coefficient check | Quarterly | ±10% |

*Based on flow-through calibration system.

# 5. Website Management and Community Interface

## 5.1 Overview

Rule 1180 requires that the real-time data collected by the fenceline monitoring system be displayed to the public using a website. The data collected at the El Segundo refinery is displayed at elsegundo1180.com. A screenshot of the **Home** page is shown in Figure 4. The website is built around the central goal of making complex air monitoring data accessible to the public. On the **Home** page, a banner displays the status of the measurements and whether they are above or below the levels of concern. The **Home** page also provides links to the other main sections of the website: **About**, **Data**, and **Resources**. These sections are described in Sections 5.2–5.4.



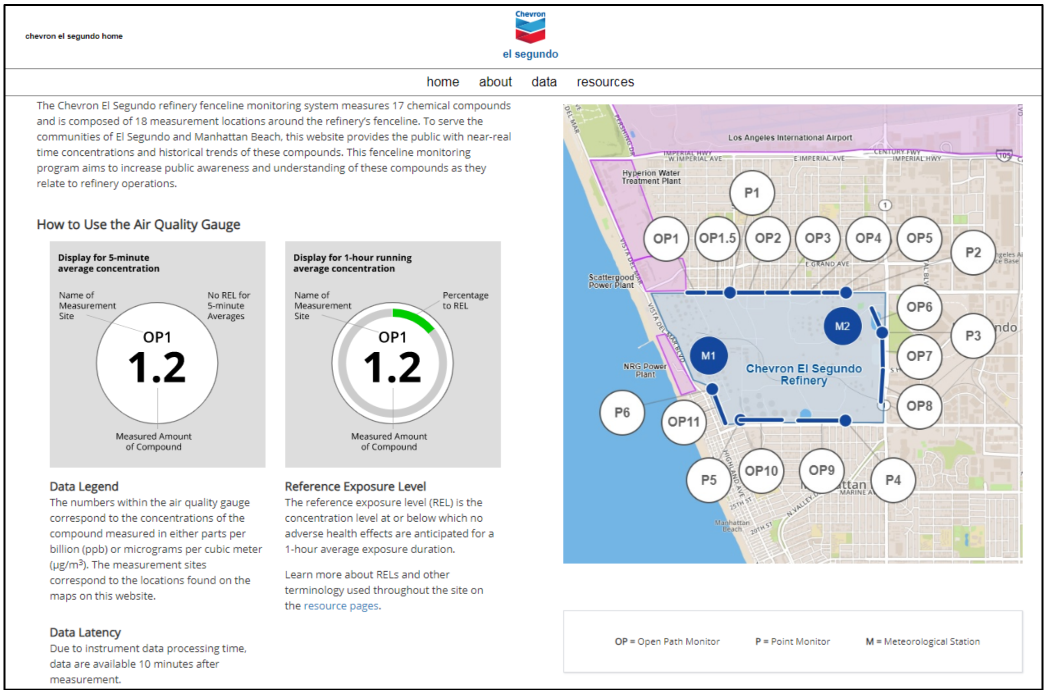
All compounds are below notification thresholds

The Chevron El Segundo refinery fenceline monitoring system measures 17 chemical compounds and is composed of 18 measurement locations around the refinery's fenceline. To serve the communities of El Segundo and Manhattan Beach, this website provides the public with near-real time concentrations and historical trends of these compounds. This fenceline monitoring program aims to increase public awareness and understanding of these compounds as they relate to refinery operations.

**Figure 4.** Screenshot of the home page for elsegundo1180.com, the Chevron El Segundo 1180 Fenceline Monitoring website. This website provides real-time data, informational items, and resources to help the public understand the data collected. The green banner indicates that all compounds are below levels of concern.

## 5.2 About Section

To aid in the public's understanding of how the data are displayed, the **About** section (Figure 5) contains a description of the data dials employed in the **Data** section. Data dials are a unique way to graphically display concentration data: as the concentration of the species goes up, the gauge indicating site concentrations changes in like an analog automobile gauge. When concentrations are below the Reference Exposure Level (REL), the gauge is green; when concentrations are above the REL, the gauge is orange. Basic acronyms and symbols are also described in the **About** page. The website has also been developed to ensure it is functional across different browsers and mobile devices.



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How to Use the Air Quality Gauge

Data Legend
The numbers within the air quality gauge correspond to the concentrations of the compound measured in either parts per billion (ppb) or micrograms per cubic meter (μg/m³). The measurement sites correspond to the locations found on the maps on this website.

Reference Exposure Level
The reference exposure level (REL) is the concentration level at or below which no adverse health effects are anticipated for a 1-hour average exposure duration.

Learn more about RELs and other terminology used throughout the site on the resource pages.

Data Latency
Due to instrument data processing time, data are available 10 minutes after measurement.

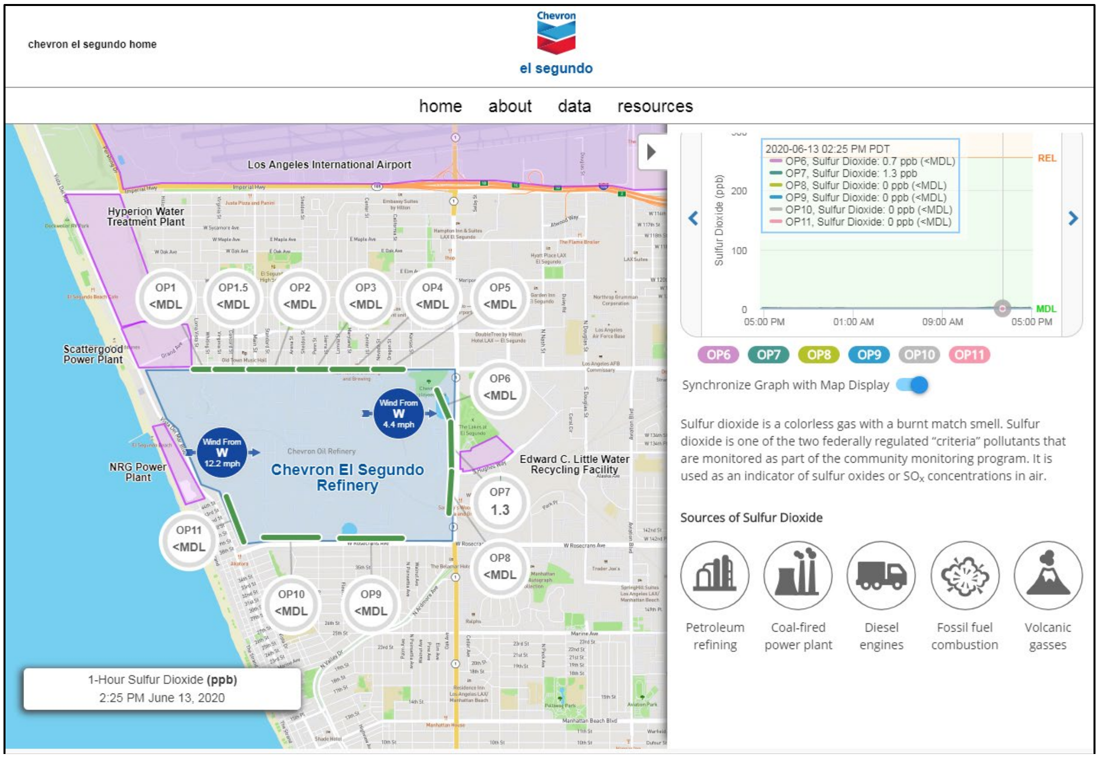
**OP** = Open Path Monitor
**P** = Point Monitor
**M** = Meteorological Station

Figure 5. Screenshot of the **About** section of the website. This portion of the site contains information necessary for a basic understanding of the data display shown on the **Data** page.

## 5.3 Data Section

The **Data** page is meant to convey the status of Rule 1180 species concentrations around the fenceline of the El Segundo Refinery at a glance. The **Data** page is shown in Figure 6. A map on the left side of the **Data** page shows gauges that indicate the concentration of a specified pollutant at each measurement site. On the right side of the **Data** page are time series graphs and infographics that give information about sources.

The default time resolution for the data display is a 1-hr rolling average; 1-hr data were chosen as the default display because they are comparable to the REL limits used to guide public understanding for Rule 1180. The REL levels are indicated by orange shading on the time series graphs. The MDLs for the pollutants are also shown on the time series graphs. Providing the public with both the REL and MDL on the graphs allows the website viewers to quickly assess whether the concentrations are at levels that can be confidently measured or are at levels they should be concerned about. When the user pans their cursor over the time series display, graphical tooltips show the exact measured values (mobile users need to physically "tap" the display to get an equivalent tooltip). If the user selects the "synchronize graph with data display" radio slider, the data gauges (including the wind speed and direction, shown as dark blue circles with arrows) on the graph synchronize to the date and time selected via the time series graph or drop-down menu. The user also has the option to change the time resolution to show the 5-minute average values. When the user selects the 5-minute data, information about the 1-hr REL is removed from the time series graph and data gauge.



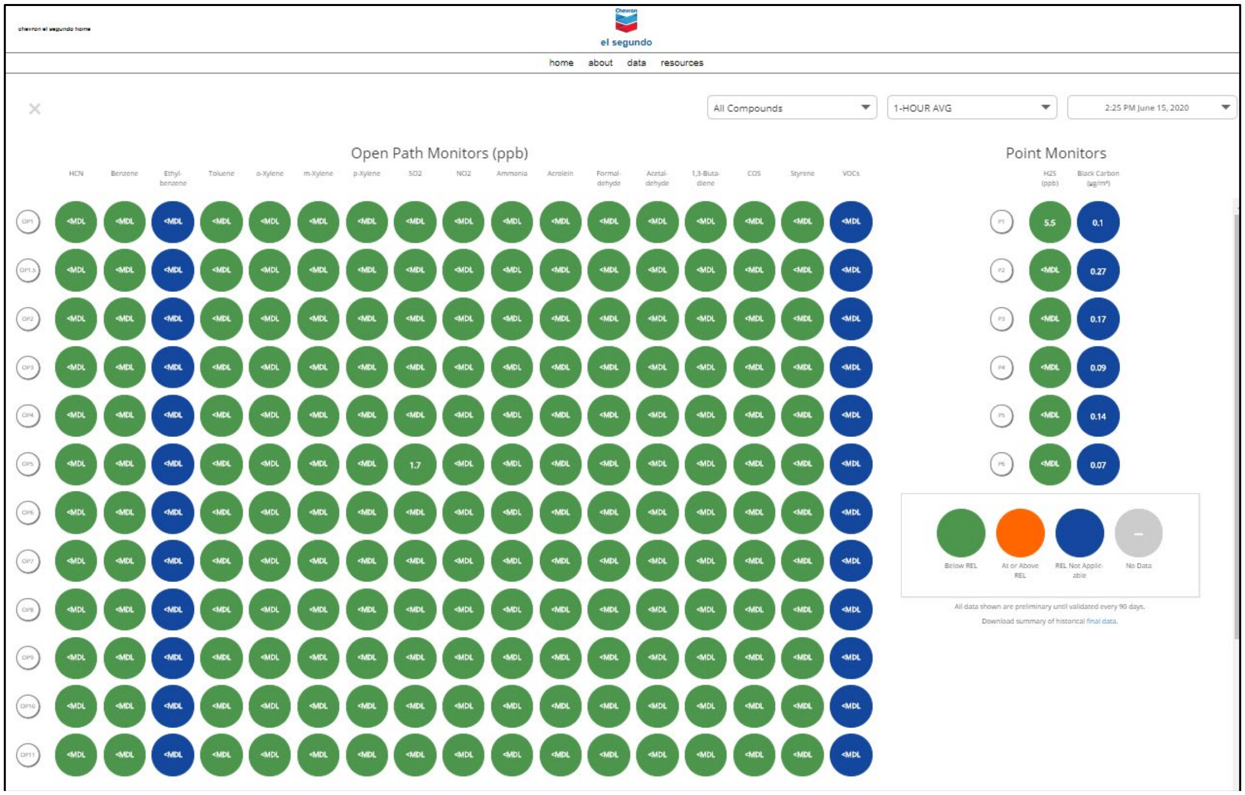
2020-06-13 02:25 PM PDT
OP6, Sulfur Dioxide: 0.7 ppb (<MDL)
OP7, Sulfur Dioxide: 1.3 ppb
OP8, Sulfur Dioxide: 0 ppb (<MDL)
OP9, Sulfur Dioxide: 0 ppb (<MDL)
OP10, Sulfur Dioxide: 0 ppb (<MDL)
OP11, Sulfur Dioxide: 0 ppb (<MDL)

Sulfur dioxide is a colorless gas with a burnt match smell. Sulfur dioxide is one of the two federally regulated "criteria" pollutants that are monitored as part of the community monitoring program. It is used as an indicator of sulfur oxides or $SO_x$ concentrations in air.

Sources of Sulfur Dioxide

**Figure 6.** Screenshot showing the landing view of the **Data** page. The default species is $SO_2$. The time series data are presented on the right side of the screen, and the map view showing concentrations at each of the paths is on the left side.

Each of the Rule 1180 species may be viewed independently or all at once using the species selection drop-down menu. When a new species is selected, the web page updates the time series graphs and data gauges to display the concentrations of the newly selected species. As each different species is selected, different infographics appear below the time series graphs to indicate sources. The map display updates with lines (to indicate open-path monitors) or dots (to indicate point monitors). To obtain the status of all species at all sites for a particular time, **All Compounds** can be selected from the species selection drop-down menu in order to show a matrix of “dots” that display data concentrations and status (below REL, above REL, REL not applicable, or no data). An example of the **All Compounds** view is shown in Figure 7. The **All Compounds** view is split between open-path measurements and point monitors because they monitor different species.



Open Path Monitors (ppb)

| | HCN | Benzene | Ethyl-benzene | Toluene | o-Xylene | m-Xylene | p-Xylene | SO2 | NO2 | Ammonia | Acrolein | Formal-dehyde | Acetal-dehyde | 1,3-Buta-diene | COS | Styrene | VOCs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OP1 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP1.5 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP2 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP3 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP4 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP5 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | 1.7 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP6 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP7 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP8 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP9 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP10 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |
| OP11 | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL | <MDL |

Point Monitors

| | H2S (ppb) | Black Carbon (µg/m³) |
|---|---|---|
| P1 | 5.5 | 0.1 |
| P2 | <MDL | 0.27 |
| P3 | <MDL | 0.17 |
| P4 | <MDL | 0.09 |
| P5 | <MDL | 0.14 |
| P6 | <MDL | 0.07 |

All data shown are preliminary until validated every 90 days.

Download summary of historical final data.

Figure 7. Screenshot of the **All Compounds** view. The rows of the matrix represent measurement sites, and the columns represent species regulated by Rule 1180. Green dots represent values below REL, orange dots represent values above REL, blue dots are associated with species that have no OEHHA 1-hr REL, and gray dots represent sites with no data.

## 5.4 Resources Section

Chevron El Segundo’s 1180 Fenceline Monitoring website contains a **Resources** section with several subsections devoted to aiding the public’s understanding of the fenceline monitoring data. These subsections include **Compounds**, **Data Flags**, **Definitions**, **FAQs**, **Feedback**, and **Historical Data**.

### 5.4.1 Compounds Subsection

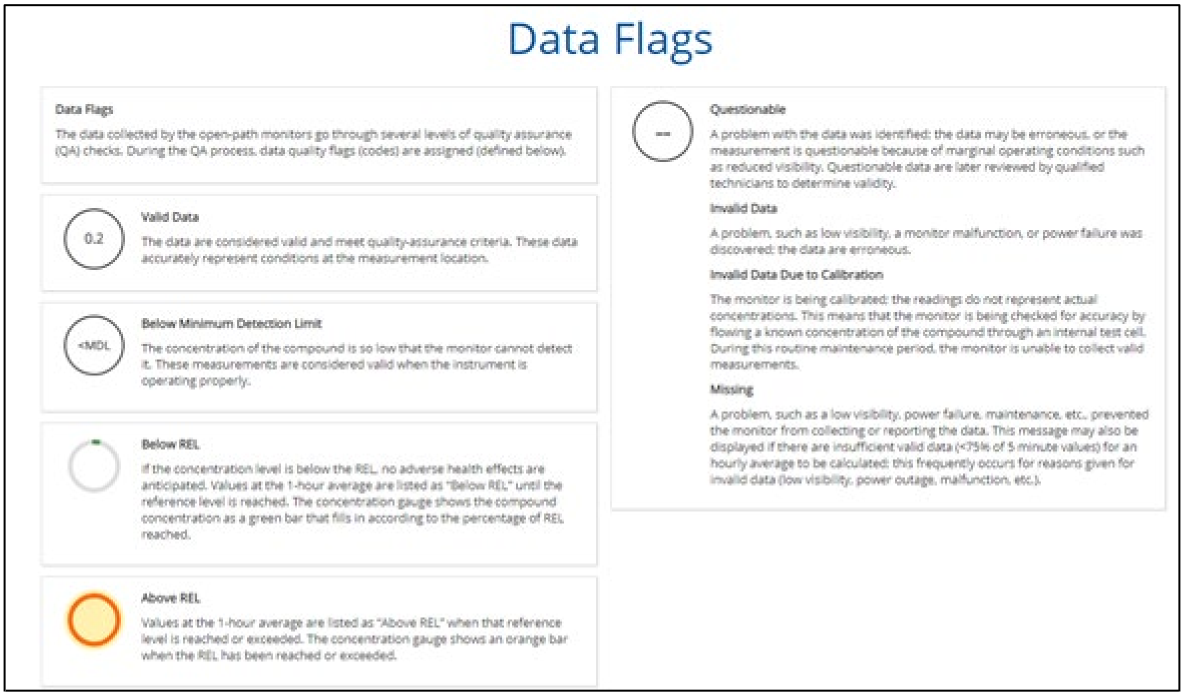
The **Compounds** subsection contains information about each pollutant measured by the fenceline monitoring system. For each pollutant, answers to the following standard questions are provided:

- What is it?
- Where does it come from?
- Why measure it?
- Where can I learn more?

Links are provided to the OEHHA website for each compound, as well as to the OEHHA website home page.

### 5.4.2 Data Flags Subsection

The **Data Flags** subsection of the website describes how and why the data appear the way they do on the **Data** page. A screenshot of the **Data Flags** section is shown in Figure 8. The data flags describe the various QC categories given to data, as discussed in Section 4.1.1. The flags described correspond to valid, below MDL (which is considered valid data), questionable ("suspect," as discussed in Section 4.1.1), invalid, or missing status. Figure 8 also indicates what data dials look like when they are above or below the REL.



Data Flags

**Data Flags**

The data collected by the open-path monitors go through several levels of quality assurance (QA) checks. During the QA process, data quality flags (codes) are assigned (defined below).

**Valid Data**

The data are considered valid and meet quality-assurance criteria. These data accurately represent conditions at the measurement location.

**Below Minimum Detection Limit**

The concentration of the compound is so low that the monitor cannot detect it. These measurements are considered valid when the instrument is operating properly.

**Below REL**

If the concentration level is below the REL, no adverse health effects are anticipated. Values at the 1-hour average are listed as "Below REL" until the reference level is reached. The concentration gauge shows the compound concentration as a green bar that fills in according to the percentage of REL reached.

**Above REL**

Values at the 1-hour average are listed as "Above REL" when that reference level is reached or exceeded. The concentration gauge shows an orange bar when the REL has been reached or exceeded.

**Questionable**

A problem with the data was identified: the data may be erroneous, or the measurement is questionable because of marginal operating conditions such as reduced visibility. Questionable data are later reviewed by qualified technicians to determine validity.

**Invalid Data**

A problem, such as low visibility, a monitor malfunction, or power failure was discovered: the data are erroneous.

**Invalid Data Due to Calibration**

The monitor is being calibrated: the readings do not represent actual concentrations. This means that the monitor is being checked for accuracy by flowing a known concentration of the compound through an internal test cell. During this routine maintenance period, the monitor is unable to collect valid measurements.

**Missing**

A problem, such as a low visibility, power failure, maintenance, etc., prevented the monitor from collecting or reporting the data. This message may also be displayed if there are insufficient valid data (<75% of 5 minute values) for an hourly average to be calculated: this frequently occurs for reasons given for invalid data (low visibility, power outage, malfunction, etc.).

Figure 8. Screenshot of the **Data Flags** subsection of the **Resources** section on the Chevron El Segundo Fenceline Monitoring website.

### 5.4.3 Definitions, FAQs, Feedback, and Historical Data Subsections

Other subsections of the **Resources** section include **Definitions**, **FAQs**, **Feedback**, and **Historical Data**. The **Definitions** section contains information about parameters, concepts, and equipment specific to the fenceline monitoring system. Similarly, the **FAQs** section contains questions and answers related to the fenceline monitoring system. There are links to the South Coast AQMD website and the OEHHA website as related to Rule 1180 and the REL levels used to initiate notifications.

# 6. Standard Operating Procedures

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

- **Attachment 1:** Standard Operating Procedures for the CEREX UV Sentry UV-DOAS
- **Attachment 2:** Standard Operating Procedures for the CEREX AirSentry FTIR
- **Attachment 3:** Standard Operating Procedures for the Magee Scientific Aethalometer Model AE33
- **Attachment 4:** Standard Operating Procedure for the Galvanic ProTech 903W
- **Attachment 5:** Standard Operating Procedures for Meteorological Instruments
- **Attachment 6:** Standard Operating Procedures for the Teledyne T640X Mass Monitor
- **Attachment 7:** Standard Operating Procedure for the SailBri Cooper Inc. Xact 625i
- **Attachment 8:** Standard Operating Procedures for Campbell Visibility Sensor (CS 120A)

# Standard Operating Procedures for the CEREX UV Sentry UV-DOAS

July 24, 2024

STI-7024

# Contents

## 1. Scope and Application

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

## 2. Introduction and Overview

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

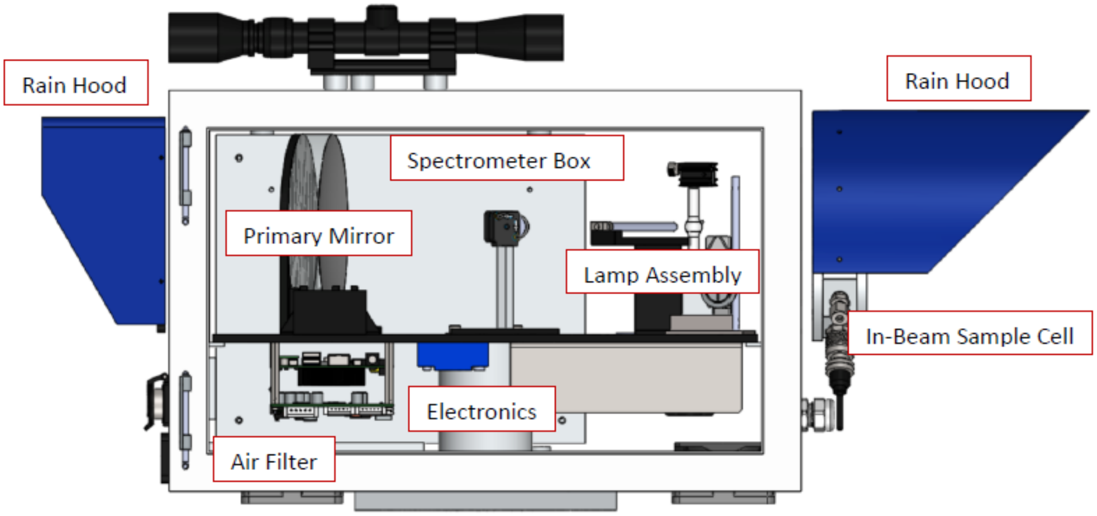


**Figure 1.** Schematic of the monostatic UV Sentry UV-DOAS analyzer.

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

## 3. Definitions

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

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

## 4. Safe Work, Hazard Identification, and Precautions

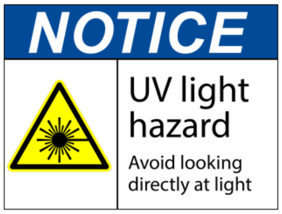
The following information is intended to provide guidance in ensuring a safe work environment.

### Operator Qualifications

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

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

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



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

### Procedure Warnings

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

### Safe Operating Precautions

Ensure that a clear escape path is identified.

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

**NOTICE**

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

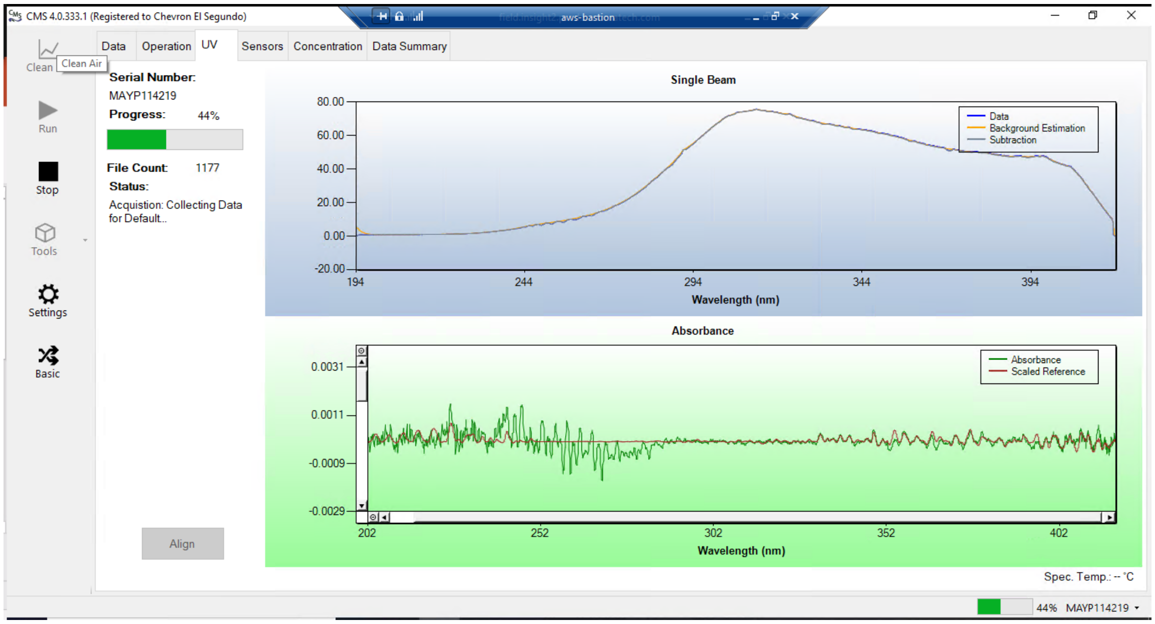
- ☐ Notify the client and project manager of maintenance tasks.
- ☐ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.

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

## 5. Routine Operations

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

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



**Serial Number:** MAYP114219
**Progress:** 44%
**File Count:** 1177
**Status:**
Acquistion: Collecting Data for Default..

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

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

Integration Time: 38

Path Length: 2.000

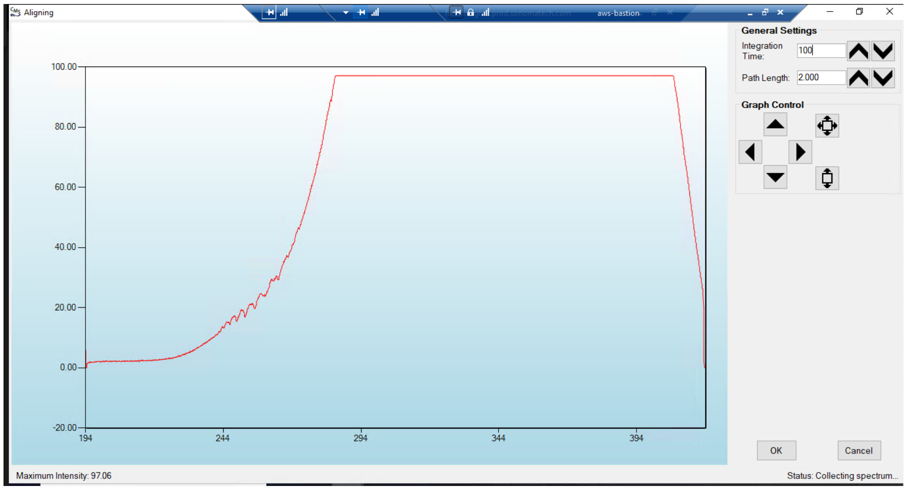
Maximum Intensity: 78.55

Status: Collecting spectrum...

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

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

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



Integration Time: 100

Path Length: 2.000

Maximum Intensity: 97.06

Status: Collecting spectrum...

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

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

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

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

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

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

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

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

## 6. Equipment and Supplies

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

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

# 7. Maintenance Activities

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

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

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

## 7.1 Visual Inspections

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

## 7.2 Filter Inspection and Replacement

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

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

**NOTICE**

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

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

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

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

### 7.2.1 Filter Installation Procedure

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

**Figure 5.** Location of filter access plate.

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

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

**Figure 7.** Filter completely removed.

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

## 7.3 Light Level Check

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

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

### *7.3.1 Check for Stray Light*

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

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

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

## 7.4 System Settings

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

## 7.5 Data Management

### *7.5.1 Archiving and Deleting Older Data*

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

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

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

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

   **Note**: This procedure excludes the Bump Test folder, which should always remain on the instrument computer.
4. Log into the brick PC located in the instrument shelter and locate the data files written from the instrument onto the external hard drive.
5. Confirm all Complete Data Summary files and Simple Data Summary files for the desired

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

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

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

### *7.5.2 Rebuilding the Instruments Indexing Preferences*

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

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

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

## 7.6 Clean Optics on Detector and Retroreflector

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

### Optic Cleaning

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

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

### *7.6.1 Retroreflector Cleaning*

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

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

***NOTICE***

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

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

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

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

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

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

### 7.7.1 Xenon UV Source Handling

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

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

### *7.7.2 UV Sentry Xenon Source Removal*

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

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

**Figure 9.** Opening the source access panel.

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

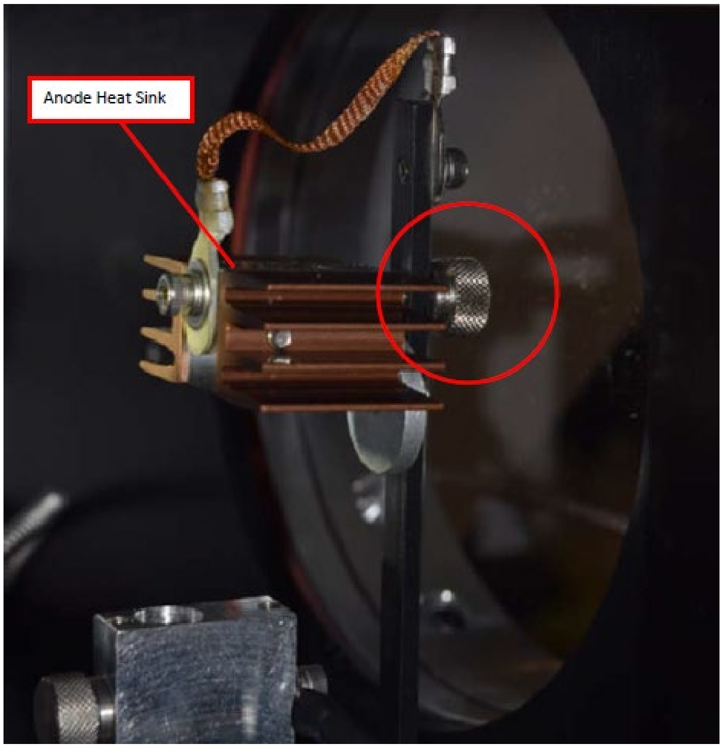

**Figure 10.** Anode heatsink at the top of the UV source.

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

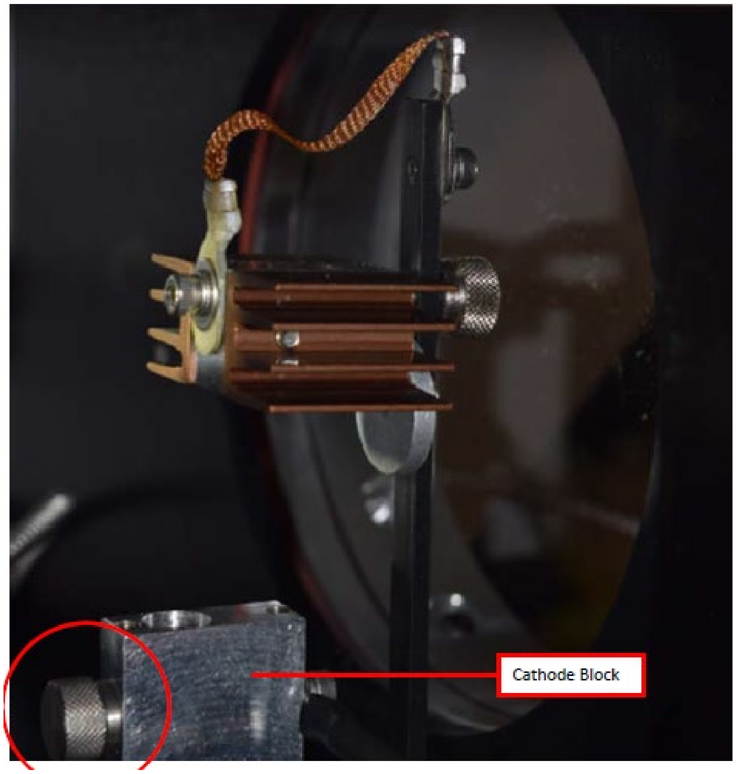

**Figure 11.** Loosen the thumbscrew on the Cathode block at the bottom of the UV source.

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

### *7.7.3 UV Sentry Xenon UV Source Installation*

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

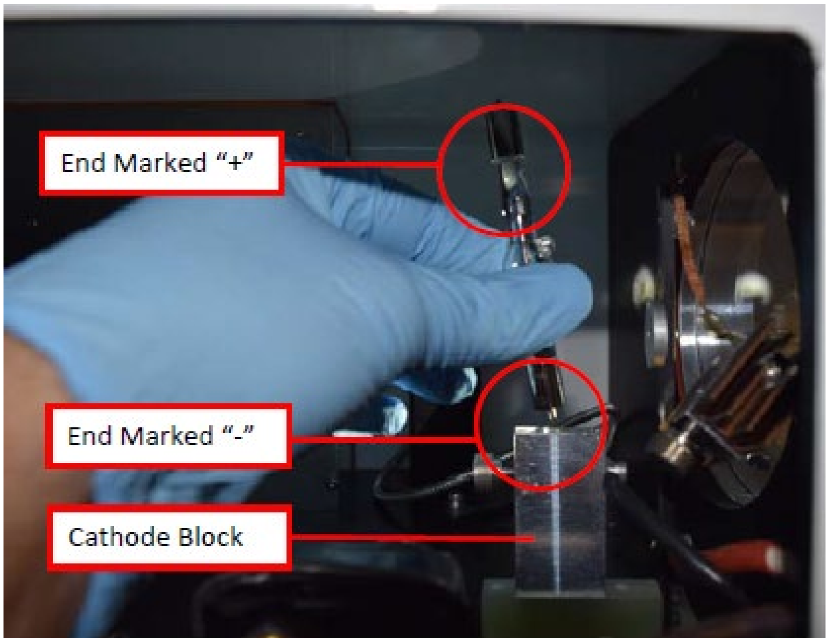

**Figure 12.** Inserting the Xenon UV Source into the Cathode block.

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

### *7.7.4 Secondary Optic Alignment*

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

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

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

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

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

## 7.8 Perform Bump Test

### *7.8.1 Apparatus Setup*

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

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

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

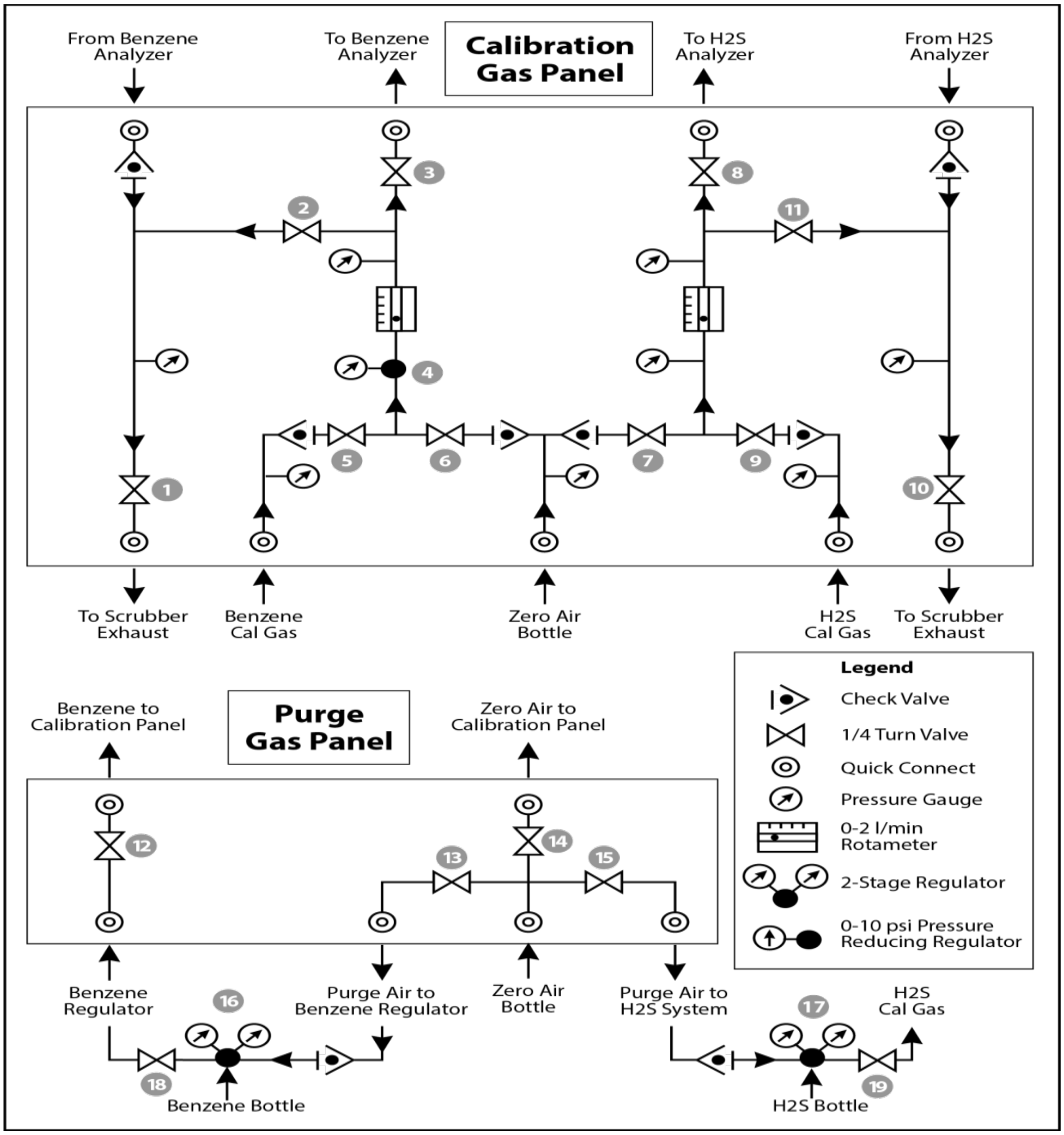

**Figure 13.** Diagram of the calibration gas panel (top) and purge gas panel (bottom) used for gas delivery.

### 7.8.2 Prepare CMS for Gas Testing

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

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

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

### 7.8.4 Configure Test Files

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

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

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

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

### *7.8.6 Bump Test with Calibration Panel*

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

#### *Background Measurement Using Zero (Purge) Gas*

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

increased.

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

### *Span Test*

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

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

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

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

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

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

### *7.8.7 Bump Test Without Calibration Panel*

#### *Background Measurement*

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

#### *Span Test*

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

4. Collect Check Gas data.
    a. Observe the concentration reported on the **DATA** tab.
    b. After the concentration becomes stable, allow the analyzer **to run until 7-15 stable measurements are made.**
    c. **Verify that the values meet the QA criteria. If the test fails QA criteria, follow the corrective actions listed at the end of this section (see: Data Evaluation, Reporting, and Corrective Action)**

*Completion of the Test*

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

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

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

### *7.8.8 Restore Normal Operation*

1. **Restore** Normal Operation.

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

2. **STOP** CMS.

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

### *7.8.9 Test Suspension*

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

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

### *7.8.10 Data Evaluation, Reporting and Corrective Action*

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

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

and the sample standard deviation (σ) as:

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

From these definitions, % error is defined as:

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

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

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

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

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

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

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

**Note:**

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

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

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

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

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

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

# 8. Data Validation and Quality Control

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

## 8.1 Daily Checks

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

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

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

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

## 8.2 Quarterly Validation

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

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

# 9. Maintenance Forms

Path:______________________________

Technician:_________________________

Date:______________________________

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

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

Upon completion sign and date:__________________________________

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

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

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

**Corrective Actions for UV-DOAS**:

# UV Sentry Fenceline Detection System

DATE: __________________ Location: __________________________________

Test Technician 1:_______________________________ 2:_______________________________

Physical one-way path length_______________ m Instrument Configuration (mono/bistatic)_______________

## Sentry Alignment and Light Levels

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

## Gas Purge System

Flow purge gas Start Time ______________________

## Prepare CMS

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

## Configure Test Files

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

## Reference Gas

Concentration ______________________ ppm
Source __________________________________________________
Date ______________________
Cylinder Pressure ______________________

NOTES:

# QA Audit Record - UV Sentry Detection System - Page 2

## Purge Flow Conditions

Start Time ______________________
Purge Gas flow ______________________ L/min
NOTES: Around 1 LPM

## Check Gas Test

Initial Gas flow ______________________ L/min
Around 1 LPM
Start Time ______________________
Collect Check Gas Data Start Time ______________________
Data Record:

| TIME | PPM | R2 |
|---|---|---|
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
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| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |

Verify Client ______________________ Init
Stop Time ______________________ Init
**O**pen the **PURGE** gas Time ______________________
Reference Concentration _________ ppm
Average Concentration _________ ppm
% error _________ %
Std Deviation _________ ppm
% CV _________ ppm

## Restore Normal Operation

**Restore running data file** ______________________ Init
Press **RUN** to begin monitoring. ______________________ Init

# Standard Operating Procedures for the CEREX AirSentry FTIR

July 24, 2024

STI-7036

# Contents

## 1. Scope and Application

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

## 2. Introduction and Overview

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

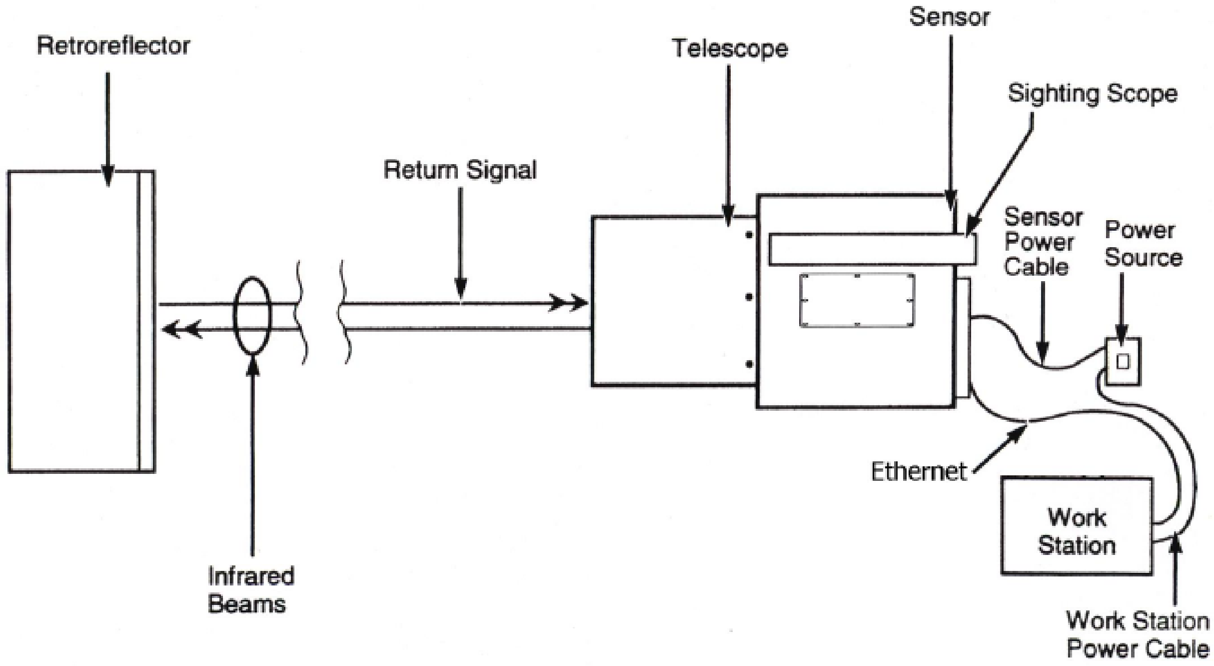


**Figure 1.** Schematic of the instrument.

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

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

## 3. Definitions

**Table 1.** List of definitions.

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

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

## 4. Safe Work and Hazard Identification

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

### Safe Operating Precautions

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

### Operator Qualifications

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

### Safe Work and Hazardous Environment Operation

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

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

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

### Procedure Warnings

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

**NOTICE**

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

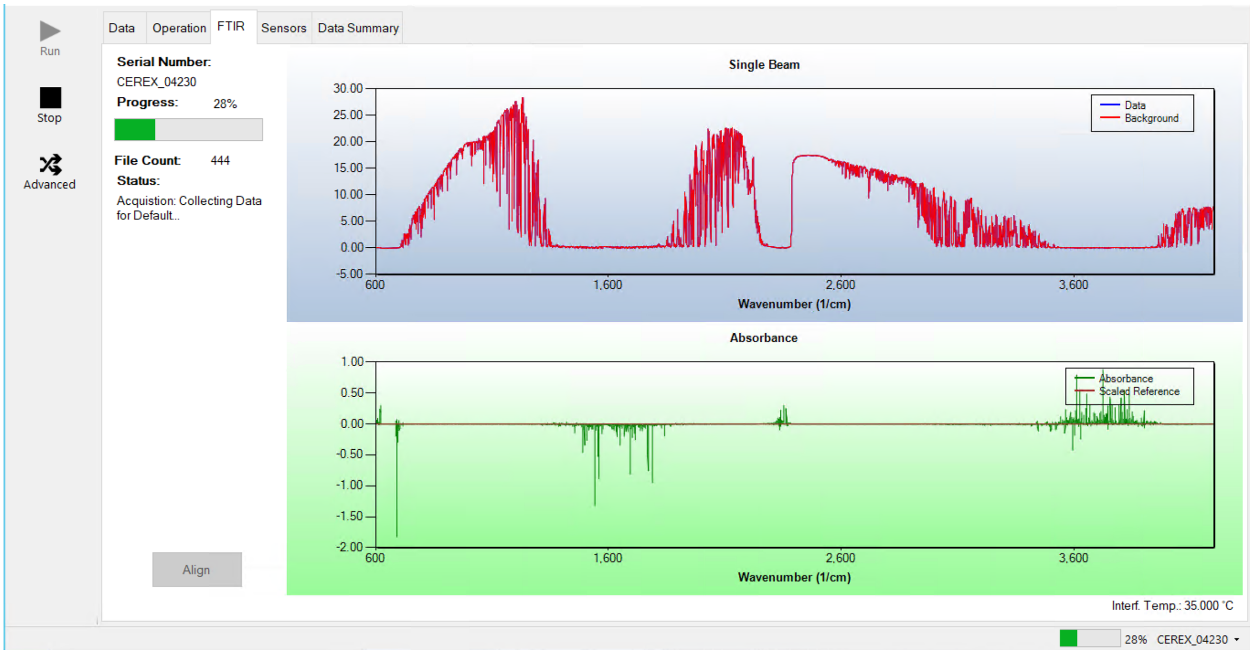
- ☐ Notify the client and project manager of maintenance tasks.
- ☐ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.

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

## 5. Routine Operations

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

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



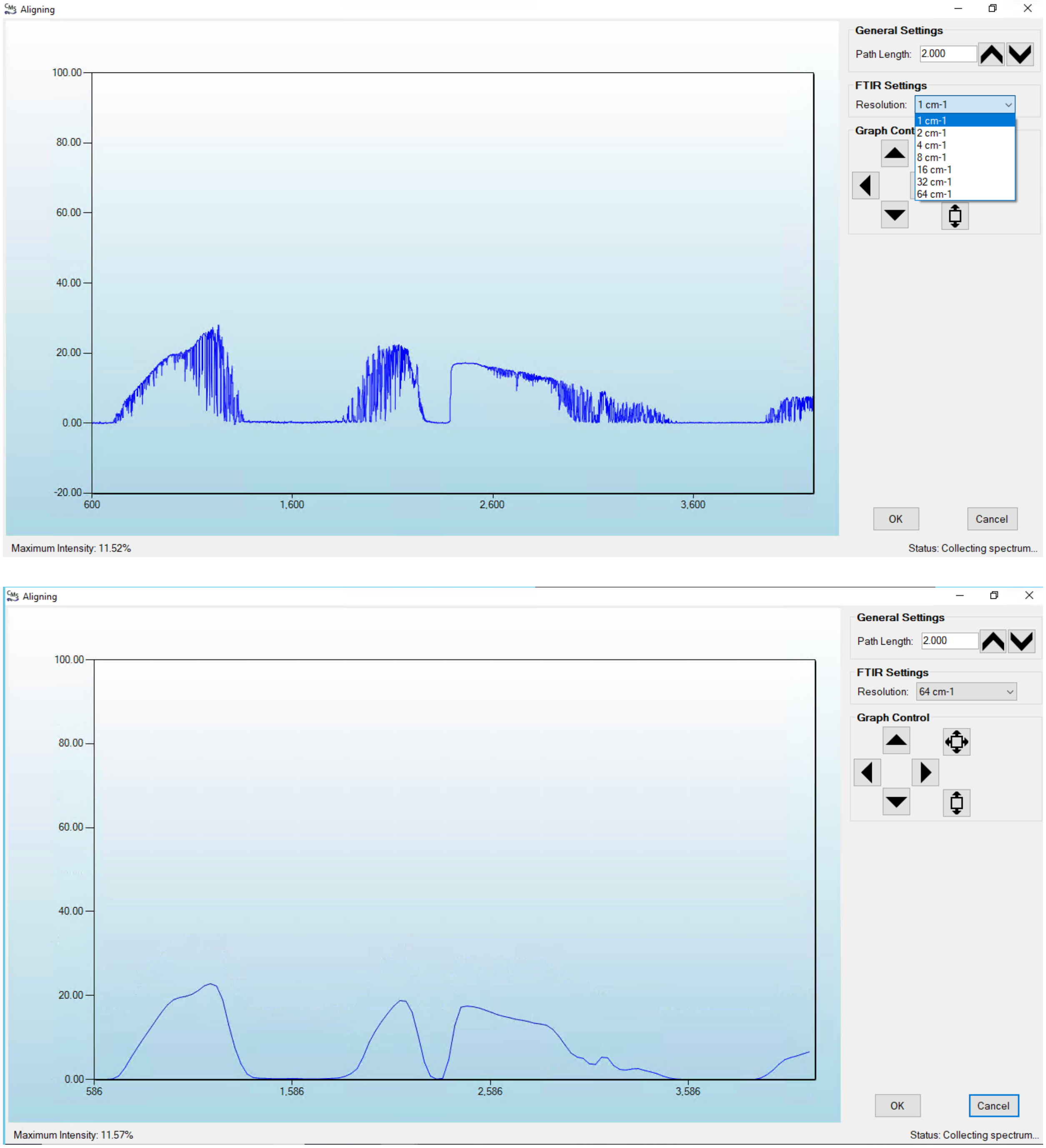
**Serial Number:** CEREX_04230
**Progress:** 28%
**File Count:** 444
**Status:** Acquistion: Collecting Data for Default...

Interf. Temp.: 35.000 °C

28% CEREX_04230

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

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



Aligning

General Settings

Path Length: 2.000

FTIR Settings

Resolution: 1 cm-1

Maximum Intensity: 11.52%

Status: Collecting spectrum...

Aligning

General Settings

Path Length: 2.000

FTIR Settings

Resolution: 64 cm-1

Maximum Intensity: 11.57%

Status: Collecting spectrum...

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

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

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

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

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

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

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

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

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

## 6. Equipment and Supplies

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

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

## 7. Maintenance Activities

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

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

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

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

## 7.1 Monthly Visual Inspections

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

## 7.2 Light Level Check

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

**Check for Stray Light**

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

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

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

## 7.3 Data Management

### 7.3.1 Archiving and Deleting Older Data

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

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

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

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

---

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

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

### *7.3.2 Rebuilding the Instruments Indexing Preferences*

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

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

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

## 7.4 Clean Optics on Detector and Retroreflector

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

### *7.4.1 Retroreflector Cleaning*

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

### 7.4.2 Window and Scope Cleaning

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

**Window Cleaning**

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

**Scope Cleaning**

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

### 7.4.3 Replace AC Fans

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

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

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

## 7.5 Perform Bump Test

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

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

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

### *7.5.1 Apparatus Setup*

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

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

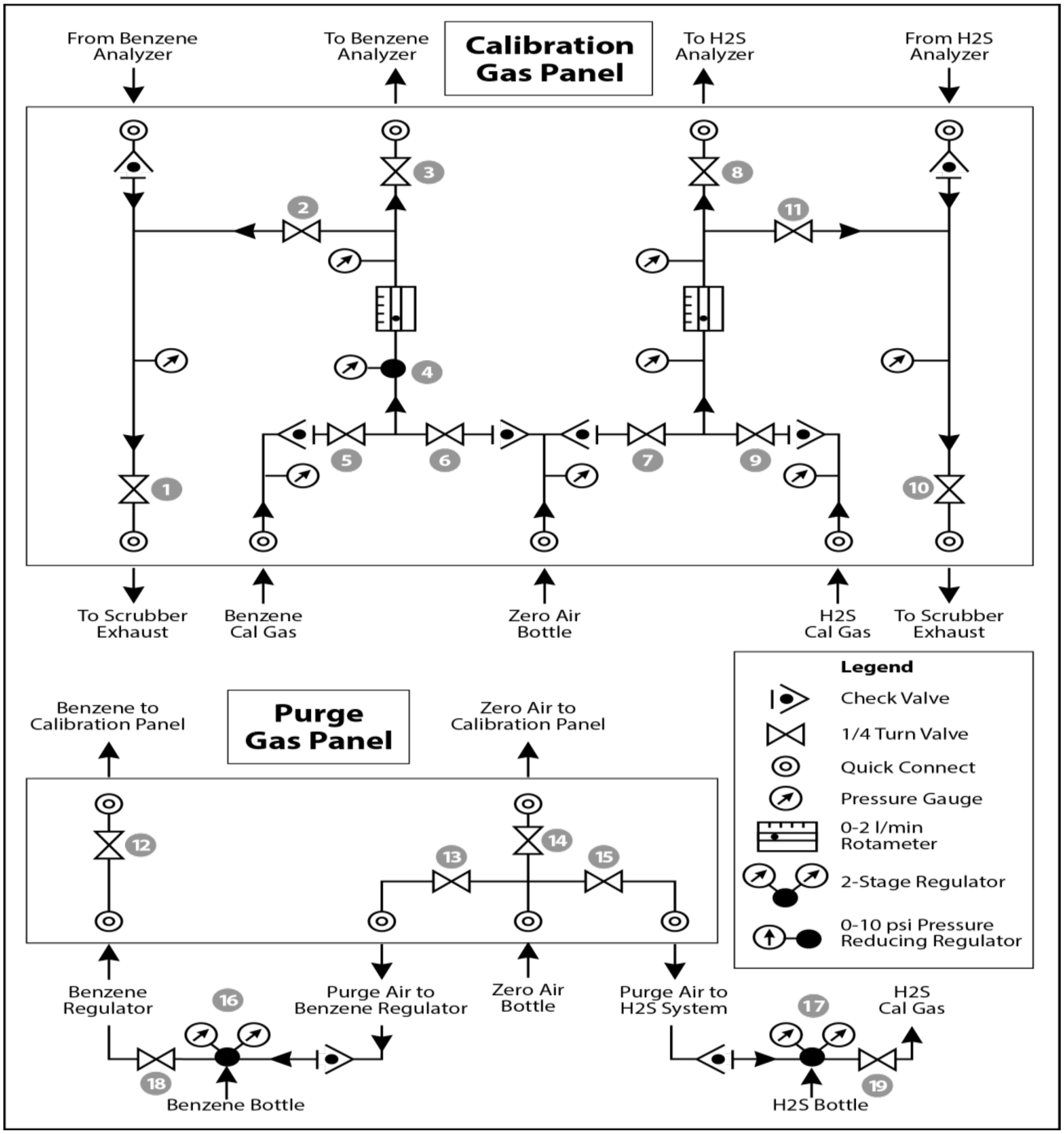


**Figure 4.** Diagram of the calibration gas panel (top) and purge gas panel (bottom) used for gas delivery. Note that the gas used will change depending on the instrument.

## Materials Required

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

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

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

### *7.5.3 Gas Test System Setup*

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

### 7.5.4 Verify Proper AirSentry Alignment

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

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

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

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

### *7.5.6 Configure Test Files*

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

### *7.5.7 Bump Test Using Calibration Panel*

#### *Gas System Purge*

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

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

### *Gas Span and QA Test*

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

*Completion of Test and Purge of Instrument Calibration Cell*

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

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

### 7.5.8 Bump Test Without Calibration Panel

*Background Measurement*

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

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

*Span Test*

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

*Completion of test*

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

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

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

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

### *7.5.9 Restore Normal Operation*

1. **Restore** Normal Operation.

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

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

#### *Test Suspension*

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

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

### *7.5.10 Data Evaluation, Reporting, and Corrective Action*

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

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

and the sample standard deviation (σ) as:

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

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

$$\% \, error = \left| \frac{\bar{x} - x_{std}}{x_{std}} \right| \times 100\% \tag{3}$$

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

$$Precision \equiv \% \, CV = \frac{\sigma}{\bar{x}} \times 100\% \tag{4}$$

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

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

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

**Note:**

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

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

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

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

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

## 7.6 Cryocooler Replacement and Calibration

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

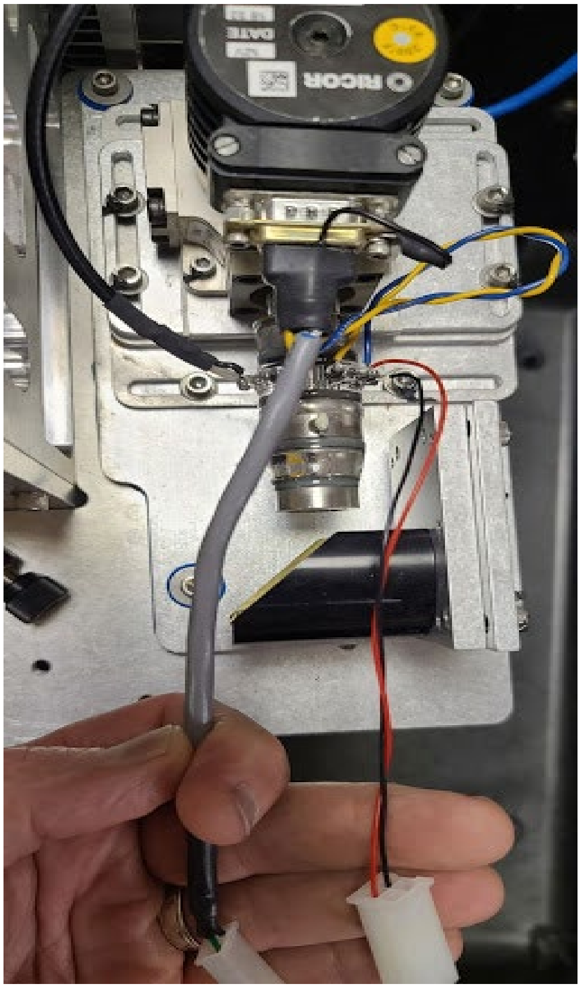


**Figure 5.** Detector assembly showing RICOR cryocooler, glass detector, DB9 connector, two white Molex connectors, and mirror.

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

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

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

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

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

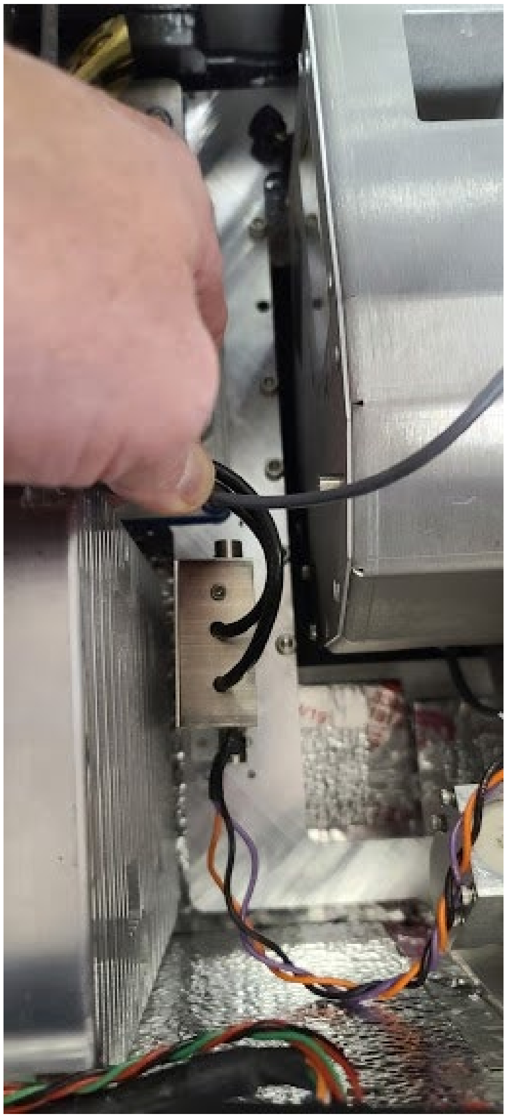


**Figure 7.** Preamp assembly (with orange, black and purple wires) between the heatsink (left) and interferometer (right).

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

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

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

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

2. Re-install cryocooler
   a. The installation process is the opposite of removal.
   b. Make sure all screws and connectors are secured and tightened.

3. Optics Calibration
   a. After replacing or installing a new detector and optics optimization is required using a small test retroreflector array.
      i. Place the test retroreflector array about 2 feet from the front of the FTIR scope. Alternatively, use a small "bike reflector" in the outgoing beam path, just before the light enters the bump test cell.
      ii. With the instrument powered on and using the Align window, set the resolution to 64 ms and align the scope to obtain the maximum signal strength possible.
      iii. Open the instrument and carefully use the beam splitter adjustment screws to maximize signal strength. This means making small adjustments to each screw until you reach the maximum signal strength (**Figure 8**).

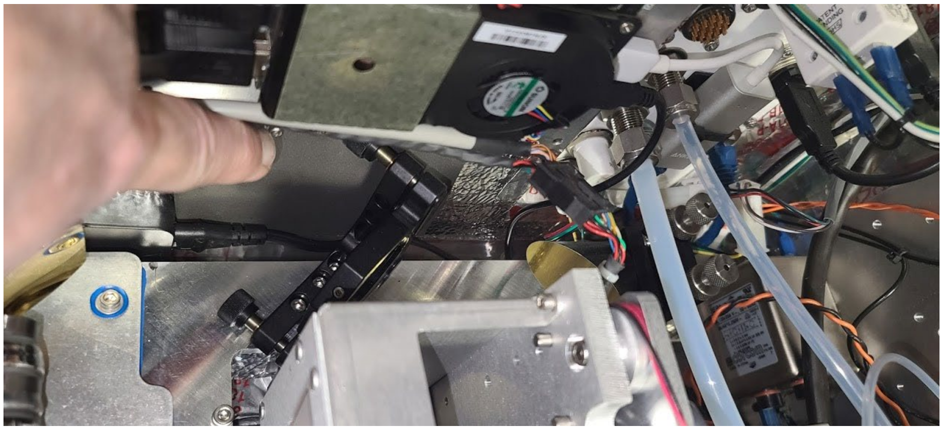


**Figure 8.** Beamsplitter (black object at 45-degree angle) with adjustment screws.

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

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

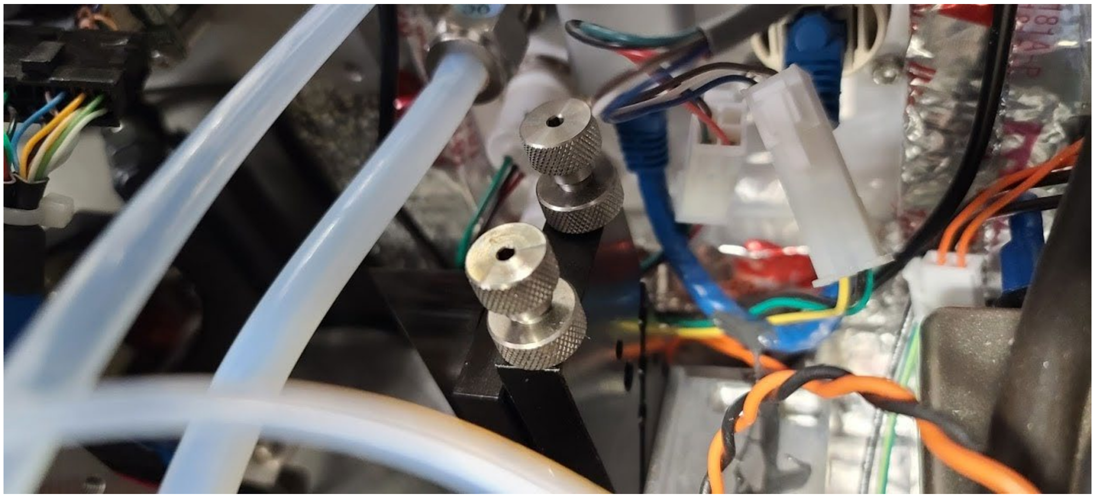


**Figure 9.** Beam steering mirror with sliver adjustment screws.

# 8. Monthly Maintenance Forms

Path:__________________________________________________

Technician:_____________________________________________

Date:__________________________________________________

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

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

☐ Notify the client and project manager of maintenance tasks.
☐ Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.
☐ Confirm that the data is invalidated on the public website before proceeding with maintenance.
☐ When maintenance is complete check the public site 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 FTIR.

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

**Corrective Actions for FTIR**:

# Cerex FTIR Air Sentry Gas Test Summary

DATE: ________________________ Location: __________________________________

Test Technician 1:______________________________ 2:______________________________

## Sentry Alignment

Signal Intensity (average) ___________________________

Signal Intensity at 966 cm$^{-1}$ ___________________________

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

% Stray Light ___________________________

## Gas Purge System

Flow purge Start Time __________________________

## Prepare CMS

Path length in the CMS Configuration _________________________ m

## Configure Test Files

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

Baseline Check _______________________ init

## Reference Gas

Concentration ______________________ ppm

Source _________________________________________________

Date _________________________________________________

NOTES:

# Gas Test Summary – Cerex FTIR - Page 2

## Purge Flow Conditions

Start Time ______________________
NOTES:

## Check Gas Test

Initial Gas Flow ______________________ L/min
Start Time ______________________
Collect Check Gas Data Start Time ______________________
Data Record:

| TIME | PPM | $R^2$ |
|---|---|---|
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
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| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |
| ___________________ | _________ | ________ |

Verify Client ______________________ Init
Stop Time ______________________ Init
Open the PURGE Gas Time ______________________
Reference Concentration _________ ppm
Average Concentration _________ ppm
% error _________ %
% Spectral Match _________ %
Standard Deviation _________ ppm
Estimated MDL (3X Standard Dev) _________ ppm

## Restore Normal Operation

**Restore running data file** _______________________ Init
Press **RUN** to begin monitoring. _______________________ Init

# Standard Operating 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.

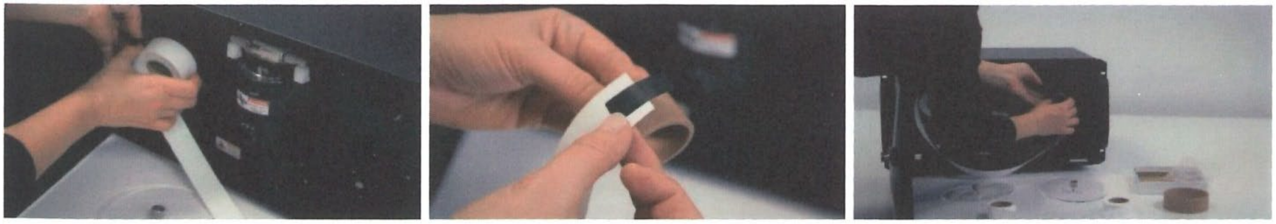
## 5.3. Install New Filter Tape Roll

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

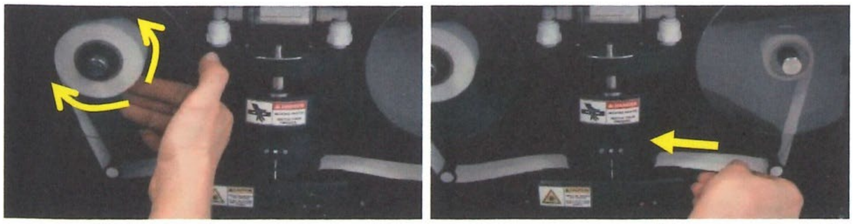
When you observe an instrument warning of tape change needed, follow these instructions to change the tape. This should occur roughly every 6 weeks or so.

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.

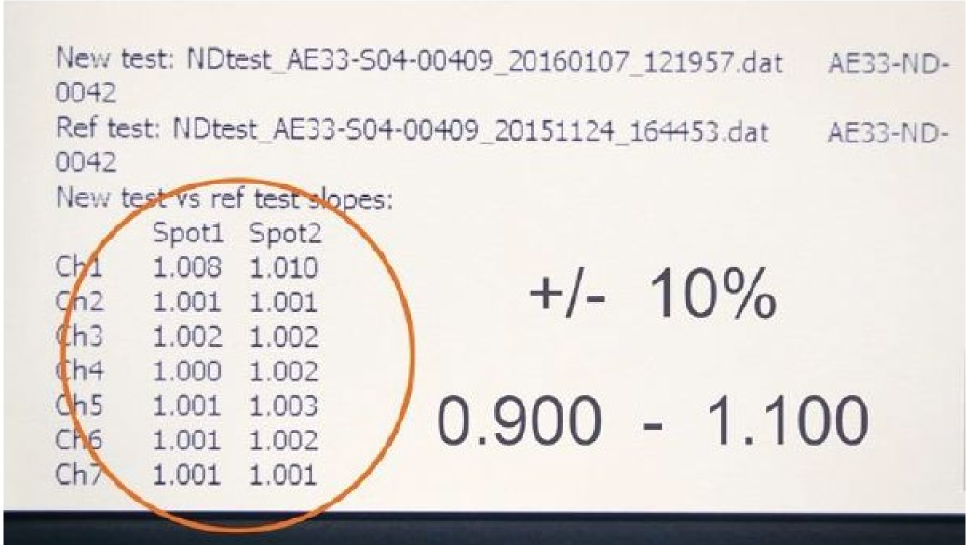
1. From the **Operation/General** screen, press **Inlet Leakage Test**.
2. Follow the instructions on the screen to insert the Flow Calibration Pad.
3. Measure the flows with an external flow meter at the two points.
4. When the test is finished, a report is generated. The leakage should be less than 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



```
New test: NDtest_AE33-S04-00409_20160107_121957.dat    AE33-ND-
0042
Ref test: NDtest_AE33-S04-00409_20151124_164453.dat    AE33-ND-
0042
New test vs ref test slopes:
        Spot1  Spot2
Ch1     1.008  1.010
Ch2     1.001  1.001
Ch3     1.002  1.002
Ch4     1.000  1.002
Ch5     1.001  1.003
Ch6     1.001  1.002
Ch7     1.001  1.001
```

+/- 10%

0.900 - 1.100

## 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 Galvanic ProTech 903W

October 17, 2025

STI-7036

APPROVED:

Sonoma Technology date

Fenceline Monitoring Refinery Representative date

## Contents

## 1. Summary

This document describes the steps necessary to maintain the Galvanic ProTech 903W $H_2S$ analyzer. The procedure is intended to ensure that the equipment is performing to expectations and that the detection and communication links are functioning correctly.

## 2. Safety and Precautions

**This equipment must be used as specified by the manufacturer or overall safety will be impaired.**

**Access to this equipment should be limited to authorized, trained personnel ONLY.**

**Observe all warning labels on the analyzer enclosures.**

**Make sure that the selected temperature is compatible with the permeation device that will be in use.**

**Certified permeation devices should be used only at the temperature specified on the certificate. Using any permeation device beyond its recommended temperature range could result in the destruction of the device by explosion and/or changes in the membrane characteristics. If in doubt, contact the manufacturer.**

**An exhaust port must be provided downstream of the sensor so that there is no backpressure on the calibrator.**

**This system, when operating in its normal mode, and/or when it is being serviced, maintained, installed, and commissioned contains items which may be hazardous to humans if handled or operated incorrectly or negligently. These items include, but are not limited to**
**a) High Voltage Electrical Energy**
**b) Toxic and Explosive Gases**

**NOTICE**

**Please check off the following steps needed to minimize false notifications to our clients and the public.**

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

**Note that field measurements are frequently carried out on off hours (early morning), so please give the web team at STI enough "heads up" so they can disable the REL notifications.**

## 3. Equipment and Supplies

Before beginning maintenance, make sure to have all of these materials:

- Analyzer Tape Replacement
- Bottle of lab grade 5% acetic acid and a small funnel
- Bottle of rubbing alcohol and a package of Q-tips
- Can of compressed air
- Nitrile gloves
- Basic hand tools
- Laptop with ProTech software functionality
- NIST traceable flow meter capable of reading 10-10,000 cc/min

If you will be using a dilution system with compressed gas and Mass Flow Controllers (MFCs), you should have the following equipment:

- Adjustable 1/4" needle valve and Teflon tubing
- 1/4" Swagelok tee fitting (or equivalent)
- A high flow MFC and a low flow MFC
- Air pump with 3 lpm capacity.
- Zero filter cartridge (activated charcoal especially suited for removing $H_2S$)
- Extension cord to connect to power outlet

If you will be using a permeation tube calibration system, you should have the following equipment and supplies:

- Adjustable 1/4" needle valve and Teflon tubing
- 1/4" Swagelok tee fitting (or equivalent)
- 1/4" to 1/8" union for connecting to Galvanic
- Span Check ™calibration unit
- Power Supply/Charger
- Permeation tube adapter bottle
- Zero filter cartridge (activated charcoal especially suited for removing $H_2S$)
- Calibration gas scrubber (absorber) filter
- Teflon output tube
- Instruction Manual(s)
- Permeation tube
- Activated charcoal scrubber
- Portable pump capable of pushing air through the activated charcoal with a flow rate greater than 1 lpm

# 4. Routine Field Operation and Maintenance: Monthly Checks

The routine maintenance of the ProTech 903W is to be performed coinciding with changing the tape in the analyzer. This is typically done every one to two months, though it is recommended that the tape length reported by the analyzer be monitored to ensure the tape never runs out.

If any hardware failure is to occur with the instrument, contact Galvanic for advice before proceeding to do a field repair.

Contact Galvanic Applied Sciences or Sonoma Technology to receive a digital copy of the manual.

## 4.1. Tape Replacement

The sensing tape is consumed during the measurement process and must be replaced on a periodic basis. The amount of tape remaining is indicated on the **Analysis** tab of the GUI and the **GEN** menu on the hand-held controller. In addition, an alarm will be presented on the **Alarms** tab of the GUI when the tape level is low.

To replace the tape:

a. Check the display for any alarms.

b. Disable alarms by pressing the **BYPASS** button on the hand-held controller

c. Figure 1 presents the open enclosure with various components identified. Remove the screw-on disks (not shown) from the supply reel (1) and take-up reel (2).

d. Remove used tape. Be sure to wear nitrile gloves whenever handling the tape to prevent contamination of the tape and personal exposure to lead contained in the tape.

**Figure 1.** Tape reels and compression head.

e. Pull back the Compression Head and inspect the Sample Chamber for paper dust and dirt. If necessary, clean the compression head and sample chamber with rubbing alcohol and a Q-tip. Dry using compressed air.

f. Take a new reel of tape and remove the adhesive tape securing the end. Place the tape reel on the supply reel. Make sure the tape is installed so that the loose end hangs down on the left side of the reel, not the right.

g. Thread the tape over the lower sample chamber guide pin (3). Push the compression head (4) back and slide the tape behind the compression head. Ensure that the tape is flat against the groove in the sample chamber (8) and has no creases.

h. Pull the tape up over the upper sample chamber guide pin (5).

i. Thread the tape over the black aluminum / grey plastic capstan of the pulse counter (6). (Note that this capstan may be either aluminum or plastic).

j. Fold over the first inch of the tape, and then slide this folded end of the tape into the slot on the take-up reel (2), as shown in Figure 2.

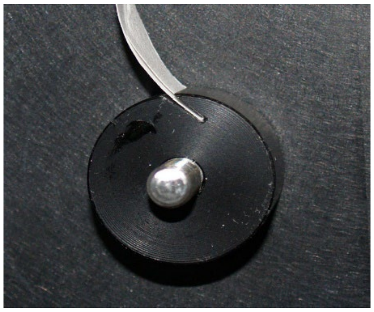


**Figure 2.** Feeding tape into upper reel

k. Replace the screw-on disks onto the supply and take-up reel.

l. Take up any slack in the tape by rotating the tape reel on the supply reel clockwise until the tape is tight. The correct installation of tape on the analyzer is shown in Figure 3. The image on the left shows the completed tape installation without the anti-coning disks, and the one on the right shows the tape installation with the disks.

m. Advance tape a few inches with the **TAPE ADV** key.

n. Check the tape for proper take-up.

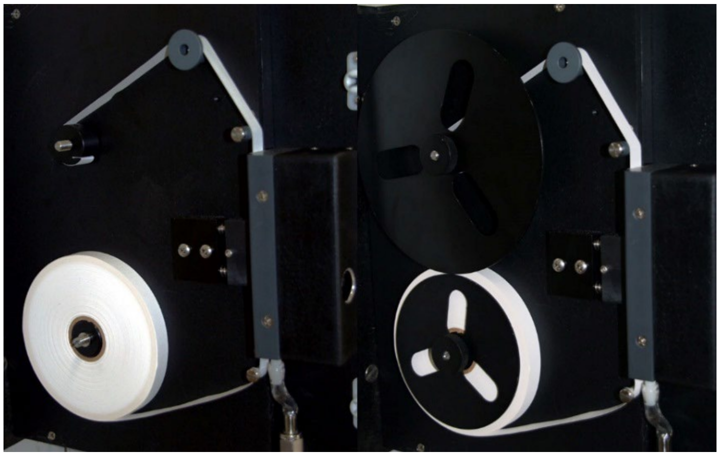


**Figure 3.** Installed tape reels.

o. Re-calibrate the sensor by selecting the **Sens** on the **GEN** menu using the key pad. Press the **EDIT** key and press **ENTER** key to toggle the parameter to **ON**. It will immediately toggle back off, but will continue with the calibration process. The voltage will fluctuate for several seconds. Once it stabilizes, take note of the voltage.

p. Check that the mV reading is 0±10 mV at the start of the cycle. If it is outside this range, advance the tape again and retry the sensor calibration.

q. Reset the tape length to 328 ft through the keypad or the GUI.

r. Take the instrument back out of Bypass mode by pressing the **Bypass** button on the handheld controller.

s. Check the flow on the flowmeter. It should be measuring around 137 sccm.

t. Wait for the instrument to do at least two measurements to ensure that it is working properly.

u. Perform a response check and calibration (if needed) using either a gas divider (Section 5) or a permeation tube (Section 6).

### 4.2. Humidifier Refill

The humidifier must be inspected with every tape replacement to ensure it has enough acetic acid to function properly. The acid is stored in a clear container on the bottom right of the instrument's interior. The acid level must be at the line on the container. If it is below the line, the container must be refilled back up to the line. To refill the acid:

a. Using the controller, put the instrument into Bypass mode by pressing the **Bypass** button.

b. Unscrew the plug from the top of the container and place a funnel into the hole.

c. Pour lab grade 5% acetic acid into the container until it is filled to the line.

d. Wipe away any spilled acid and replace the plug.

e.

f. Take the instrument back out of Bypass mode by pressing the **Bypass** button on the controller.

g. Check the instrument for one to two measurements to ensure it is functioning properly.

## 5. Response Checks and Calibrations Using a Gas Divider

The Galvanic should be calibrated using the procedure described in this section. The procedure described here requires the instrument be zeroed, span tested, and zeroed again. Galvanic suggests calibrating the instrument following a tape change.

Due to the temperature dependent response of the Galvanic ProTech 903, it is important to develop calibration procedures in which the temperature variation during the test is minimized, similar to regular operation of the instrument. The Galvanics are typically housed in an analyzer cabinet equipped with climate control. This cabinet remains closed during normal operation of the instrument. This procedure describes how to perform a calibration while keeping the door to the cabinet shut. The diagram below shows a schematic of the system during such a calibration.

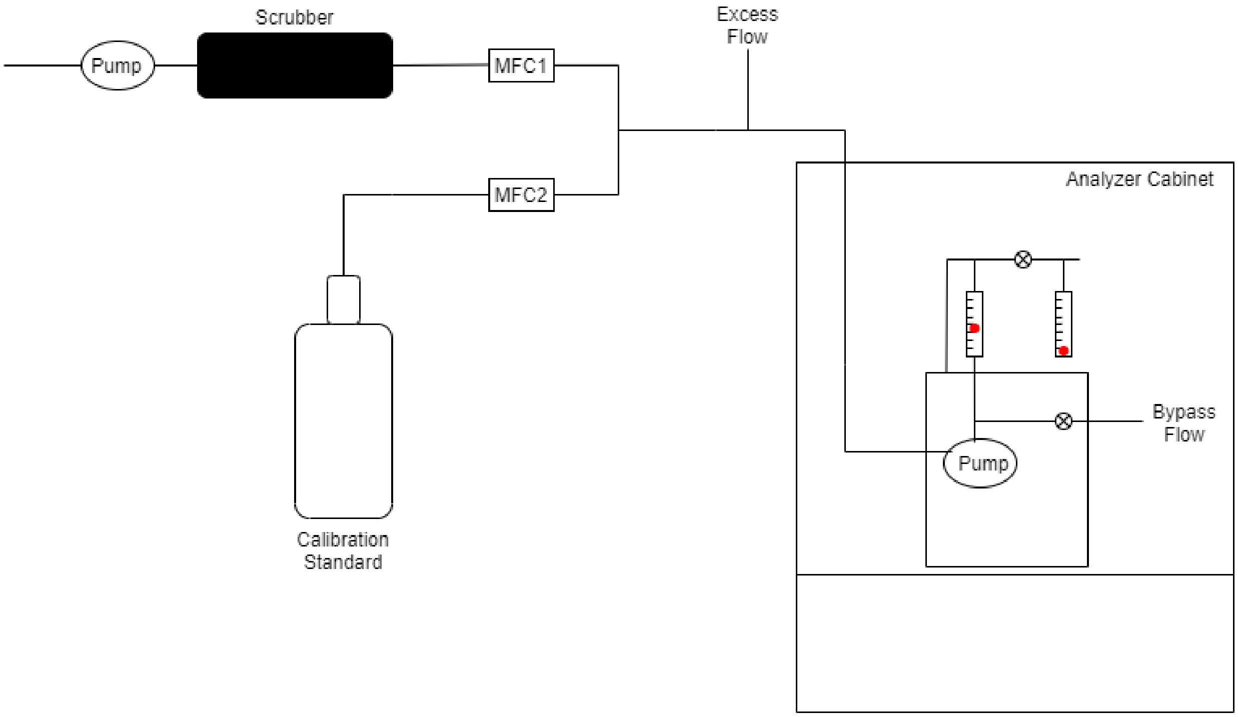


**Figure 4.** Gas delivery apparatus and Galvanic instrument flow diagram.

## 5.1. Zero Procedure

**NOTE** Door is to remain closed during the entirety of this procedure. If you need to open the door briefly to get the notebook, allow 10 minutes for cabinet temperature to equilibrate.

1. Verify proper instrument operation by remotely connecting to the data logger or connecting to the USB bulkhead on the side of the cabinet.
2. Disconnect existing sample inlet cone if applicable.
3. Connect a laptop to the USB bulkhead to connect to the Galvanic analyzer and the Campbell logger.
4. Open the ProTech software and connect to the analyzer on your laptop. You may have to change the settings to make sure the correct COM port is selected.
5. Check the internal MFC flow to make sure it is within 10% of set flow (by accessing LoggerNet from a laptop).

6. Assemble external gas delivery apparatus including pump, scrubber, MFCs, compressed gas standard, and excess flow tee.
7. Turn on the pump connected to the scrubber and adjust the flow to 3 slpm. Ensure the flow is greater than the inlet flow! Inlet flow should be around 2 slpm. If the flow is not greater than the inlet flow, you may need to close the bypass valve on the analyzer. This will introduce scrubbed air into the sample inlet.
8. Let the readings stabilize for one or two 5-min cycles.
9. If the zero reading is outside the range stated in the QAPP, change the zero-offset using the ProTech software.
10. Collect 7 zero readings, average them, and use this to record or change the zero offset.

## 5.2. Span Procedure

**NOTE** Door is to remain closed during the entirety of this procedure. If you need to open the door briefly to get the notebook, allow 10 minutes for cabinet temperature to equilibrate.

1. Connect a laptop to the USB bulkhead to connect to the Galvanic analyzer and the Campbell logger.
2. Open the ProTech software and connect to the analyzer. You may have to change the settings to make sure the correct COM port is selected.
3. Calculate span gas concentration. The following is an example for delivery of 50 ppb calibration gas:

$$CalGasConc = \frac{MFC2\ Flow}{MFC2\ Flow + MFC1\ Flow} \times Bottle\ Conc = \frac{50\ sccm}{50\ sccm + 5{,}000\ sccm} \times 5ppm = 0.0495\ ppm\ or\ 49.5\ ppb$$

4. Following the example in step 3 (you will need to adjust the values to match your desired concentration), with MFC1 (gas divider major flow) still set to deliver zero air at 5,000 sccm, turn on the calibration gas flow (MFC2, gas divider minor flow) to deliver 50 sccm through MFC2.
5. Once the concentration reading on the Galvanic has stabilized, allow the measurement to continue for 30 minutes, equivalent to 7 readings.

   The accuracy of the calibration is termed “% deviation” and is calculated as

$$\%Deviation = \frac{Analyzer\ Value - Reference\ Value}{Reference\ Value} \times 100\%$$

   The acceptable limit for $H_2S$ calibrations is documented in the QAPP.

6. If the instrument is outside the acceptable limit, calculate the new gain according to the following equation:

$$New\ Gain\ Factor = \frac{Calibration\ Gas\ Concentration\ (ppb)}{Current\ Analyzer\ Reading\ (ppb)} \times Current\ Gain\ Factor$$

   In the case that the instrument is outside the acceptable limit, perform a recalibration. If repeated measurements appear nonconforming, initiate corrective action investigation.

7. Adjust the gain in using the ProTech software on a laptop and record in the instrument logbook and maintenance forms.
8. Turn off calibration gas flow.
9. Zero the instrument again using the procedure described in Section 5.2, steps 6-8.

### 5.3. Multipoint Calibration Procedure

**NOTE** Door is to remain closed during the entirety of this procedure. If you need to open the door briefly to get the notebook, allow 10 minutes for cabinet temperature to equilibrate.

1. Connect a laptop to the USB bulkhead to connect to the Galvanic analyzer and the Campbell logger.
1. Open the ProTech software and connect to the analyzer. You may have to change the settings to make sure the correct COM port is selected.
2. Repeat steps 3-5 of the Span procedure (Section 5.2) using three different concentrations specified in the QAPP. Use the span check form noting each concentration in the provided field. Do not run zero in between concentration runs.
3. If the three-point check fails based on the criteria listed in the QAPP, adjust the gain by using the middle concentration as a reference. Use the ProTech software on a laptop to make the adjustment. Record this in the instrument logbook and maintenance forms.
4. Turn off calibration gas flow. Zero the instrument again using the procedure described in Section 5.1, steps 6-8.
5. If an adjustment was necessary, run the three-point check again. Record the results using the span check form noting each concentration in the provided field.
6. Turn off calibration gas flow. Zero the instrument again using the procedure described in Section 5.1, steps 6-8.

## 6. Calibration Check Using Permeation Tubes

### 6.1. Overview

If a permeation device is used for the calibration of $H_2S$. Two types of portable permeation device calibration systems are described here: a KIN-TEK SpanChek 8700 and a VICI Metronics

Dynacalibrator Model 120. These portable calibration gas generators can be used with the permeation devices to generate the zero and span checks. Permeation devices contain the pure calibration chemical in a two-phase equilibrium between the gas and liquid phases. The permeation device emits the calibration compound through a semi-permeable membrane at a known constant rate, provided the temperature is constant. One of the main functions of the calibration systems is to keep the permeation device at a fixed temperature with a known carrier gas flow so that a constant, known gas concentration is generated. When the permeation devices are not being used, they are to be kept inside the protective container provided by the manufacturer. As recommended in the BAAQMD's Manual of Procedures (MOP) volume 6 section 1.5.3, they are also to be stored under dry nitrogen at a temperature between 20° and 25°C. Prior to calibration, the permeation device will be allowed to equilibrate for 24 hours, as specified by the MOP. The permeation devices will be certified every six months either gravimetrically or against an acceptable reference method.

A copy of the MOP can be found at: https://www.baaqmd.gov/~/media/files/records/mop/vol-6/vol6.pdf?la=en

The flow system of the Galvanic 903W is shown in **Figure 4**. Both the Dynacal and Kin-Tek calibration systems have internal pumps that deliver a set amount of flow. The flowrate from the calibration system is a determining factor of the calibration gas concentration and thus cannot be changed without changing the concentration. The general strategy for calibrating the Galvanic with the calibration systems described here is to provide a higher flow rate of gas than the Galvanic is set to take (93 cc/min, rotameter set at 3). Therefore, the excess flow from the calibrator must be carried away using a needle valve ("excess flow" by the "cal gas inlet" in Figure 4).

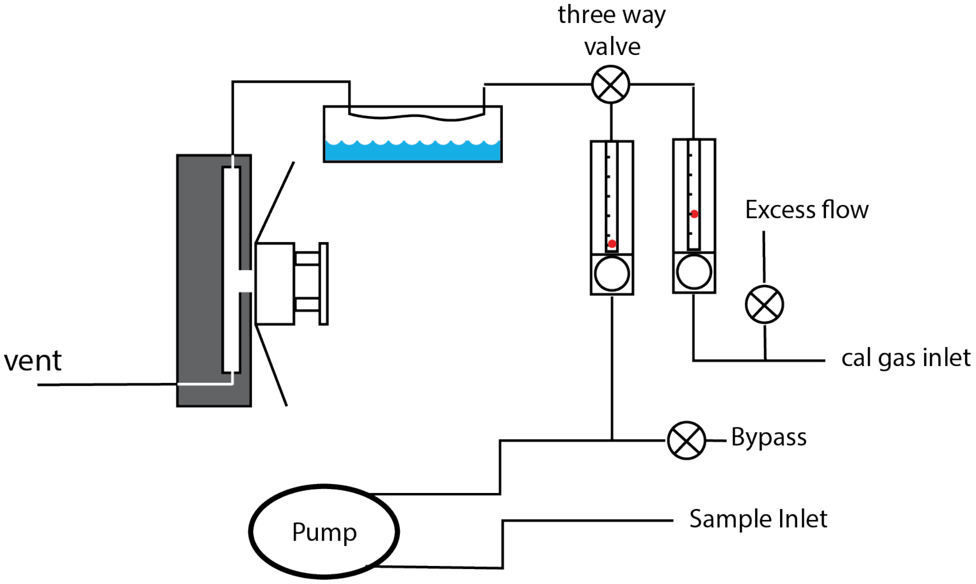


**Figure 5.** The flow system of the Galvanic Applied Sciences ProTech 903W.

## 6.2. Kin-Tek SpanChek 8700

The Kin-Tek permeation tube calibrator consists of a temperature-controlled permeation tube chamber, a pump, and a battery. **Figure 5** shows a Flow Diagram (SpanChek) dilution calibrator. The pump generates a flow of air through a scrubber to serve as dilution air that travels into the temperature-controlled permeation chamber. There are no flow meters provided with the calibration system, so it is critical that the technician carefully verify flowrates prior to calibration using a NIST traceable flow meter. The temperature control is shown in **Figure 6**.

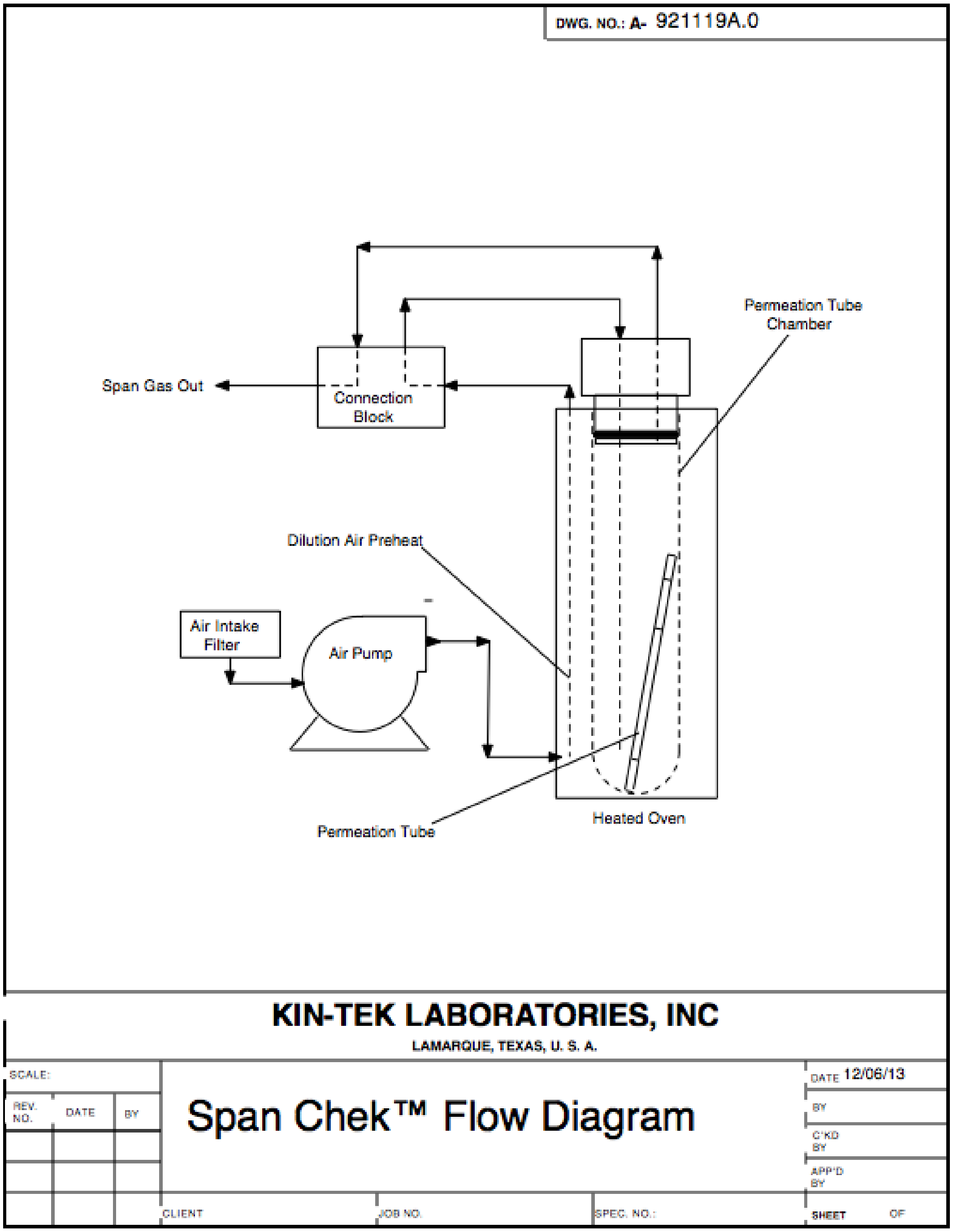


Figure 6. Schematic of the Kin-Tek SpanChek 8700 dilution calibrator.

**Figure 7.** The temperature control of the SpanChek.

The calibration gas concentration is calculated via the following equation:

$$\boldsymbol{C}=E/F$$

Where, C is the concentration in ppm, E is the emission rate of the permeation tube in nanoliters per minute and F is the dilution flow in cc/min.

The flow (F) required to give the desired concentration is calculated as:

$$F = \frac{E \times K_{25}}{C}$$

Where $K_{25}$ is the conversion constant for the compound in the tube:

$$K_{25} = 24.25 \text{ x MW}$$

Where MW is the molecular weight in g/mol (for $H_2S$ it is 34.081 g/mol).

When the controlled flow of dilution air mixes with the permeate flow at the specified temperature, a precisely known, trace concentration gas mixture is formed. The typical temperature set point is 30°C and the typical flow set point is 610 cc/min to generate calibration gas at 60 ppb.

### *6.2.1. Set the Dilution Flow*

1. Connect a suitable flow meter to the output so the span gas from the SC8700 flows through the flow meter
2. Loosen the locking collar on the flow adjust screw located adjacent to the air intake hole on top to the SC8700.
3. Using this adjustment screw, set flow to the required level as observed on the flow meter.
4. When the flow is properly set, retighten the locking collar on the flow adjust screw.

### 6.2.2. Initial Equilibration

1. Set the SC8700 on its power supply/charger base.
2. Plug the power supply into the side of the SC8700 using the 4-prong plug.
   Plug the power supply into an A.C. outlet (either 115/60 or 230/50, depending on voltage requirements.)
3. GENTLY place the permeation device in the chamber, spacer end first. The wafer side should be facing upward.

**NOTE: be careful when placing the permeation device in the GLASS permeation chamber. Wafer devices are heavy and can break the permeation chamber if carelessly dropped inside.**

4. Insert and turn the key to switch on the SC8700. At this point the power light should come on, the heater light should come on, and you should hear the air pump
5. Set temperature to what is written on perm tube for desired concentration.
6. Allow 2 hours for warm-up and stabilization
7. The temperature control system is on-off acting. Thus, the heater light will burn steadily and then go out. You should be able to observe the heater cycling
8. Check the oven temperature to be sure it is not overheating.
9. For an accurate temperature reading, insert a precision thermometer into the oven block. A thermometer hole is provided in the top of the block. This hole will accept most standard laboratory thermometers. The thermometer should make close contact with the block. To ensure good contact, use a heat transfer medium such as water or silicone grease

### 6.2.3. Connections to Monitor and Calibration

This SOP is written for use with the Galvanic Applied Sciences ProTech instrument, which uses a sample pump to pull approximately 93 cc/min (rotameter setting of 3, see page 27 of the Galvanic ProTech manual). The Kin-Tek will produce a higher flowrate of calibration gas than is used by the Galvanic instrument, therefore, the excess flow will exit through the bypass (Figure 4) that is controlled by the needle valve. This bypass can be connected to the charcoal scrubber on the side of the Kin-Tek, when working with higher concentrations.

Kin-tek has already been preset with a flow of 610 SCCM, which will give the desired concentration of 60.65 ppb.

$$C = \frac{37\ nL/min}{610\ cc/min} * 1000\ ppb/ppm = 60.65\ ppb$$

1. Place the Galvanic analyzer in Bypass Mode by pressing the **BYPASS** button on the keypad.
2. Connect ¼ in sample line with the needle valve from the span outlet to the 1/8 CAL port on the Galvanic (tubing and connectors should be with stored with the Kin-Tek).
3. Switch both of the valves on the Galvanic to CAL.
4. Open the Rotometer all the way using the knob underneath. (ball should jump all the way to the top of the Rotometer).
5. Use the Needle valve to slowly bring the flow to where the Rotometer ball is set at 2.
6. Allow 20-30 minutes for the Galvanic to equilibrate, then begin taking readings. Average 5 or 8 readings to get the deviation.
7. Span according to the procedure in Section 7.2.

### *6.2.4. Shut Down*

1. Disconnect all tubing and fittings from the analyzer and put back in the Kin-Tek bag for future use
2. Turn off by turning the key and replace it back on the Velcro of the base. Disconnect the power from the base.
3. Remove the permeation device from the chamber. For a wafer device, removal may be facilitated removing the glass tube from the heater and sliding the perm tube out. (CAREFUL: the O-ring is very tight and it is hard to remove the cap.)
4. Charge the battery while on site or when calibration is done.

## 6.3. Calibration Using the VICI Dynacal Model 120

**Figure 7** shows a schematic of the Dynacalibrator 120 (Dynacal 120) dilution calibrator. The pump generates a flow of air through a scrubber to serve as dilution air that travels into the temperature-controlled permeation chamber. The temperature-controlled permeation tube chamber can be used to hold one or more permeation devices. The permeation chamber temperature is used to control the rate of diffusion from the permeation device. The temperature of the permeation chamber is set by the digital temperature controller on the front of the device (**Figure 8**).

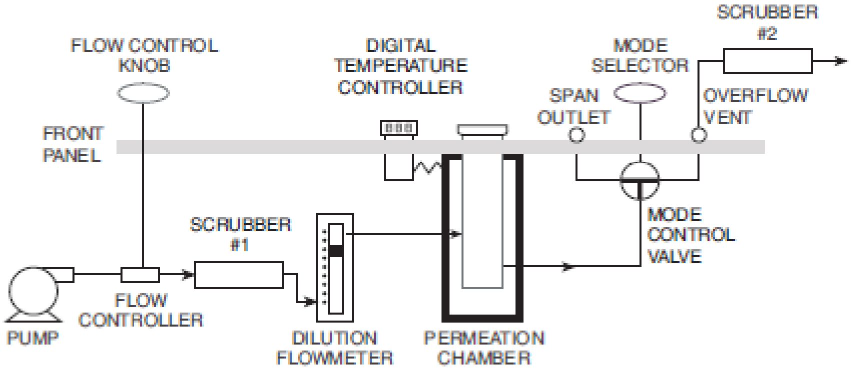


**Figure 8.** Schematic of the Dynacalibrator 120 dilution calibrator.

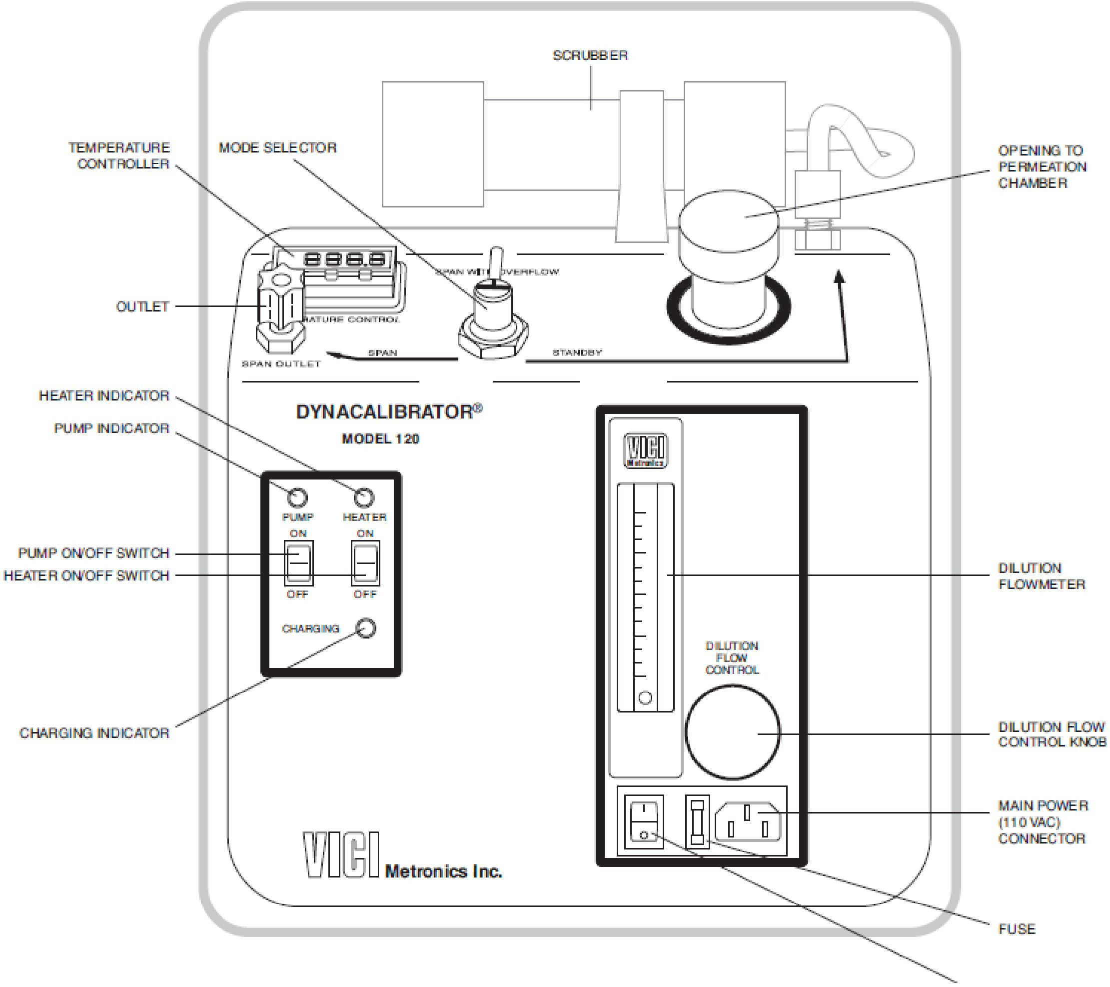


**Figure 9.** The front panel of the Dynacal 120.

Concentration is calculated via the following equation:

$$Concentration\ (ppm) = \frac{K \times R_{perm}}{F}$$

Where K=24.45/M.W.(calibrant), $R_{perm}$ is the permeation rate in ng/min (included with the permeation tube documentation), and F is the chamber carrier flow (mL/min). Flow must be corrected to standard temperature and pressure using:

$$F = (0.6262)F_c\sqrt{\frac{P}{T}}$$

Where F is indicated flow corrected to standard temperature and pressure (0°C and 1 atm), P is ambient pressure in mmHg, T is the temperature in Kelvin, and $F_c$ is the calibrated flow when the flowmeter is at standard conditions.

### 6.3.1. *Sample Calculation*

Given: $R_{perm}$ = 20.17 ng/min
Flow = 420 cc/min (from flow rate table of Dynacal 120 (**Table 2**); this corresponds to a float setting of 0.40)
Ambient temperature = 17.5°C
Ambient pressure: 1,013 hPa
$H_2S$ gas M.W. = 34.081 g/mol
First, calculate the pressure: $1013\ hPa\left(\frac{100\ Pa}{1\ hPa}\right)\left(\frac{760\ mmHg}{101325\ Pa}\right) = 759.8\ mmHg$
Then, calculate the flow: $F = (0.6262) \times 420 \times \sqrt{\frac{759.8}{(273.15+17.5)}} = 425.23\ mL/min$
Now calculate the concentration:

$$Concentration\ (ppm) = \frac{K * R_{perm}}{F} = \frac{24.45 * 20.17}{34.081 * 425.24} = 0.03403\ ppm\ (34.03\ ppb)$$

### 6.3.2. *Initial Equilibration of the Permeation Device*

1. Turn on the Dynacalibrator 120 by turning on the main power switch.
2. Turn on the pump and heater.
3. Put the Dynacal 120 on standby.
4. Set dilution flow to the lowest flow setting on the flow meter.
5. Set the temperature by pressing the **UP** and **DOWN** buttons on the temperature controller. Holding the buttons down longer will make the input temperature change faster.

6. If using a wafer permeation device, fit the 1/4" x 3.5 cm spacer on the non-permeating end of the stainless-steel wafer device body. This positions the wafer device for optimal temperature control within the chamber.

**NOTE: Be careful when placing the permeation device in the GLASS permeation chamber. Wafer devices are heavy and can break the permeation chamber if carelessly dropped inside.**

7. Using forceps provided, GENTLY place the permeation device in the chamber, spacer end first. The wafer side should be facing upward.
8. Allow 30 minutes for the permeation chamber to equilibrate.

### 6.3.3. Span Calibration

This SOP is written for use with the Galvanic Applied Sciences ProTech instrument, which is diagrammed in Figure 4. The Dynacal is capable of producing 1000 cc/min span gas flow while the flow going to the tape in the ProTech sensor is only 62 cc/min. In order to adjust the flow, a needle valve must be attached to the span flow of the Dynacal system using an 1/8" tee fitting (the other end goes to the ProTech 903 W). To generate calibration gas in this mode of operation:

1. Connect a 1/8" tee to the calibration gas inlet of the ProTech instrument (just before the rotameter).
2. Connect a needle valve to one side of the tee and open it all the way.
3. Connect a sample line from the span outlet to the Dynacal.
4. Switch the mode selector on the Dynacal to **SPAN**.
5. Adjust the flow of the Dynacal such that it generates the desired concentration (using the example above, set to 0.40 for 34 ppb). At the same time, adjust the needle valve attached to the tee so that the rotameter of the Galvanic reads 2.0.
6. Follow the span procedure in Section 7.2.

### 6.3.4. Standby Mode

When not in use, the Dynacal 120 can be placed in standby mode:

1. Set the mode selector to **STANDBY** position.
2. Turn the flow control knob counterclockwise to set the pump at the minimum setting.
3. Leave the permeation device in the chamber to maintain equilibrium until the next use.

### 6.3.5. Shut Down

1. Remove the permeation device from the chamber. For a wafer device, removal may be facilitated by inverting the entire Dynacal so that the device slides out.
2. Recharge the battery by connecting it to 120 VAC.

**Table 1.** Example flow rate table for the Dynacal 120.

| Float Setting | Calibrated Flow (cc/min) | Concentration Given (T=21C, P=1013 hPa) |
|---|---|---|
| 0.2 | 241 | 59.66 |
| 0.4 | 420 | 34.23 |
| 0.6 | 622 | 23.12 |
| 0.8 | 840 | 17.12 |
| 1 | 1041 | 13.81 |

## 7. Calibration of the Galvanic ProTech 903

The Galvanic should be calibrated using the procedure described in this section. The procedure described here requires to first zero the instrument, followed by a span, followed by another zero. Galvanic suggests calibrating the instrument following a tape change.

| Galvanic ProTech 903W $H_2S$ Analyzer | | |
|---|---|---|
| Span | Monthly | ±20% |
| Zero | Monthly | ± 2.5 ppb |
| Multipoint calibration at 0, 25, 50, 74 ppb | Initially and then a minimum twice per year at least 4 calendar months apart. Additional calibrations following major repair. | ± 2.5 ppb for zero<br>± 20 % of expected value |

### 7.1. Zero the Galvanic

1. Attach pump to the input side of the activated charcoal scrubber.
2. Let the readings stabilize for 2 5-minute cycles.
3. Collect 5 zero readings, average them, and use this as the zero offset.
4. Change the zero offset using the Galvanic keypad.

## 7.2. Span the Galvanic

1. Set up the calibration to Span the Galvanic as described in Section 6.
2. Once the concentration reading on the Galvanic has stabilized, allow the measurement to continue for 30 minutes.

   The accuracy of the calibration is termed “% deviation” and is calculated as

   $$\%Deviation = \frac{Analyzer\ Value - Reference\ Value}{Reference\ Value} \times 100\%$$

   The acceptable limit for $SO_2$ calibrations is ±20% deviation.

3. If the instrument is outside the acceptable limit of ±20%, calculate the new gain according to the following equation:

   $$New\ Gain\ Factor = \frac{Calibration\ Gas\ Concentration\ (ppb)}{Current\ Analyzer\ Reading\ (ppb)} \times Current\ Gain\ Factor$$

   In the case that the instrument is outside the acceptable limit of ±20% (for both accuracy and precision), perform a recalibration using a separate maintenance sheet. If repeated measurements appear nonconforming, initiate corrective action investigation.

4. Adjust the gain in using the Galvanic keypad and record in the instrument logbook and maintenance forms.
5. Zero the instrument again using the procedure described in Section 7.1.

Galvanic ProTech Maintenance Form

# NOTICE

**Please check off the following steps needed to minimize false notifications to our clients and the public.**

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

DATE: ____________________________________ Location: ____________________________________

Technician: __________________________________

| Activity | Monthly |
|---|---|
| Check for alarms | |
| Inspect sample line tubing. | |
| Inspect data cables. | |
| Check compression head and sample chamber for dust, clean if necessary. | |
| Check Tape, replace. | |
| Check acid level in humidifier, refill if necessary. | |
| Check voltage reading. | |
| Perform zero air test for analyzer response. | |
| **Activity** | **Quarterly** |
| Perform gas span test for analyzer response. | |

Tape length as found: _______________________ ft
New Tape Length (if changed): _______________________ ft

Acid level as found (above, below, at line): _______________________
New acid level (if refilled): _______________________

Voltage reading as found: _______________________mV
New voltage (if recalibrated): _______________________mV

MFC  flow as found: _______________________
MFC flow before leaving site: _______________________

**Corrective Actions for Galvanic Analyzer**:

# Galvanic ProTech Analyzer Response Summary

Date: ____________________ Location: _____________________________________

Technician: _____________________

## Gas Purge

Flow purge gas Start Time ________________________
End Time ________________________

## $H_2S$ Calibration Gas Span Check

Bottle Concentration: __________________________________ppb
Bottle Identification Number: __________________________
Gas Calibrator Concentration (calculated): ______________ppb
Sample Flow (from MFC): _____________________________ sccm ( 137±10%)
Calibrator Flow (if permeation): _______________________ sccm
Gas Divider Minor Flow (MFC2): ______________________________ sccm
Gas Divider Major Flow (MFC1): ______________________________ sccm
Cal gas flow start time: ________________________

| Average Measured Concentration | Percent Error |
|---|---|
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |
| ________________________ ppb | ____________________ % |

Percent Difference (±20% is passing) ____________________ %
Precision (±20% is passing) ____________________ %

Cal gas flow end time: ________________________

Zero Offset as found: __________________________
Zero Offset (if changed): ________________________

## $H_2S$ Calibration Zero Check

Sample Flow (from MFC): ______________________sccm (137±10%)
Calibrator Flow: ______________________ sccm

Zero air flow start time: ______________________

Average Measured Concentration

______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb
______________________ ppb

Average Concentration (<2.6 ppb is passing) ______________________ ppb

Zero air flow end time: ______________________

Zero offset as found: ______________________
Zero offset (if changed): ______________________

NOTES:

# Standard Operating Procedures for Meteorological Instruments

June 24, 2024

STI-7179

# Contents

# 1. Scope and Applicability

This standard operating procedure (SOP) provides instructions for servicing the meteorological instruments at the Chevron El Segundo Refinery in El Segundo, CA. The 10-m meteorological towers have instruments that measure wind speed, wind direction, temperature, relative humidity, and visibility, and are integrated into the monitoring shelter design for stability. **Table 1** lists the equipment make and model installed on the towers. Operating procedures for these instruments are listed in Section 3.

**Table 1.** Meteorological equipment list.

| Parameter | Manufacturer |
|---|---|
| Wind Speed / Direction | RM Young, Model 5305 |
| Ambient Temperature / Relative Humidity, 2-m | Campbell Scientific, Model EE181 |
| Visibility Sensor | Campbell Scientific, Model CS120A |

# 2. Routine Service and Maintenance

Routine service tasks are designed to maintain the meteorological equipment in good working condition. This is intended to lower the frequency of non-routine maintenance. The routine service tasks are described below. The site should be serviced once every 2 to 4 weeks. If no problems are encountered, the site visit will take about 1 hour.

## 2.1 Maintenance Checklist

Table 2 depicts the maintenance activities that must be performed during each site visit to ensure all instruments are performing correctly.

**Table 2.** Routine quarterly 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. |
| Visibility | Visually inspect the system, including all cables. Ensure they are not fraying. |
| | Inspect optics on detector and clean if necessary. |
| | Check calibration. An acceptable % accuracy is less than 25% |
| 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. |
| 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. |

[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 3 and 4 to help estimate wind speed and temperature.

**Table 3.** 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 4.** 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

Quarterly audits are conducted on meteorological instrumentation. The meteorological instrumentation calibrations are conducted with reference to the recommendations in the EPA's *Quality Assurance Handbook for Air Pollution Measurement Systems (QA Handbook), Volumes I, II, and IV* (U.S. Environmental Protection Agency, 2017b, 1994, 2008) and in accordance with the *Technical Assistance Document for the National Air Toxics Trends Stations Program, Revision 3* (U.S. Environmental Protection Agency, 2016a) and the *Technical Assistance Document for Sampling and Analysis of Ozone Precursors for the Photochemical Assessment Monitoring Stations Program*, Revision 2 (Battelle, 2018).

As part of the calibration process, each instrument will first be tested to determine whether it is operating within the prescribed operational limits and whether non-routine maintenance or adjustments are required. Based on an instrument's response to the initial performance test with respect to the minimum acceptable performance criteria (see data quality objectives in the QAPP), the instrument will then be repaired, calibrated, or in rare cases, replaced. A standard form 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 5.

**Table 5.** 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:

$$\textit{Difference} = \textit{Station Wind Direction} - \textit{Reference Wind Direction}$$

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:

$$\text{Difference} = \text{Station Temperature} - \text{Reference Temperature}$$

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 0.1°C.

## 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:

$$\%\ \text{RH Difference} = \text{Station}\ \%\ \text{RH} - \text{Reference}\ \%\ \text{RH}$$

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

## 3.5 Visibility Sensor Calibration

### 3.5.1 Materials Needed

- Microfiber cloth
- Calibration bungs
- Calibration disk
- Micro-USB to USB-A cable

### 3.5.2 Startup Checklist

Verify that the following actions are completed when starting up the Campbell Visibility Sensor:

_____ Verify that serial connections to the datalogger are correct (sensor TX to logger RX, sensor RX to logger TX, and sensor ground to any ground terminal on the logger).

_____ Check datalogger to see if data is coming from the sensor.

_____ Check the data to make sure it makes sense (visibility value is a reasonable number and the correct values are being recorded to the right parameters).

_____ Make sure the lenses are clean and clear of obstructions (spider webs, etc.).

_____ Use a microfiber cloth (you can use a blower first). Do not use abrasive cleaners; use isopropyl alcohol only if needed.

### 3.5.3 System Verification Procedure

The following tests are performed as a verification of analyzer operation.

**Calibration Prep**

The sensor can be checked and adjusted using the optional sensor high-grade calibration kit Part Number 28678 from Campbell Scientific. The calibration must be run using the onboard menu system. Access this menu via LoggerNet's terminal emulation program using the port to which the sensor is connected. For more information on how to use this program, see LoggerNet's documentation, which can be accessed on Campbell Scientific's website.

The test should ideally be performed under the following conditions:

- Ambient temperature between 0ºC and 50ºC.
- The local visibility approximately 10,000 meters or more.

The system is self-regulating. However, it is recommended that the sensor be calibrated at least every two years.

The calibration is performed from Menu Item 3 on the main terminal screen.

Once you have selected Menu Item 3, the following screen should appear.

```
CS125 CALIBRATION - MENU 3
ID 0
S/N 1006
(1) Perform calibration
(2) Restore the factory calibration
(3) Perform dirty windows zero offset calibration
(4) Restore dirty windows factory calibration

(9) Refresh
(0) Return to main menu
```

Select **Option 1** to start the calibration. Confirm that a calibration is to be performed. Please note that once “**Yes**” is entered, exiting the program is not possible until the test is complete. However, power cycling the unit at this point will have no adverse effect on the sensor.

Once the test has started, the program will ask for the sensor calibrator serial number and coefficient with a confirmation at each step giving the opportunity to correct typing mistakes.

```
Starting calibration.
Input the sensor calibrator serial number ->E2002
Is E2002 correct? (Y/N)?
Input the sensor calibrator constant ->28.8
Is 28.8 correct? (Y/N)?
```

Place one calibration bung into each hood, and then press any key.

### Dark Level Calibration

Once calibrator information has been entered, the sensor will until the foam bungs are placed into the sensor hoods. The bungs are designed to block all light from the outside from reaching inside the head. Place one bung into each hood. If either of the bungs is damaged or appears to have any gaps around the edge, contact Campbell Scientific.

```
Starting dark level calibration.
This test will take approximately two minutes
```

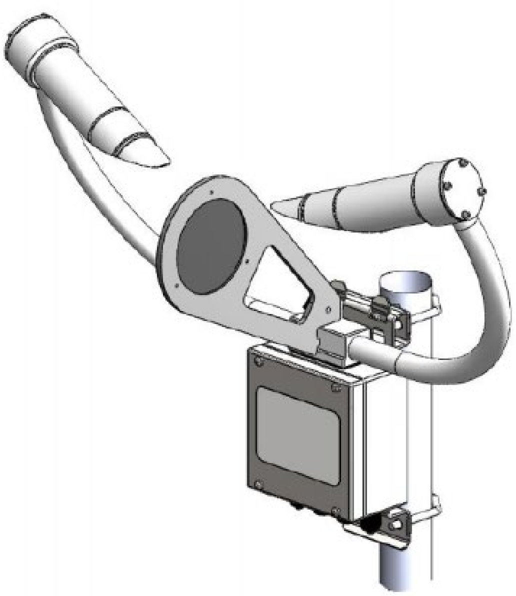
This part of the test will take approximately two minutes. Every ten seconds, a dot should appear indicating that the test is progressing as normal.

```
Dark level test complete. Please remove the bungs.
Now place the sensor calibrator into the sampling
volume.
Press any key once this is done.
```

Remove the bungs once the sensor instructs for this to be done.

### Light Level Calibration

Place the sensor calibrator into the volume by fastening it to the central mounting point.



```
Starting light level calibration.
This test will take approximately two minutes.
```

This part of the test will take approximately two minutes. Every ten seconds, a dot should appear indicating that the test is progressing as normal.

```
Calibration is now complete.
Saving user settings
Press any key to exit.
```

Once the second stage of the test has been completed, the new calibration constants are saved automatically. All calibration constants, including both the user and the factory setting, can be viewed from Menu Item 4 from the main menu once the test is completed. Document the new user calibration constant and the factory setting each time a calibration is done.

REMEMBER to remove the calibration disk once finished.

# 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.

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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. | |
| Visibility | Visually inspect the system, including all cables. Ensure they are not fraying. | |
| | Inspect optics on detector and clean if necessary. | |
| | Check calibration. An acceptable % accuracy is less than 25% | |
| 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. | |
| 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. | |

| Item | Action | Observation / Completion Date |
|---|---|---|
| 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. | |

| | | |
|---|---|---|
| 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 |
| ____________________° | ____________________° | ____________________________________ |
| Estimated Visibility | Visibility Reading | Difference / Comment |
| ___________________mi | ___________________mi | ____________________________________ |

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:

## 6.3 Campbell 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:

# 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%<br>PID[1] value < 85% | Monthly |
| Check for leaks with zero filter | Acceptance criterion is 0.0–0.3 µg/m$^3$<br>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.

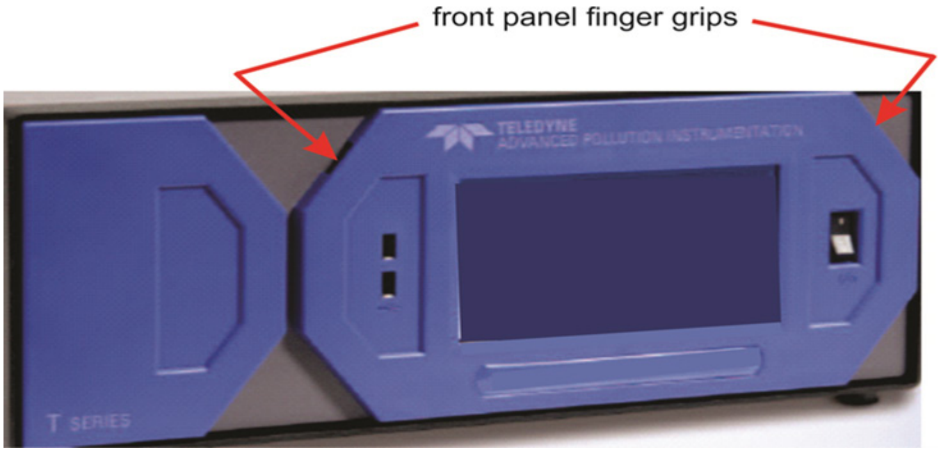


**Figure 3.** Opening the front panel.

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**).

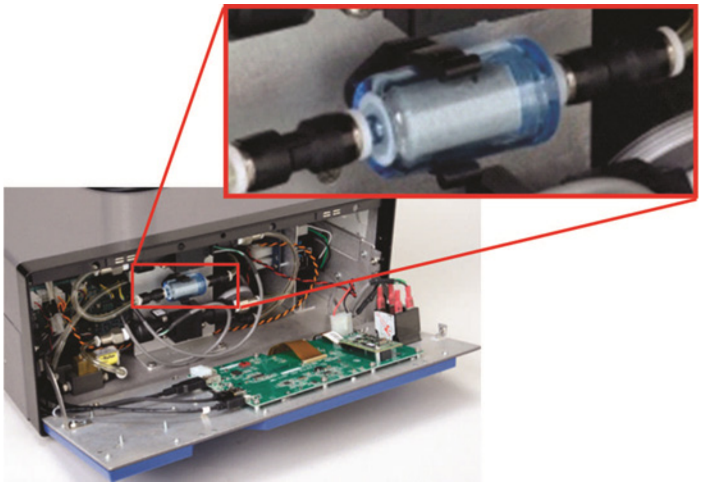


**Figure 4.** Internal DFU.

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.

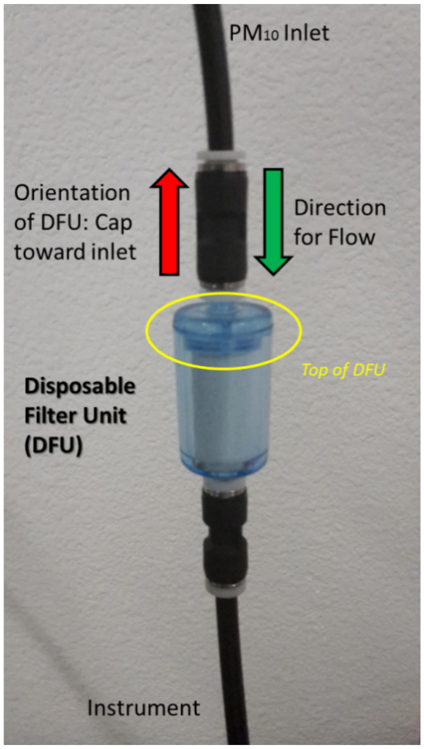


**Figure 5.** External DFU.

### 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.

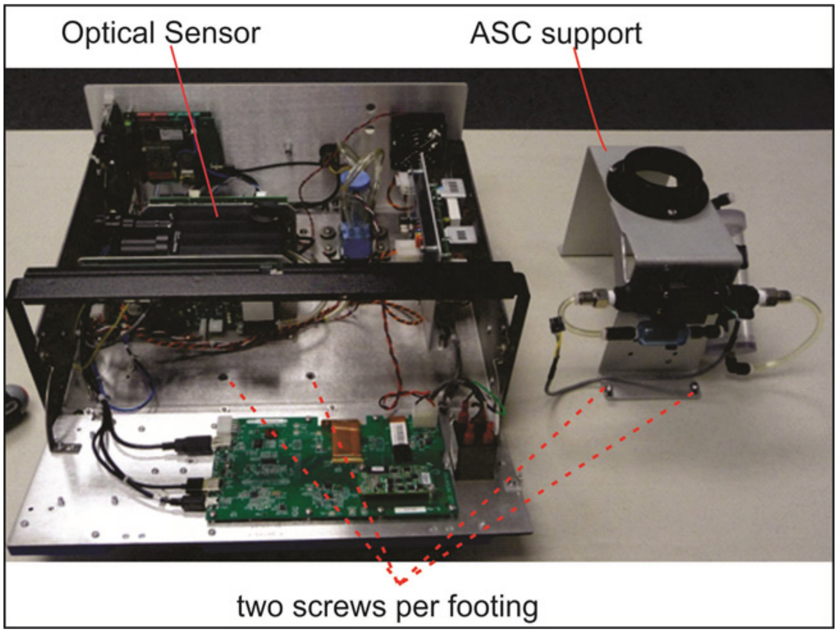


**Figure 7.** Maintenance of the optical chamber and RH/T sensor access.

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

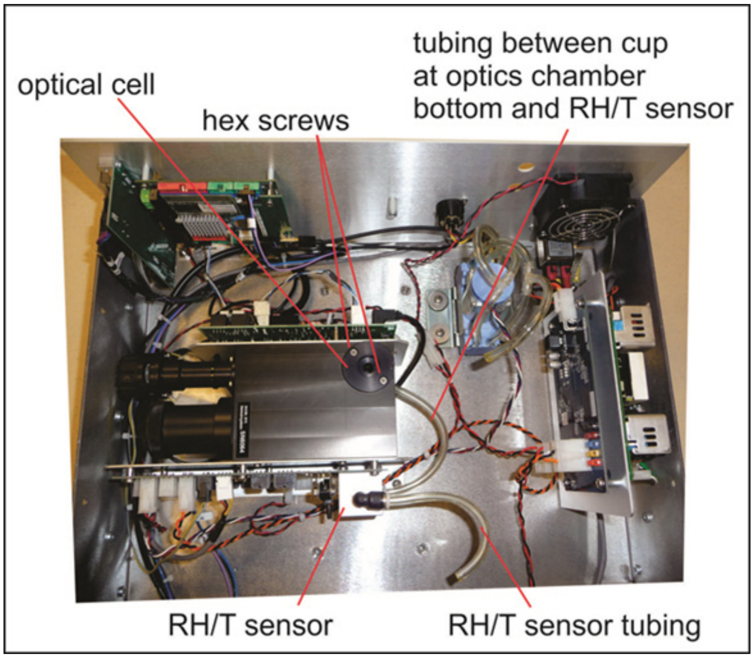


**Figure 8.** Maintenance: location of the optics chamber and RH/T sensor.

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.

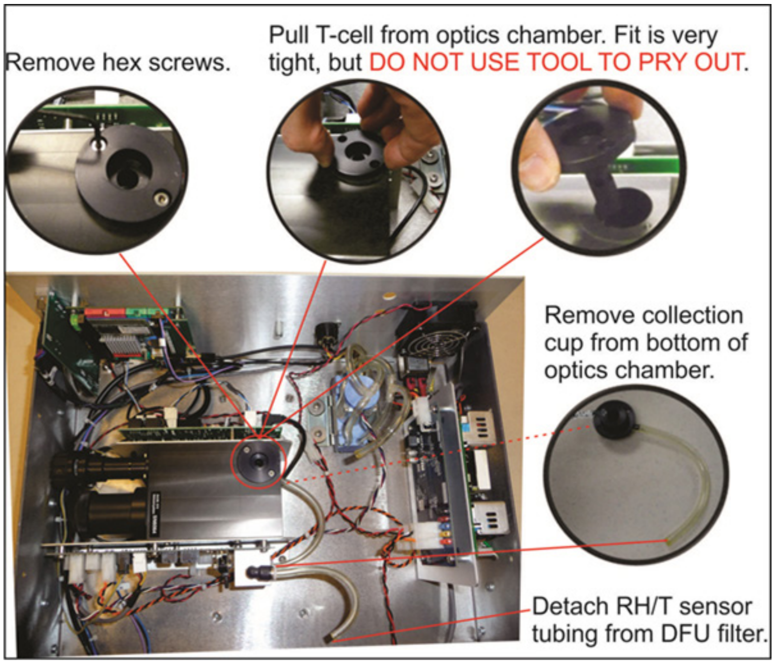


**Figure 9.** Maintenance: Optical Chamber Disassembly

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

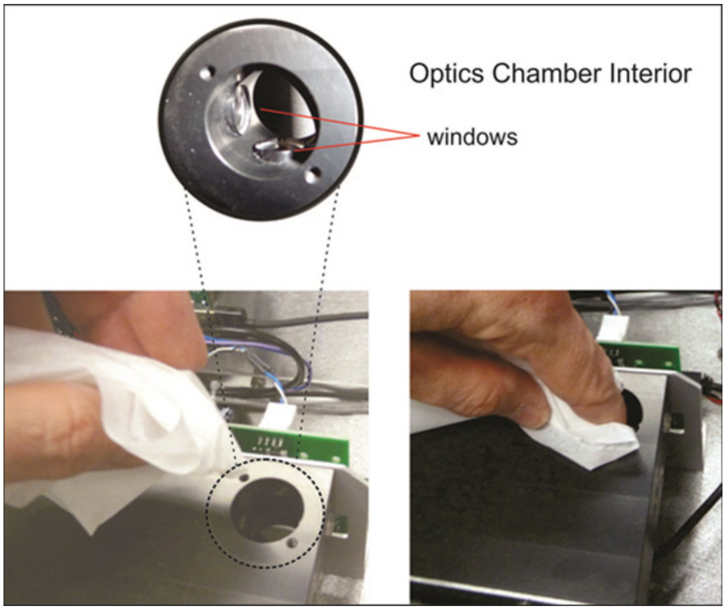


**Figure 10.** Maintenance: optics chamber windows.

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**).

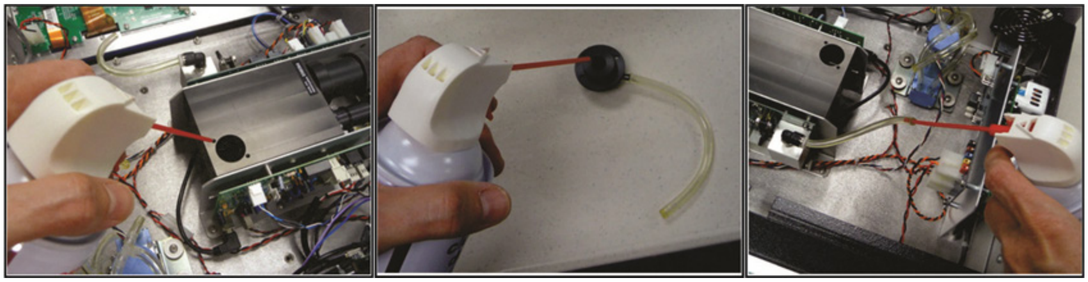


**Figure 11.** Maintenance: final dusting.

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$^{TM}$ 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**).

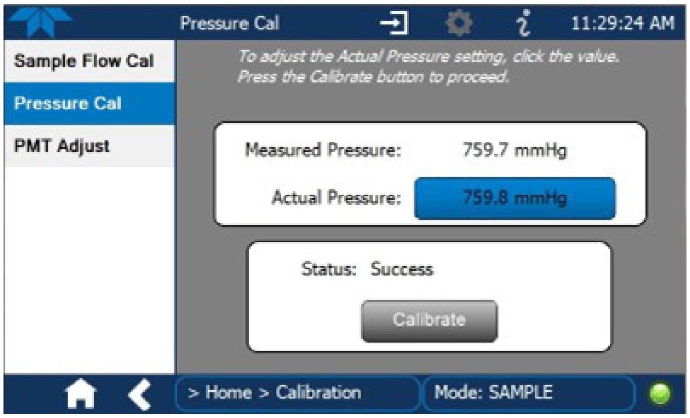
**Figure 13.** Slip coupler moved to the side to allow monitor use with audit devices.

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.



*To adjust the Actual Pressure setting, click the value.*
*Press the Calibrate button to proceed.*

Measured Pressure: 759.7 mmHg
Actual Pressure: 759.8 mmHg
Status: Success

**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).

*To adjust the Actual Flow setting, click the value.*
*Press the Calibrate button to proceed.*

Measured Flow: 4.80 LPM

Actual Flow: 5.00 LPM

Status: Never Run

Mode: SAMPLE

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

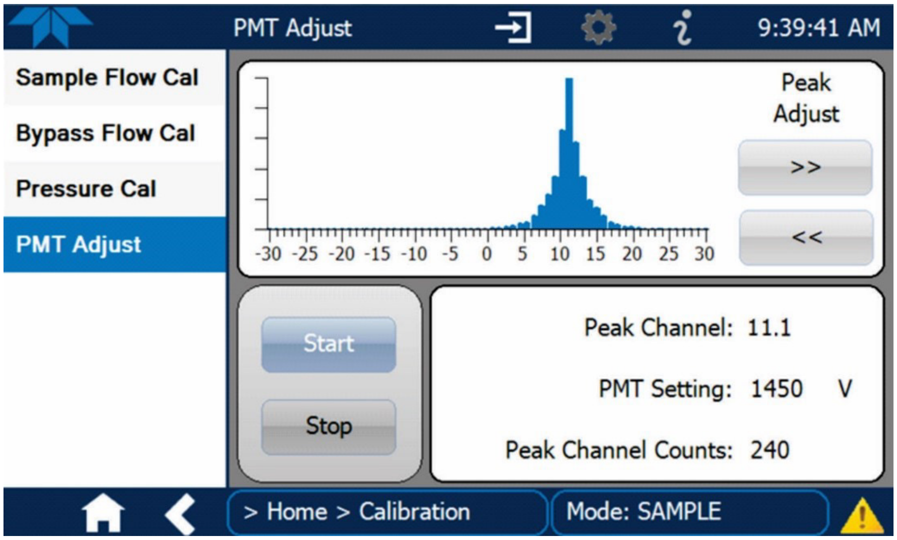
For this procedure, ensure data are “Off Scan.”

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$^{TM}$ 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.



Peak Channel: 11.1
PMT Setting: 1450 V
Peak Channel Counts: 240

**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™.

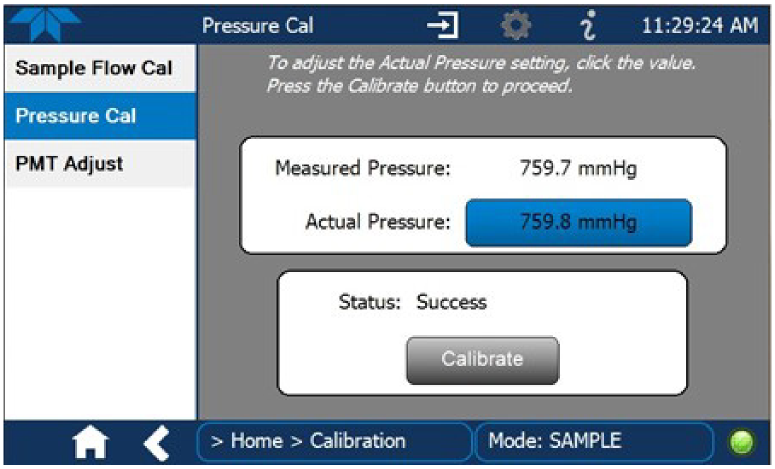
### 6.5.1 Pressure Calibration

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.



*To adjust the Actual Pressure setting, click the value.*
*Press the Calibrate button to proceed.*

Measured Pressure: 759.7 mmHg
Actual Pressure: 759.8 mmHg

Status: Success

**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.

*To adjust the Actual Flow setting, click the value.*
*Press the Calibrate button to proceed.*

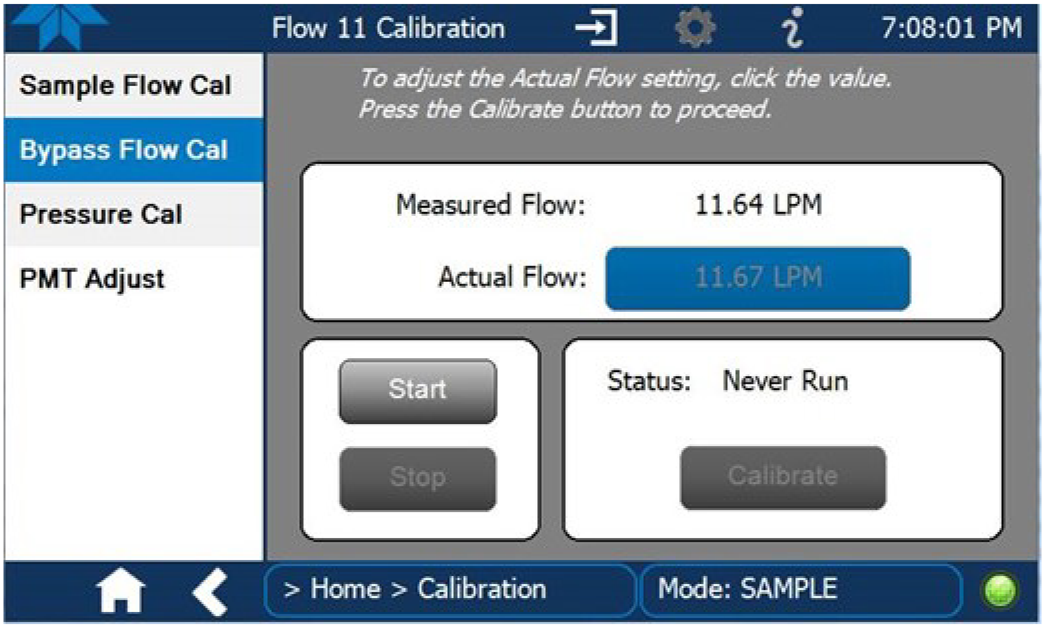
Measured Flow: 4.80 LPM
Actual Flow: 5.00 LPM
Status: Never Run

**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.



*To adjust the Actual Flow setting, click the value.*
*Press the Calibrate button to proceed.*

Measured Flow: 11.64 LPM

Actual Flow: 11.67 LPM

Status: Never Run

**Figure 19.** Bypass Flow calibration screen.

### 6.5.3 PMT Calibration

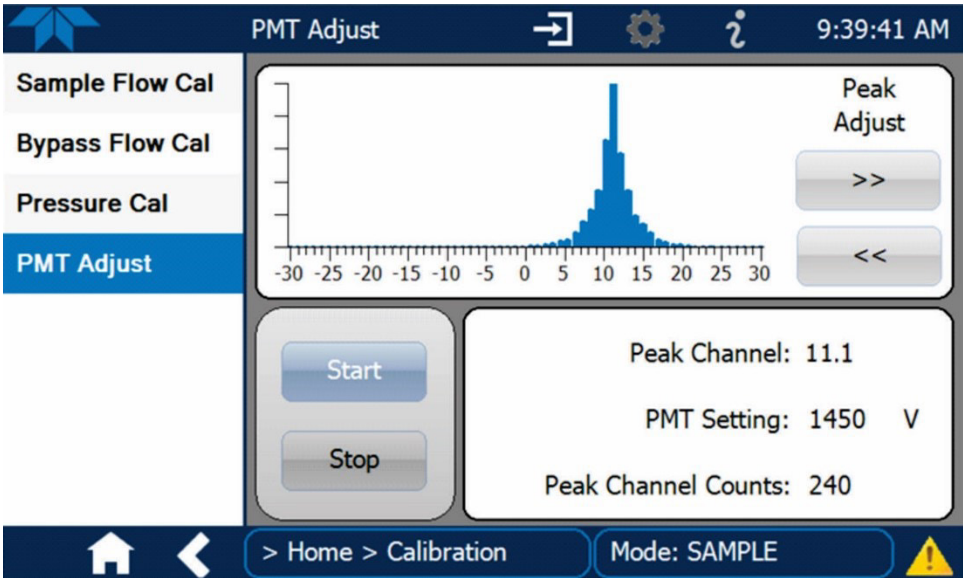
Once all verifications and any necessary calibrations to the pressure and flow systems are complete, an adjustment of the Particle Sensor PMT may be performed using SpanDust™. A calibration of the PMT is an adjustment in the field for drift caused by contamination of the optics. Note: Ensure that a minimum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



Peak Channel: 11.1

PMT Setting: 1450 V

Peak Channel Counts: 240

**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.<br>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.<br>Re-calibrate flow. |
| Bypass Flow Low | The Bypass Flow is less than 11.08 lpm | Check pneumatics.<br>Check for blockages. Re-calibrate flow. |
| Sample RH High | The Sample RH is above the set point | Check if the ASC is plugged in.<br>Check whether the ASC control LED is illuminated on the control board.<br>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.<br>Call Tech Support. |
| Check PMT | The PMT HV setting is out of range (800-2200) | Check sensor with SpanDust™.<br>Clean the optical chamber.<br>Call Tech Support. |
| Sample Flow Slope OOR | The Sample Flow Calibration Slope is Out of Range (OOR) | Check pneumatics for leaks.<br>Rerun flow calibration.<br>Call Tech Support. |
| BYPS Flow Slope OOR | The Bypass Flow Calibration Slope is Out of Range | Check pneumatics for leaks.<br>Rerun flow calibration.<br>Call Tech Support. |

| Message | Description | Possible Solution(s) |
|---|---|---|
| Check Int Pump | Check the internal pump if the PWM is > 80% | Check pneumatics for blockages.<br>Check pneumatics for leaks.<br>Check flow calibration.<br>Replace pump. |
| Check Ext Pump | Check the external pump and/or bypass flow control valve if valve PID > 85% | Check pneumatics for blockages.<br>Check pneumatics for leaks.<br>Check external pump.<br>Check flow calibration.<br>External pump or bypass flow control valve may need replacing. |
| Sample Temp Warning | Sample Temperature Warning (>60) | Check the ASC (is it latched ON?)<br>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).<br>Replace pressure sensor.<br>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**).

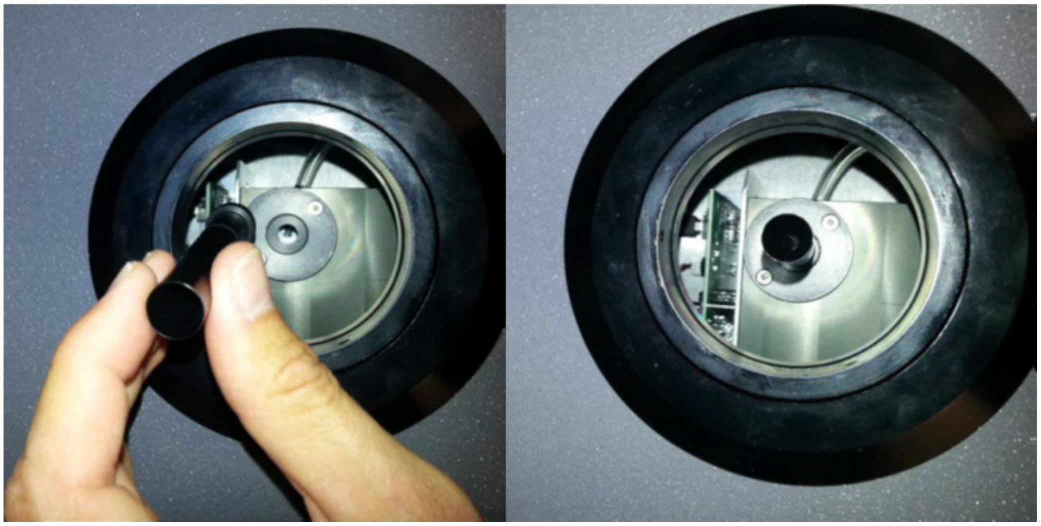


**Figure 21.** ASC Setup: inlet nozzle.

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

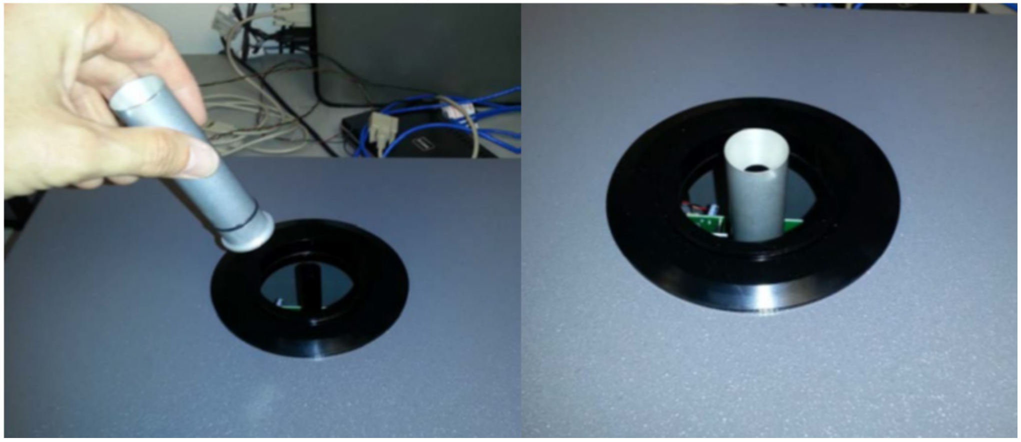


**Figure 22.** ASC setup: aluminum adapter.

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.

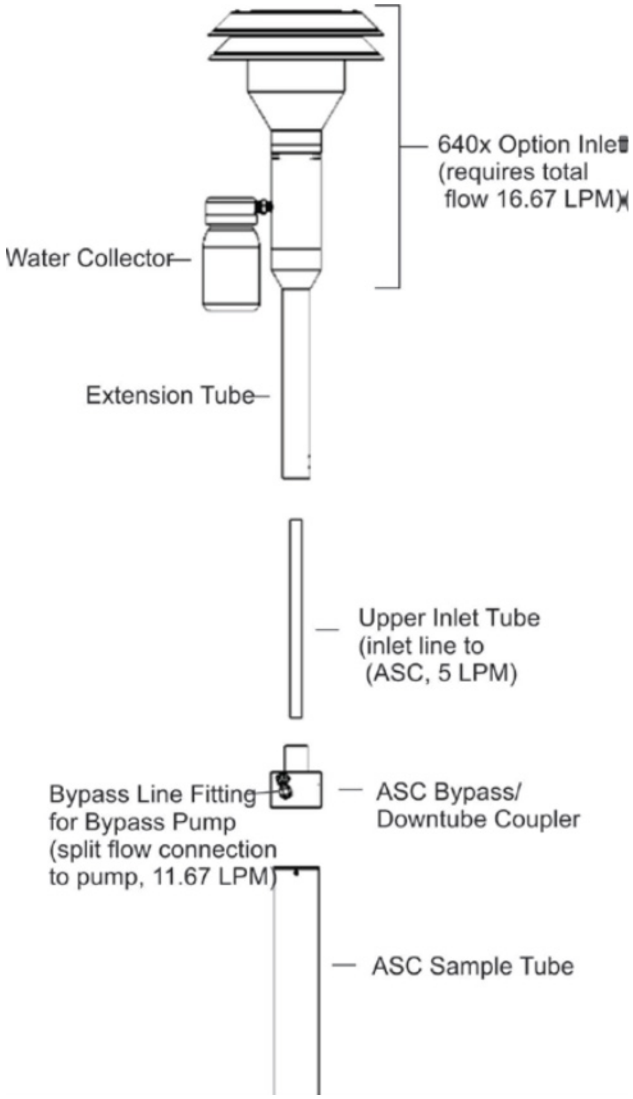


**Figure 24.** 640x inlet and ASC assembly.

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**.

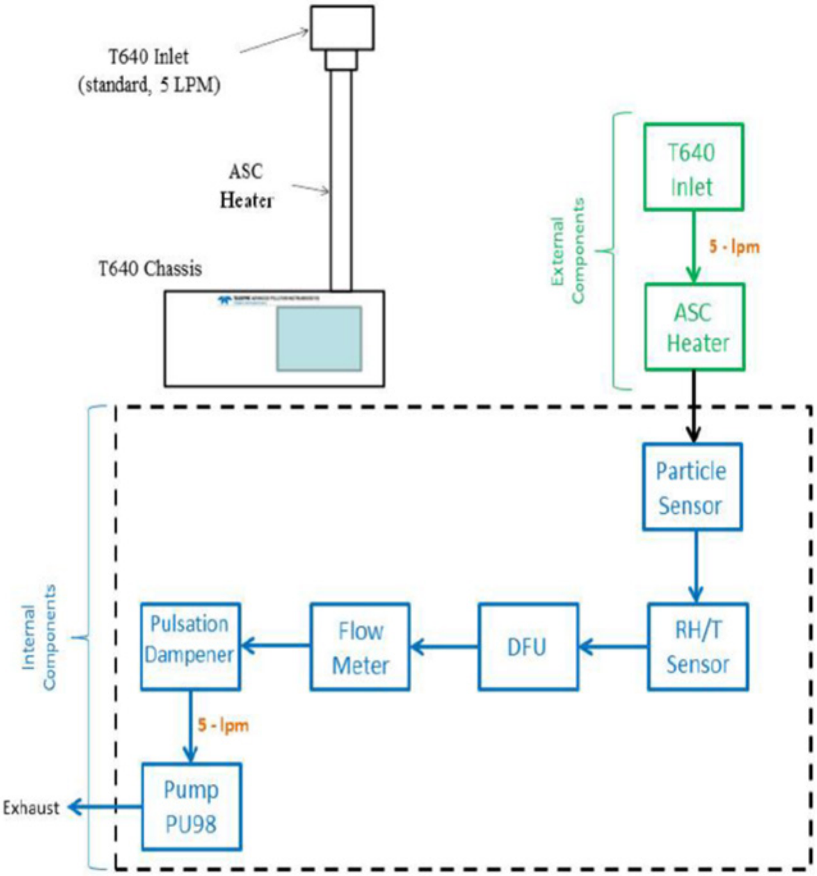
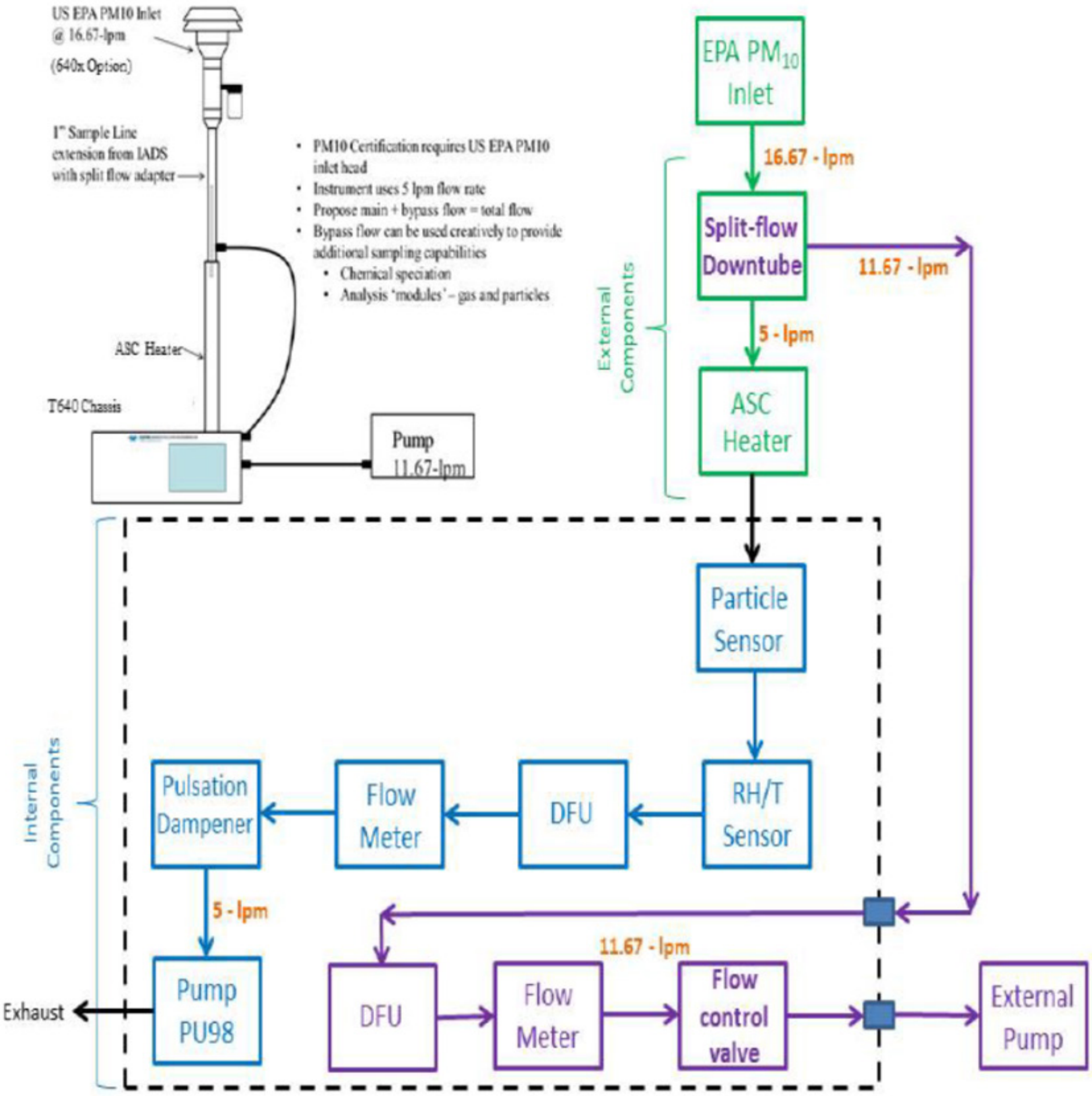


**Figure 27.** T640 pneumatics.



- PM10 Certification requires US EPA PM10 inlet head
- Instrument uses 5 lpm flow rate
- Propose main + bypass flow = total flow
- Bypass flow can be used creatively to provide additional sampling capabilities
  - Chemical speciation
  - Analysis 'modules' – gas and particles

**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

| | |
|---|---|
| Station: | |
| 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 | |

***Order of Monthly Checks:***

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.

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

| ***Additional Checks and Maintenance (less frequently than monthly):*** | | ***Date Completed*** |
|---|---|---|
| **Quarterly** | 1. Clean PM$_{10}$ inlet (above the PM$_{10}$ well) | |
| **Every 6 Months** | 1. Clean Optical Chamber<br>2. Clean RH Sensor<br>3. Clean Ta Sensor | |

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

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

August 5, 2024

STI-8177

# Contents

# 1. Scope and Application

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

# 2. Introduction and Overview

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

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

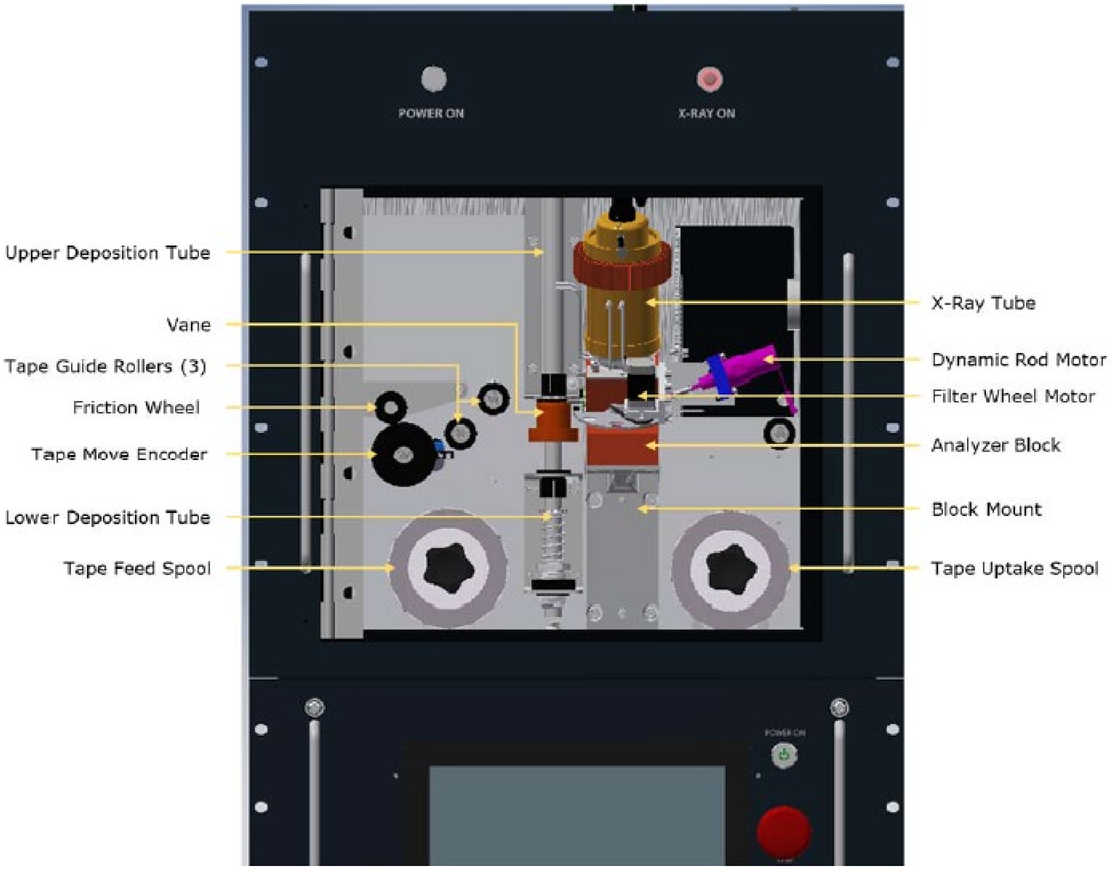


**Figure 1.** Schematic of the Xact 625i analyzer.

## 3. Definitions

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

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

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

## 4. Safe Work, Hazard Identification, and Precautions

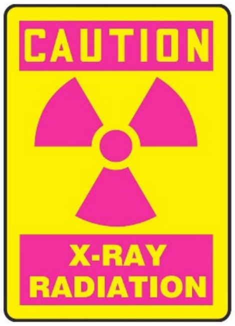
The following information is intended to provide guidance to ensuring a safe work environment.

### Operator Qualifications

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

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

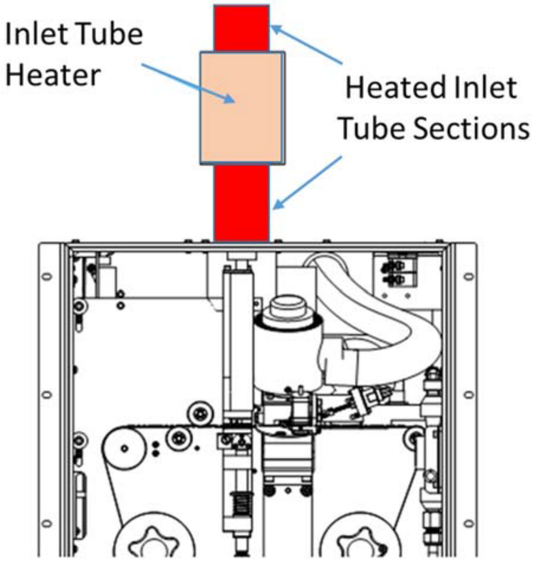
### Hazard Warnings



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

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

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



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

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

### Safe Operating Precautions

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

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

**NOTICE**

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

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

## 5. Startup and Routine Operation

The Xact 625i starting sequence is as follows:

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

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

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

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

## 6. Equipment and Supplies

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

## 7. Maintenance Activities

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

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

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

## 7.1 Visual Inspections

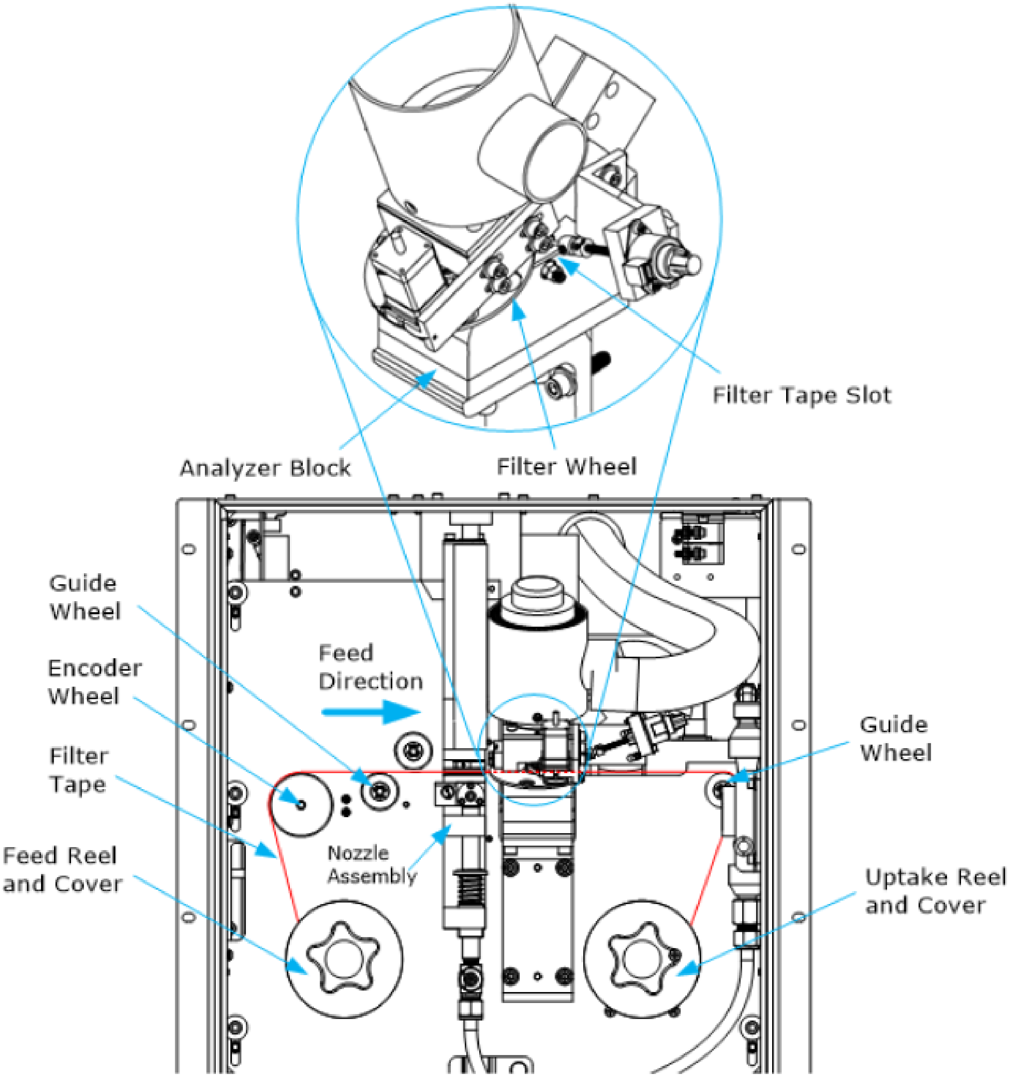
1. Ensure that the instrument is running and that the data look reasonable.
2. Clean and correct any obvious problems with the system (e.g., the presence of cobwebs, rodent nests, etc.).
3. Inspect all electrical cables for wear; replace as needed.
4. Indicate that these visual checks are complete on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

## 7.2 Tape Change

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

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

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



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

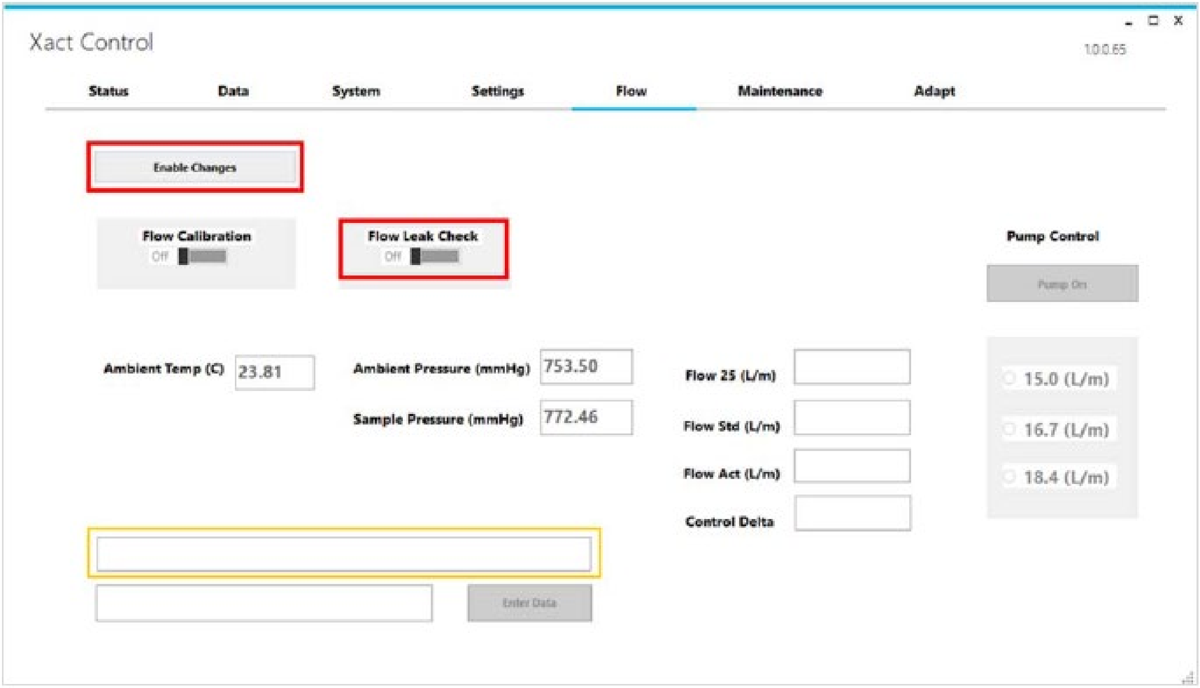
***IMPORTANT**: Ensure that the tape is in the tape slot and not the filter wheel slot. Properly installed tape should be flat and not angled.*

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

## 7.3 Leak Check

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

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



Flow Calibration: Off
Flow Leak Check: Off
Ambient Temp (C): 23.81
Ambient Pressure (mmHg): 753.50
Sample Pressure (mmHg): 772.46

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

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

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


OPEN Position


CLOSE Position


Xact 625i Pump

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

      Initial Sample Pressure (mmHg)

      Final Sample Pressure (mmHg)

      Elapsed Time (sec)

      Leak Rate (mmHg/min)

      Leak Check Result: PASS/FAIL

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

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

## 7.4 Flow Check

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

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

form and calculate the average of all the percentage differences.

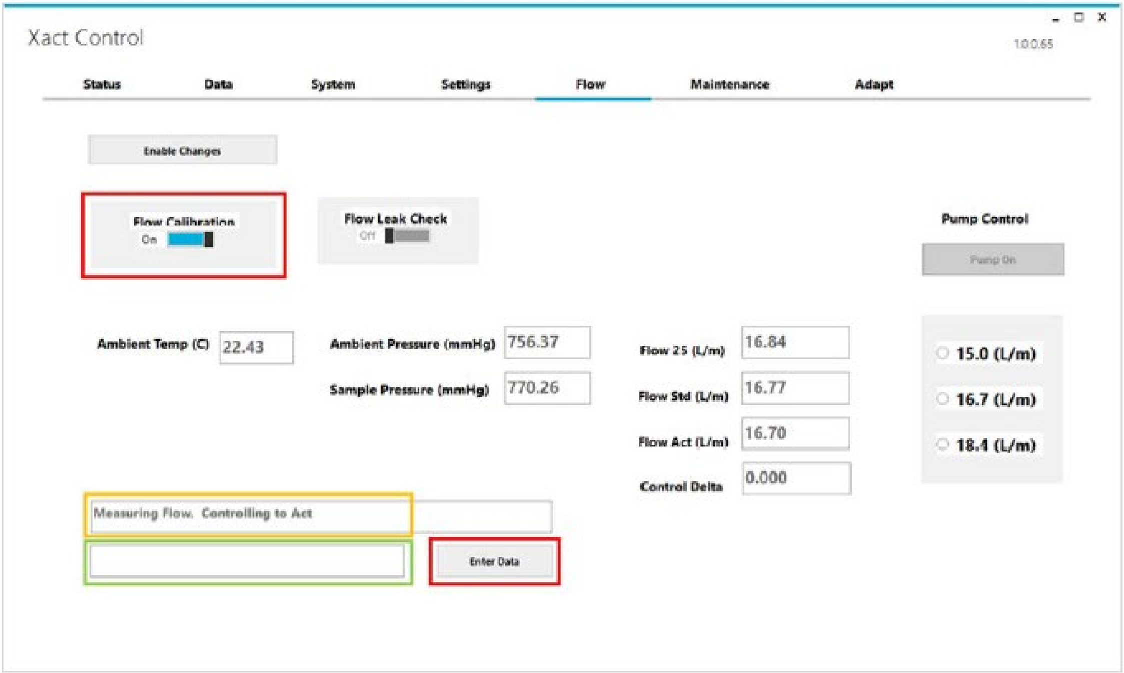
9. To complete the flow check, click on “Disable Changes.”

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

## 7.5 Flow Calibration

Follow these instructions to perform a Flow Calibration:

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



Ambient Temp (C) 22.43
Ambient Pressure (mmHg) 756.37
Sample Pressure (mmHg) 770.26
Flow 25 (L/m) 16.84
Flow Std (L/m) 16.77
Flow Act (L/m) 16.70
Control Delta 0.000
Measuring Flow. Controlling to Act

## 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.

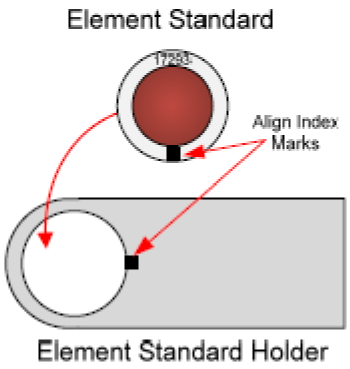
To manually perform the QA Check:

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.

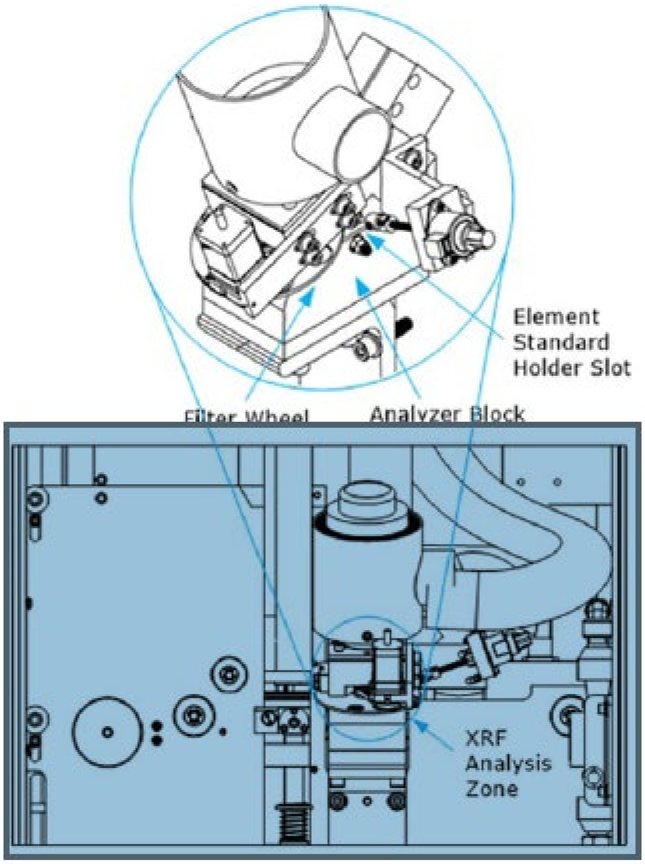
⚠ **CAUTION:** *Always handle Element Standards by their plastic ring edge. Store them in their individual containers when not in use. Nitrile gloves or powderless latex gloves are recommended during this procedure, although they are not mandatory.*

5. Remove the filter tape from the analysis block.

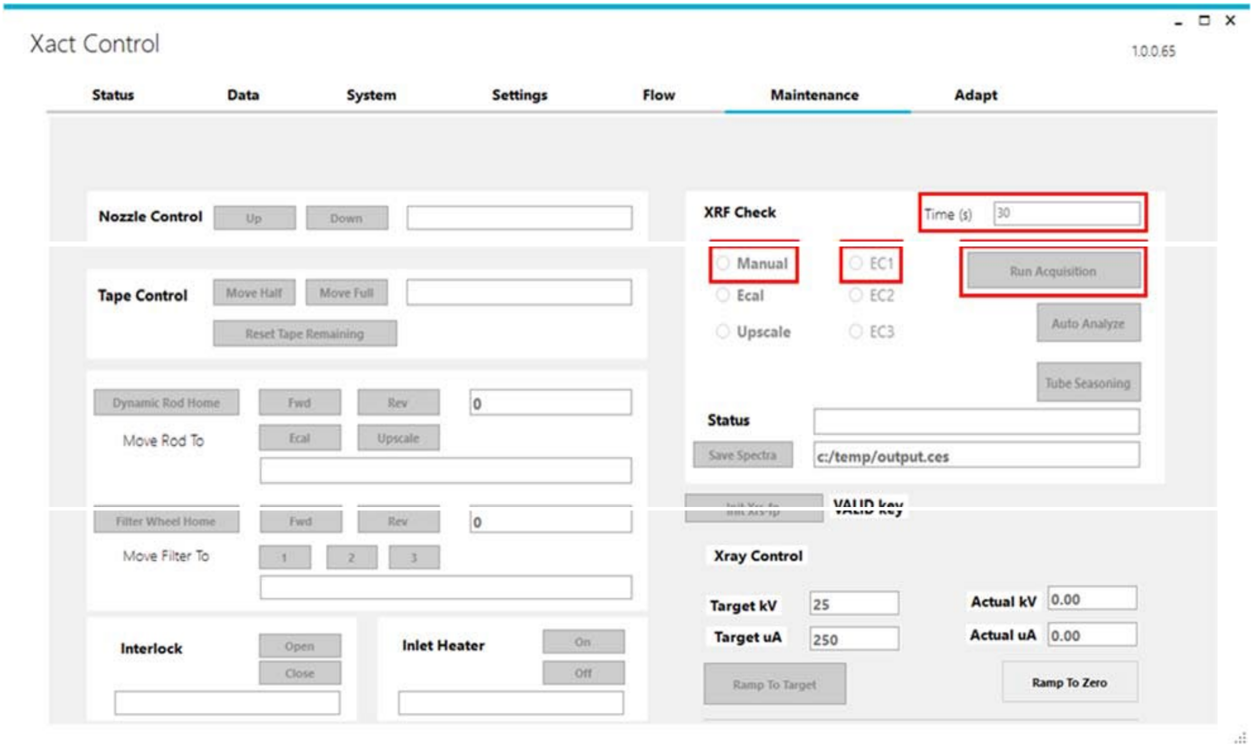
6. Place the first Element Standard into the Element Standard holder; the Standard should be oriented with the plastic ring up. Align the index mark on the Element Standard with the index mark on the Element Standard holder. The Element Standards are very fragile! Extreme care should be taken not to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



Time (s): 30

Dynamic Rod: 0

Filter Wheel: 0

c:/temp/output.ces

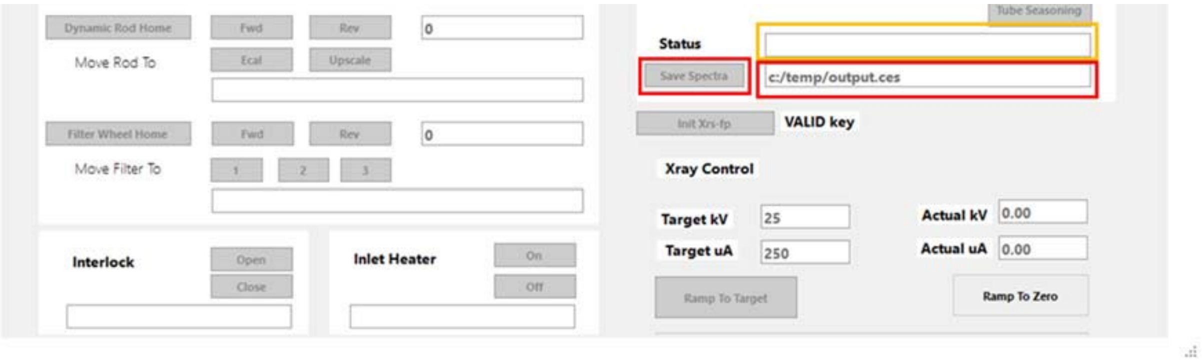
Target kV: 25

Target uA: 250

Actual kV: 0.00

Actual uA: 0.00

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.”



Dynamic Rod: 0

Filter Wheel: 0

c:/temp/output.ces

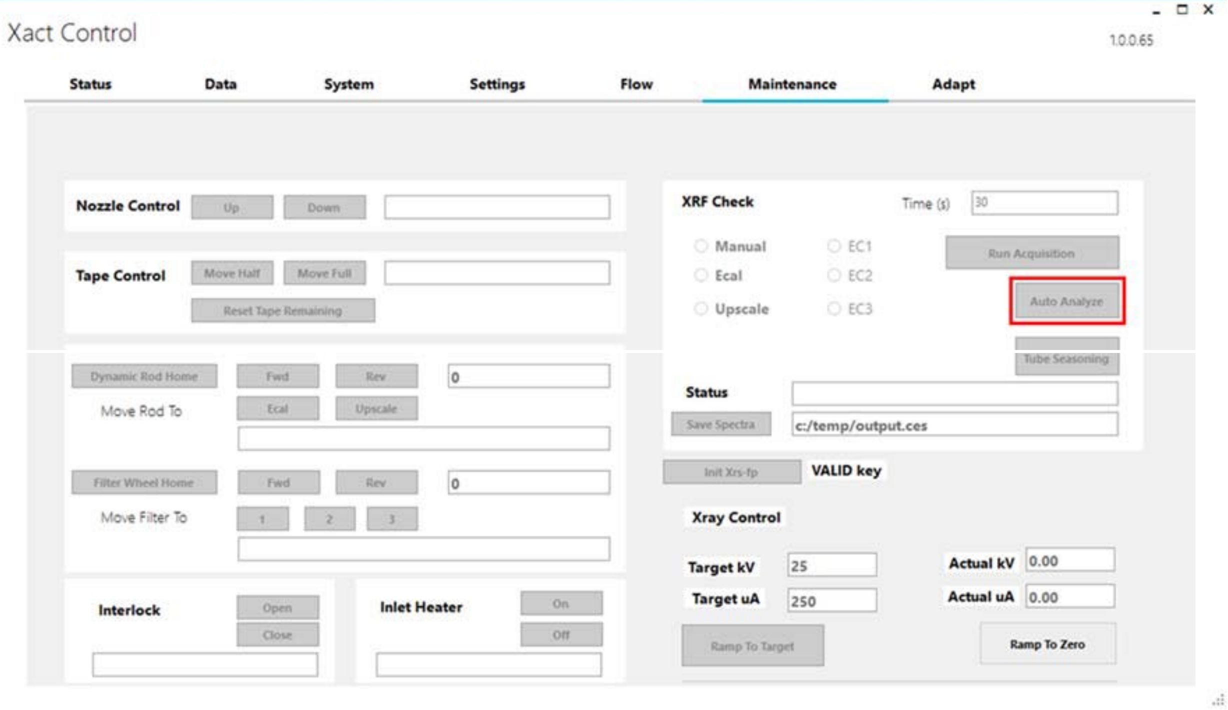
Target kV: 25

Target uA: 250

Actual kV: 0.00

Actual uA: 0.00

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



1.0.0.65

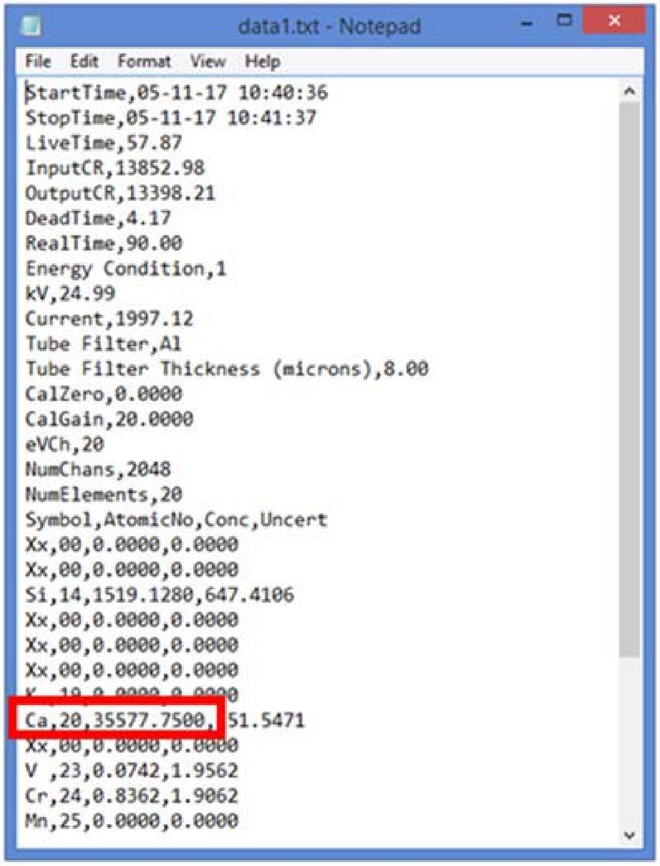
Time (s) 30

c:/temp/output.ces

VALID key

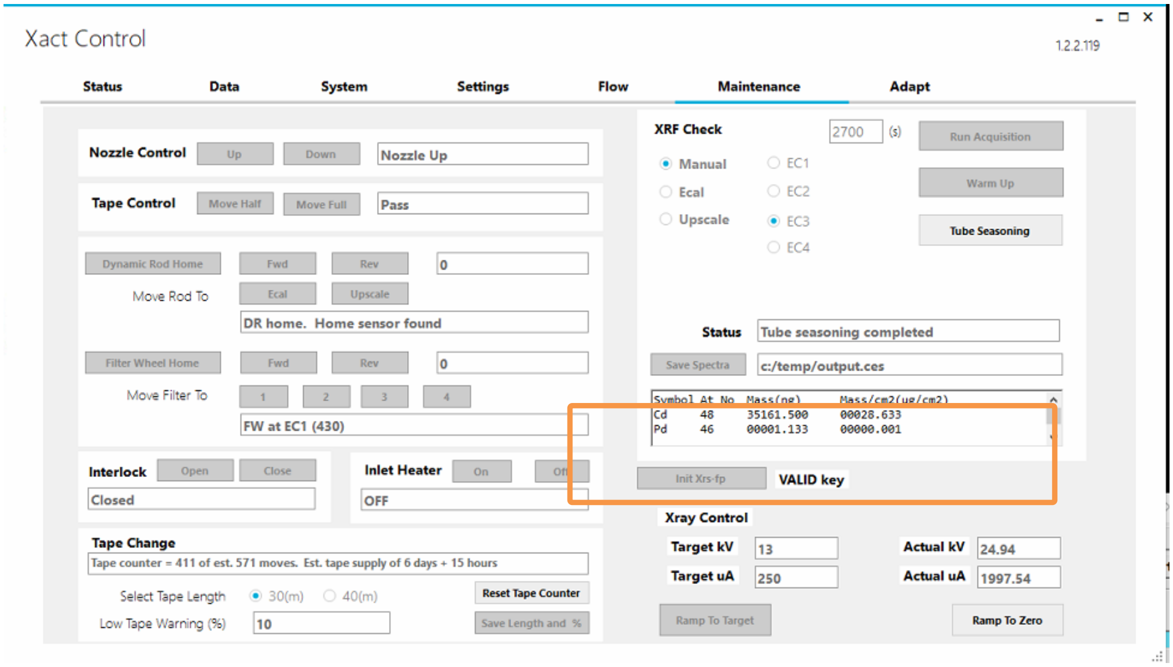
**Target kV** 25
**Target uA** 250
**Actual kV** 0.00
**Actual uA** 0.00

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.



```
StartTime,05-11-17 10:40:36
StopTime,05-11-17 10:41:37
LiveTime,57.87
InputCR,13852.98
OutputCR,13398.21
DeadTime,4.17
RealTime,90.00
Energy Condition,1
kV,24.99
Current,1997.12
Tube Filter,Al
Tube Filter Thickness (microns),8.00
CalZero,0.0000
CalGain,20.0000
eVCh,20
NumChans,2048
NumElements,20
Symbol,AtomicNo,Conc,Uncert
Xx,00,0.0000,0.0000
Xx,00,0.0000,0.0000
Si,14,1519.1280,647.4106
Xx,00,0.0000,0.0000
Xx,00,0.0000,0.0000
Xx,00,0.0000,0.0000
K ,19,0.0000,0.0000
Ca,20,35577.7500, 51.5471
Xx,00,0.0000,0.0000
V ,23,0.0742,1.9562
Cr,24,0.8362,1.9062
Mn,25,0.0000,0.0000
```

Reported mass will also be populated under "Save Spectra" (orange box below).



Nozzle Control: Nozzle Up

Tape Control: Pass

Move Rod To: 0

DR home. Home sensor found

Move Filter To: 0

FW at EC1 (430)

Interlock: Closed

Inlet Heater: OFF

Tape counter = 411 of est. 571 moves. Est. tape supply of 6 days + 15 hours

Select Tape Length ● 30(m) ○ 40(m)

Low Tape Warning (%) 10

XRF Check: 2700 (s)

● Manual ○ Ecal ○ Upscale

○ EC1 ○ EC2 ● EC3 ○ EC4

Status: Tube seasoning completed

Save Spectra: c:/temp/output.ces

```
Symbol At No  Mass(ng)       Mass/cm2(ug/cm2)
Cd     48     35161.500      00028.633
Pd     46     00001.133      00000.001
```

VALID key

Target kV 13

Target uA 250

Actual kV 24.94

Actual uA 1997.54

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

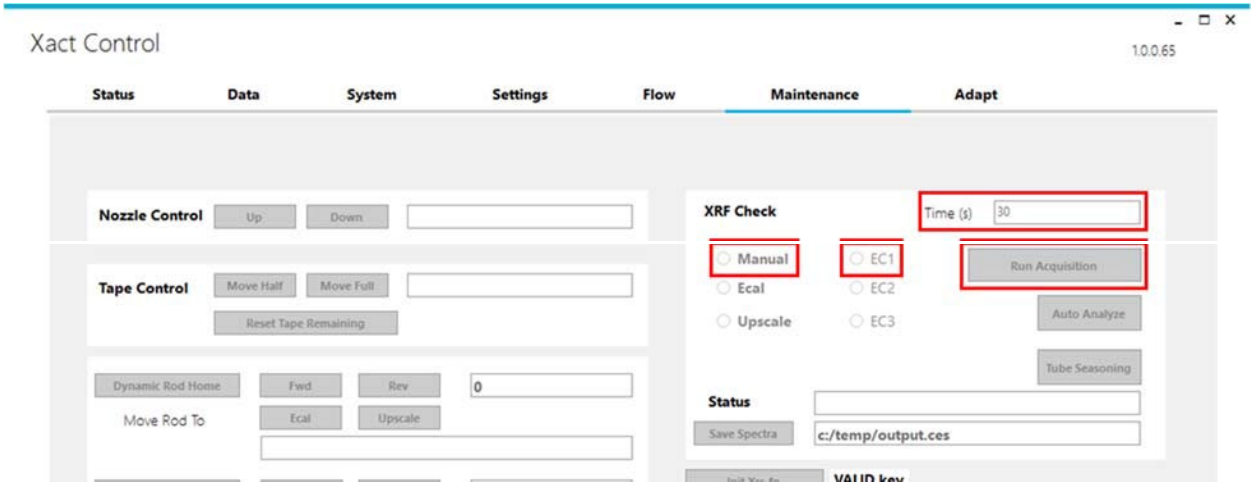
Xact Recalibration is performed when a new X-ray tube is installed or if the user wants to change Xact 625i settings for monitoring to focus on a group of elements different from those the instrument was calibrated for at the factory. Since Xact 625i is a precisely calibrated instrument for user requested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



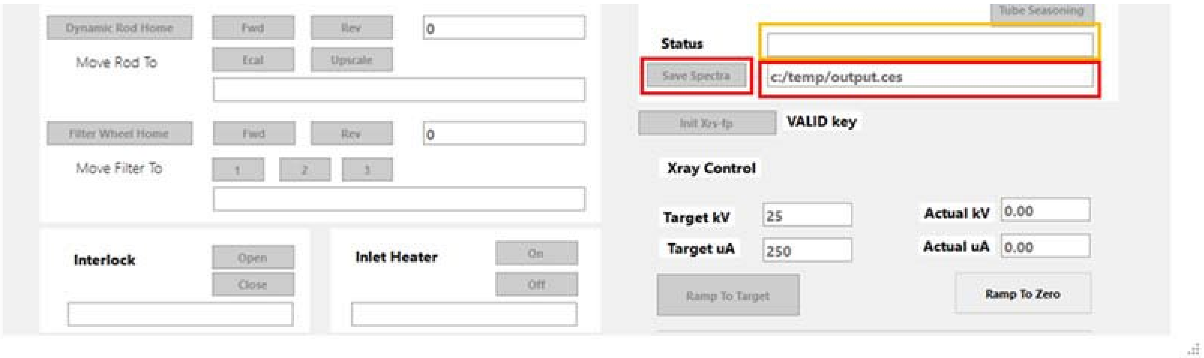
Time (s): 30

c:/temp/output.ces

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."



c:/temp/output.ces

Target kV: 25
Target uA: 250
Actual kV: 0.00
Actual uA: 0.00

3. Wait until the status window indicates that X-rays have ramped down, then click "Auto Analyze."
4. The resulting EC1 elemental masses for Blank can be viewed in the process data file located at C:\process_data\data1.txt.
5. Repeat the process for EC2 and EC3 based on the times in the acquisition time table.
6. Routinely monitor the QA Blank values to capture any systematic deviations with time.

# 8. Maintenance Forms

Instrument:______________________________

Technician:_________________________

Date:______________________________

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

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

Upon completion sign and date:__________________________________

**Table 2.** Maintenance activities and performance indicator checks for the Xact 625i.

| Activity / Check | Completed (Y/N) |
|---|---|
| Visually inspect the system | |
| QA Upscale Tracking | |
| Tape Change | |
| Leak Check | |
| Flow Check | |
| XRF Calibration Check | |
| Flow Calibration | |
| Blank Check | |
| Xact Recalibration | |

# Xact 625i Leak Check Form

**Instrument:________________________________**

**Technician:_________________________________**

**Date:______________________________________**

| Parameter | Observed | Acceptance Criteria |
|---|---|---|
| Initial Sample Pressure (mmHg) | | |
| Final Sample Pressure (mmHg) | | |
| Elapsed Time (sec) | | |
| Leak Rate (mmHg/min) | | |

Acceptance criteria for each test are defined by the QAPP.

# Xact 625i Flow Check

**Instrument:**____________________________

**Technician:**_____________________________

**Date:**_________________________________

| | Flow Rate (LPM) | Xact | Reference |
|---|---|---|---|
| **Trial 1** | 16.7 | | |
| | 15.0 | | |
| | 18.4 | | |
| **Trial 2** | 16.7 | | |
| | 15.0 | | |
| | 18.4 | | |
| **Trial 3** | 16.7 | | |
| | 15.0 | | |
| | 18.4 | | |

| Flow Rate (LPM) | Average | %Difference |
|---|---|---|
| 15.0 | | |
| 16.7 | | |
| 18.4 | | |

# Xact 625i XRF Calibration Check Form

**Instrument:______________________________**

**Technician:______________________________**

**Date:____________________________________**

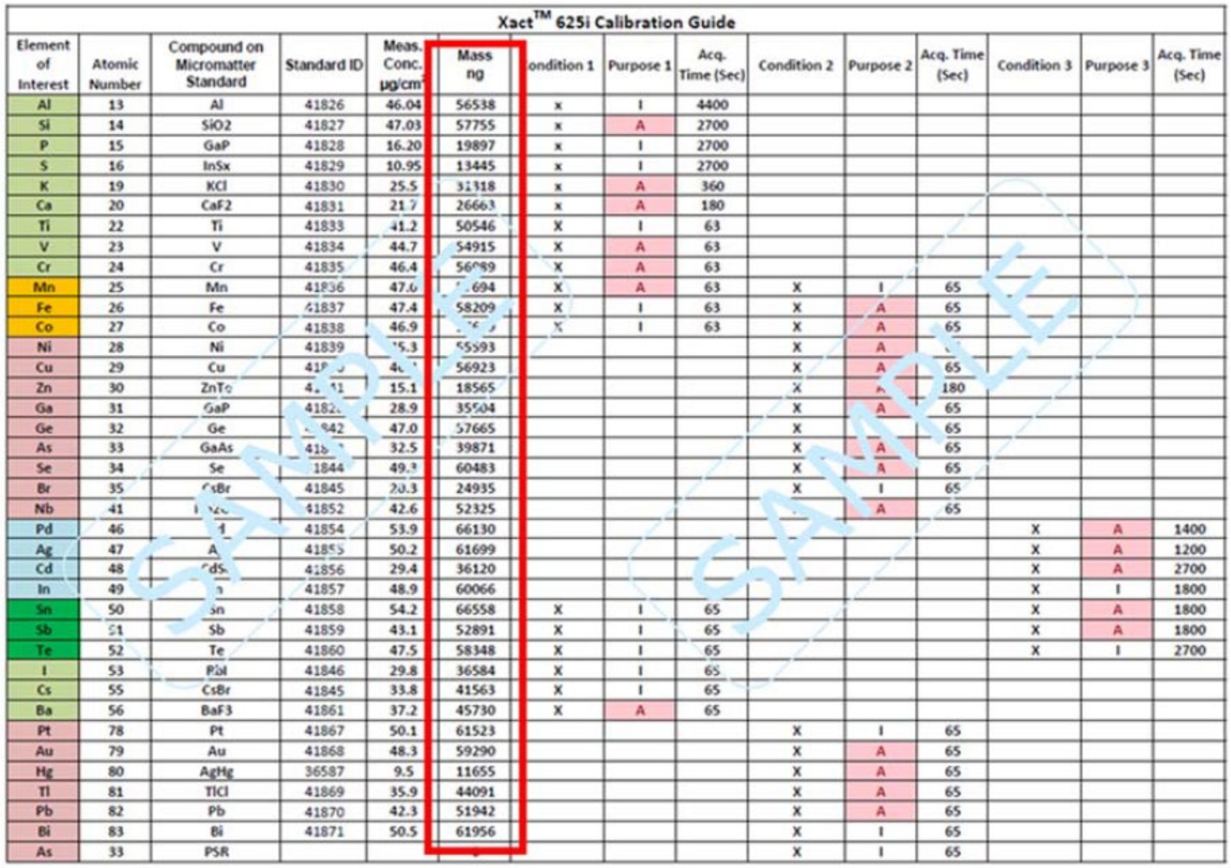
**2x EC1, 2x EC2, and 1x EC3 are required**

| Element | Atomic Number | Standard Compound | Standard ID | Energy Condition | Acq. Time (sec) | Mass (ng) | Reported Mass (ng) | % Diff |
|---|---|---|---|---|---|---|---|---|
| Ca | 20 | $CaF_2$ | | 1 | 120 | | | |
| Mn | 25 | $MnF_2$ | | 1 | 60 | | | |
| Se | 34 | Se | | 2 | 70 | | | |
| Pb | 82 | Pb | | 2 | 70 | | | |
| Cd | 48 | CdSe | | 3 | 2700 | | | |

Optional

| Element | Atomic Number | Standard Compound | Standard ID | Energy Condition | Acq. Time (sec) | Mass (ng) | Reported Mass (ng) | % Diff |
|---|---|---|---|---|---|---|---|---|
| Al | 13 | Al | | 1 | 4400 | | | |
| Fe | 26 | Fe | | 2 | 70 | | | |
| Pd | 46 | Pd | | 3 | 900 | | | |
| Ag | 47 | Ag | | 3 | 1200 | | | |
| Sn | 50 | Sn | | 3 | 1800 | | | |

**Table 3.** Example calibration guide that comes with the thin-film standards. Be sure to use the guide that corresponds with your standards



| Xact™ 625i Calibration Guide | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Element of Interest | Atomic Number | Compound on Micromatter Standard | Standard ID | Meas. Conc. $\mu g/cm^2$ | Mass ng | ondition 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] | 49.3 | 60483 | | | | X | A | 65 | | | |
| Br | 35 | CsBr | 41845 | 20.3 | 24935 | | | | X | I | 65 | | | |
| Nb | 41 | [illegible] | 41852 | 42.6 | 52325 | | | | | A | 65 | | | |
| Pd | 46 | [illegible] | 41854 | 53.9 | 66130 | | | | | | | X | A | 1400 |
| Ag | 47 | [illegible] | 41855 | 50.2 | 61699 | | | | | | | X | A | 1200 |
| Cd | 48 | CdS | 41856 | 29.4 | 36120 | | | | | | | X | A | 2700 |
| In | 49 | [illegible] | 41857 | 48.9 | 60066 | | | | | | | X | I | 1800 |
| Sn | 50 | Sn | 41858 | 54.2 | 66558 | X | I | 65 | | | | X | A | 1800 |
| Sb | 51 | Sb | 41859 | 43.1 | 52891 | X | I | 65 | | | | X | A | 1800 |
| Te | 52 | Te | 41860 | 47.5 | 58348 | X | I | 65 | | | | X | I | 2700 |
| I | 53 | PbI | 41846 | 29.8 | 36584 | X | I | 65 | | | | | | |
| Cs | 55 | CsBr | 41845 | 33.8 | 41563 | X | I | 65 | | | | | | |
| Ba | 56 | BaF3 | 41861 | 37.2 | 45730 | X | A | 65 | | | | | | |
| Pt | 78 | Pt | 41867 | 50.1 | 61523 | | | | X | I | 65 | | | |
| Au | 79 | Au | 41868 | 48.3 | 59290 | | | | X | A | 65 | | | |
| Hg | 80 | AgHg | 36587 | 9.5 | 11655 | | | | X | A | 65 | | | |
| Tl | 81 | TlCl | 41869 | 35.9 | 44091 | | | | X | A | 65 | | | |
| Pb | 82 | Pb | 41870 | 42.3 | 51942 | | | | X | A | 65 | | | |
| Bi | 83 | Bi | 41871 | 50.5 | 61956 | | | | X | I | 65 | | | |
| As | 33 | PSR | | | | | | | X | I | 65 | | | |

## Xact 625i Minimum Detection Limits

**Table 4.** Xact 625i minimum detection limits.

| Element | Atomic Number | Detection Limits* (ng/m$^3$) at Sample Times | | | | | |
|---|---|---|---|---|---|---|---|
| | | 15 mins | 30 mins | 60 mins | 120 mins | 180 mins | 240 mins |
| Al | 13 | 840 | 290 | 100 | 35 | 19 | 12 |
| Si | 14 | 150 | 51 | 17.8 | 6.3 | 3.4 | 2.2 |
| P | 15 | 44 | 15 | 5.2 | 1.8 | 0.99 | 0.64 |
| S | 16 | 26 | 9.1 | 3.16 | 1.1 | 0.6 | 0.39 |
| Cl | 17 | 15 | 5 | 1.73 | 0.61 | 0.33 | 0.21 |
| K | 19 | 9.8 | 3.4 | 1.17 | 0.41 | 0.22 | 0.14 |

| Element | Atomic Number | Detection Limits* (ng/m$^3$) at Sample Times | | | | | |
|---|---|---|---|---|---|---|---|
| | | 15 mins | 30 mins | 60 mins | 120 mins | 180 mins | 240 mins |
| Ca | 20 | 2.5 | 0.86 | 0.3 | 0.1 | 0.057 | 0.037 |
| Ti | 22 | 1.3 | 0.46 | 0.16 | 0.056 | 0.03 | 0.02 |
| V | 23 | 1 | 0.34 | 0.12 | 0.042 | 0.023 | 0.015 |
| Cr | 24 | 0.97 | 0.33 | 0.12 | 0.041 | 0.022 | 0.014 |
| Mn | 25 | 1.2 | 0.41 | 0.14 | 0.05 | 0.027 | 0.018 |
| Fe | 26 | 1.4 | 0.49 | 0.17 | 0.061 | 0.033 | 0.021 |
| Co | 27 | 1.1 | 0.39 | 0.14 | 0.049 | 0.026 | 0.017 |
| Ni | 28 | 0.78 | 0.27 | 0.1 | 0.034 | 0.018 | 0.012 |
| Cu | 29 | 0.65 | 0.23 | 0.079 | 0.028 | 0.015 | 0.01 |
| Zn | 30 | 0.55 | 0.19 | 0.067 | 0.023 | 0.013 | 0.008 |
| As | 33 | 0.52 | 0.18 | 0.063 | 0.022 | 0.012 | 0.008 |
| Se | 34 | 0.66 | 0.23 | 0.081 | 0.029 | 0.016 | 0.01 |
| Br | 35 | 0.85 | 0.3 | 0.1 | 0.037 | 0.02 | 0.013 |
| Ag | 47 | 16 | 5.5 | 1.9 | 0.68 | 0.37 | 0.24 |
| Cd | 48 | 21 | 7.2 | 2.5 | 0.89 | 0.48 | 0.31 |
| In | 49 | 26 | 8.9 | 3.1 | 1.1 | 0.6 | 0.39 |
| Sn | 50 | 33 | 12 | 4.1 | 1.4 | 0.78 | 0.51 |
| Sb | 51 | 42 | 15 | 5.2 | 1.8 | 0.99 | 0.64 |
| Ba | 56 | 3.3 | 1.1 | 0.39 | 0.14 | 0.074 | 0.048 |
| Hg | 80 | 0.99 | 0.35 | 0.12 | 0.043 | 0.023 | 0.015 |
| Tl | 81 | 0.95 | 0.33 | 0.12 | 0.041 | 0.022 | 0.014 |
| Pb | 82 | 1 | 0.36 | 0.13 | 0.045 | 0.024 | 0.016 |
| Bi | 83 | 1.1 | 0.37 | 0.13 | 0.046 | 0.025 | 0.016 |

[*] Interference-free one sigma detection limits for a 0.707 inch$^2$ spot sample size at a 68% confidence level (C1σ) per U.S. EPA IO-3.3 and Currie, 1968.

References: (1) U.S. EPA Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, June 1999: Method IO-3.3. (2) Currie, L. A., "Detection and Quantification in X-Ray Fluorescence Spectrometry" in

T. G. Dzubay, X-ray Fluorescence Analysis of Environmental Samples, Ann Arbor Science, 1977; and L. A. Currie, Analytical Chemistry, 40, p586, March 1968.

# Standard Operating Procedure for Campbell Visibility Sensor (CS 120A)

February 13, 2024

STI-7504

# Contents

# 1. Scope and Applicability

This standard operating procedure (SOP) provides instructions for servicing the Campbell visibility sensors used in fenceline monitoring applications. The procedures here cover routine maintenance and calibration of the Campbell CS120A visibility sensor.

# 2. Routine Service and Maintenance

Routine service tasks are designed to maintain the visibility sensor in good working condition. This is intended to lower the frequency of non-routine maintenance. The routine service tasks are described below. The site should be serviced once every four weeks. If no problems are encountered, the site visit will take less than one hour.

When maintenance is complete, the maintenance forms in Section 6 should be saved in the maintenance folder for the project located on Sonoma Technology's shared drive. Data will be flagged in a manner consistent with the QAPP if there are issues that cannot be immediately corrected. In the case of extended down time, the sensor should be replaced with a working sensor.

## 2.1 Maintenance Checklist

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

**Table 1.** Routine quarterly maintenance checklist.

| Action |
|---|
| Visually inspect the system, including all cables. Ensure they are not fraying. |
| Inspect optics on detector and clean if necessary. |
| Check calibration. An acceptable % accuracy is less than 25% |

[a] Lowering the meteorological tower is not necessary for routine site maintenance visits. Do not attempt to lower the tower with fewer than two people.

After physically inspecting the meteorological sensors, the technician should take note of the current visibility reading from the instrument and confirm that it matches current atmospheric conditions. Visibility data from the National Weather Service can be used to aid in this task.

## 2.2 Securing the Shelter

Turn off the computer's display monitor, and record your completion time in the Site Log form. Turn off the shelter lights and lock the shelter.

# 3. Calibration and Standard Operating Procedures for Meteorological Sensors

Annual audits will be conducted on meteorological instrumentation. The meteorological instrumentation calibrations will be conducted with reference to the recommendations in the EPA's *Quality Assurance Handbook for Air Pollution Measurement Systems (QA Handbook), Volumes I, II, and IV* (U.S. Environmental Protection Agency, 2017b, 1994, 2008) and in accordance with the *Technical Assistance Document for the National Air Toxics Trends Stations Program, Revision 3* (U.S. Environmental Protection Agency, 2016a) and the *Technical Assistance Document for Sampling and Analysis of Ozone Precursors for the Photochemical Assessment Monitoring Stations Program*, Revision 2 (Battelle, 2018).

As part of the calibration process, each instrument will first be tested to determine whether it is operating within the prescribed operational limits and whether non-routine maintenance or adjustments are required. Based on an instrument's response to the initial performance test with respect to the minimum acceptable performance criteria (see data quality objectives in the QAPP), the instrument will then be repaired, calibrated, or in rare cases, replaced. A standard form will be used to document the performance of each sensor before and after any adjustments. A digital copy of this document is to be kept on the STI servers. Notes on what was performed are also to be recorded in the station logbook. The performance criteria for the visibility sensor is that the measured extinction coefficient must be within 25% of the reference value.

## 3.1 Visibility Sensor Testing and Calibration

### 3.1.1 Materials Needed

- Microfiber cloth
- Calibration bungs
- Calibration disk
- Micro-USB to USB-A cable

### 3.1.2 Startup Checklist

Verify that the following actions are completed when starting up the Campbell Visibility Sensor:

_____ Verify that serial connections to the datalogger are correct (sensor TX to logger RX, sensor RX to logger TX, and sensor ground to any ground terminal on the logger).

_____ Check datalogger to see if data is coming from the sensor.

_____ Check the data to make sure it makes sense (visibility value is a reasonable number and the correct values are being recorded to the right parameters).

_____ Make sure the lenses are clean and clear of obstructions (spider webs, etc.).

_____ Use a microfiber cloth (you can use a blower first). Do not use abrasive cleaners; use isopropyl alcohol only if needed.

### 3.1.3 System Verification Procedure

The following tests will be performed as a verification of analyzer operation.

#### Testing and Calibration Prep

The sensor can be checked and adjusted using the optional sensor high-grade calibration kit Part Number 28678 from Campbell Scientific. The calibration must be performed using the onboard menu system. To access this menu via LoggerNet's terminal emulation program, see procedure in Section 4.

The test should ideally be performed under the following conditions:

- Ambient temperature between 0ºC and 50ºC.
- The local visibility is approximately 10,000 meters or more.

To perform the verification test, follow these steps:

1. Select Menu Item 4 on the main terminal screen. Once you have selected Menu Item 4, the following is an example of what should appear on the screen.

```
CS120A INFORMATION - MENU 4
 ID 0
 S/N 1234
 OS version: 007646v12
                                   Alarm   Value
- Last visibility reading:          -       65m
- Overall system status:            0       No faults
- Emitter dirty window alarm:       0       0%
- Emitter internal temperature:     0       27.4
- Detector dirty window alarm:      0       -4%
- Detector internal temperature:    0       23.2
- Detector DC light saturation:     0       -
- Hood heater temperature:          0       16.9
```

```
- CS120A Calibrator Serial No:       -       1192
- CS120A Calibrator EXCO:            -       48.4
- Calibration value factory offset: -       0.025
- Calibration value factory scale:  -       0.02630
- Calibration value cal offset:     -       0.090
- Calibration value cal scale:      -       0.02814
- Signature fault:                  0       -
- Flash write errors:               0       0
- Flash read errors:                0       0
- Supply voltage:                   <7.0V  12.0V
- Aux supply voltages:              +5V=4.9 -5V=-5.1 +6V=6.0
(8) Get debug
(9) Refresh
(0) Return to main menu
```

2. Make note of the extinction coefficient on the sensor calibrator. Once suitable local visibility conditions have been verified, place the sensor calibrator into the volume by fastening it to the central mounting point.

3. Allow 5-10 minutes for the measurements to stabilize.

4. Record the As Found system parameters, that can be found in Menu 4.

5. Enter 9 as needed to continue to refresh the data to see the last visibility reading.

6. Once the last visibility reading is consistent, take note of the new reading.

7. The conversion of the visibility reading to the extinction coefficient for comparison is 3000 divided by the last reading.

8. Calculate the percent error between this new value and the extinction coefficient. The percent error should be equal to or less than the %Error specified in the QAPP.

9. If the precent error is greater than specified in the QAPP, attempt cleaning the lenses. If the percent error is still greater than the value specified in the QAPP, proceed with calibration.

### 3.1.4 System Calibration Procedure

1. To perform the calibration, select Menu Item 3 on the main terminal screen. Once you have selected Menu Item 3, the following screen should appear.

```
CS125 CALIBRATION - MENU 3
ID 0
S/N 1006
(1) Perform calibration
(2) Restore the factory calibration
(3) Perform dirty windows zero offset calibration
(4) Restore dirty windows factory calibration
```

```
(9) Refresh
(0) Return to main menu
```

2. Select **Option 1** to start the calibration.

3. Confirm that a calibration is to be performed. Please note that once “**Yes**” is entered, exiting the program is not possible until the test is complete. However, power cycling the unit at this point will have no adverse effect on the sensor.

4. Once the test has started, the program will ask for the sensor calibrator serial number and coefficient with a confirmation at each step giving the opportunity to correct typing mistakes.

```
Starting calibration.
Input the sensor calibrator serial number ->E2002
Is E2002 correct? (Y/N)?
Input the sensor calibrator constant ->28.8
Is 28.8 correct? (Y/N)?
```

5. Start the dark level calibration by placing one calibration bung into each hood, and then pressing any key.

   Once calibrator information has been entered, the sensor will hold until the foam bungs are placed into the sensor hoods. The bungs are designed to block all light from the outside from reaching inside the head. Place one bung into each hood. If either of the bungs is damaged or appears to have any gaps around the edge, contact Campbell Scientific.

```
Starting dark level calibration.
This test will take approximately two minutes
```

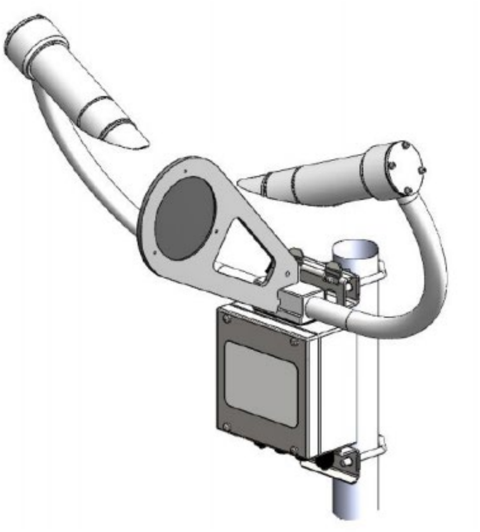
   This part of the test will take approximately two minutes. Every ten seconds, a dot should appear indicating that the test is progressing as normal.

```
Dark level test complete. Please remove the bungs.
Now place the sensor calibrator into the sampling
volume.
Press any key once this is done.
```

6. Remove the bungs once the sensor instructs for this to be done.

## Light Level Calibration

7. Place the sensor calibrator into the volume by fastening it to the central mounting point. Press any key.



```
Starting light level calibration.
This test will take approximately two minutes.
```

This part of the test will take approximately two minutes. Every ten seconds, a dot should appear indicating that the test is progressing as normal.

```
Calibration is now complete.
Saving user settings
Press any key to exit.
```

Once the second stage of the test has been completed, the new calibration constants will be saved automatically. Exit the menu by pressing any key. All calibration constants, including both the user and the factory setting, can be viewed from Menu Item 4 from the main menu once the test is completed.

8. Document the new user calibration constant and the factory setting each time a calibration is done.

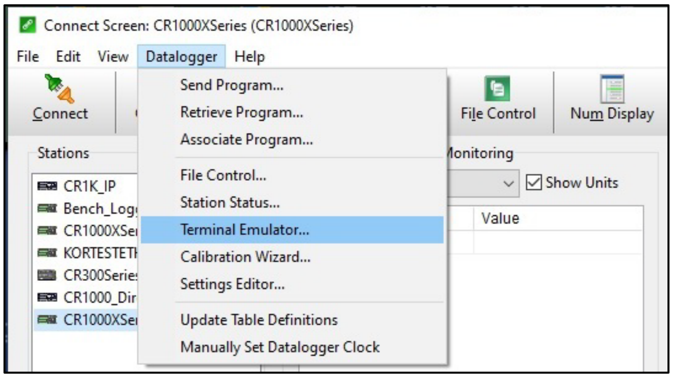
9. REMEMBER to remove the calibration disk once finished.

# 4. Campbell Terminal Emulator Connection Procedure

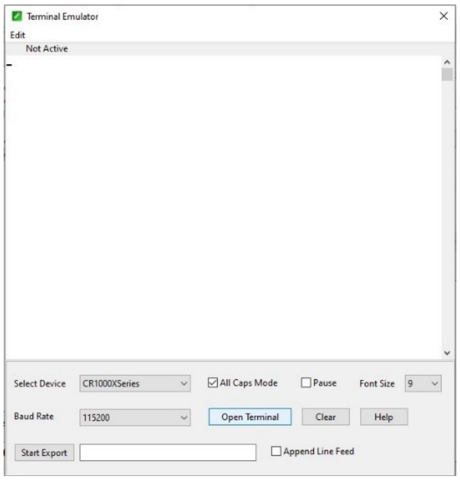
The following is a procedure to access the real-time visibility sensor data with a Campbell Scientific Data Logger through LoggerNet Terminal Emulator.

1. Connect a laptop to the Campbell Scientific Data Logger with a USB cable, RS232 cable, or via ethernet cable and IP address.
2. From the LoggerNet application, open the “Connect Screen” through “Main” and “Connect” options.

3. Select the “Datalogger” tab at the top right of the “Connect Screen.” Then select “Terminal Emulator…” from the drop down menu.

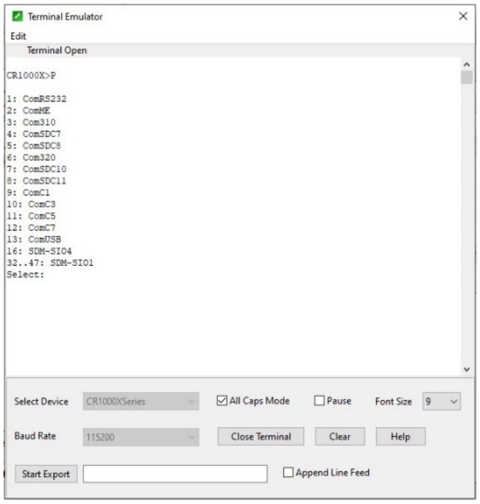


4. A blank window will display, but the terminal emulator is not open yet. To open connection to the terminal emulator, select “Open Terminal” at the bottom of the Terminal Emulator window.



Select Device: CR1000XSeries
☑ All Caps Mode
☐ Pause
Font Size: 9
Baud Rate: 115200
☐ Append Line Feed

5. When the terminal is open, the button that previously said, “Open Terminal,” will change to “Close Terminal.” Press enter until “CR1000X>_” appears in the terminal.
6. Type the capital letter “P” to display comport options.



```
CR1000X>P

1: ComRS232
2: ComME
3: Com310
4: ComSDC7
5: ComSDC8
6: Com320
7: ComSDC10
8: ComSDC11
9: ComC1
10: ComC3
11: ComC5
12: ComC7
13: ComUSB
16: SDM-SIO4
32..47: SDM-SIO1
Select:
```

Select Device: CR1000XSeries
☑ All Caps Mode
☐ Pause
Font Size: 9
Baud Rate: 115200
☐ Append Line Feed

7. Look at the lowest terminal bar on the data logger and identify which terminal port has a blue wire to the left of a white wire. The terminal port that the blue wire is connected to corresponds to the comport that needs to be selected. For example the “C1” terminal port corresponds to the option “9: comC1.” Type the list number after “Select:_” that corresponds to the correct comport and press enter.
8. If the correct comport is selected “opening [comport number]; press ESC ESC ESC ESC to close” will display and sometimes will be followed by an array of numbers. Now type “open 0” and press enter. Note, often the curser or the text will not be visible during this step. Also, frequently, the first attempt will not work. Allow time for the command to process. Typically,

additional rows of array numbers will display after failed attempts are finished processing. Continue to enter “open 0” until the following setup menu displays.

```
WELCOME TO THE CAMPBELL SCIENTIFIC LTD CS120A SETUP MENU
 ID 0
 S/N 1234
 (1) Message output menu
 (2) User alarm menu
 (3) Calibrate CS120A
 (4) System information
 (5) Communications setup
 (6) System Configuration
 (9) Exit and save
 (0) Exit and don't save
  ->
```

9. Enter “4” for “System information” and the real time data from the visibility sensor will display.
10. Enter “9” as needed to continue to display the most current data.
11. To exit the terminal emulator session, enter zero to exit the information menu and return to the main menu.
12. Enter zero again to exit and not save.
13. Press Esc four times to close.
14. Select “Close Terminal” to close the terminal
15. Close the terminal emulator window.
16. LoggerNet can be closed and the laptop can be disconnected from the logger.
17. Note: opening the terminal emulator will halt data transfer from the data logger. To re-establish data transfer, reset the data logger by disconnecting the power source, wait 10 seconds, and plug the power source back into the data logger.
18. Confirm data flow has been re-established.

# 5. References

U.S. Environmental Protection Agency (1994) Quality assurance handbook for air pollution measurement systems, Volume I: a field guide to environmental quality assurance. Report prepared by the U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA/600/R-94/038a. Available at **https://www3.epa.gov/ttn/amtic/qalist.html**.

U.S. Environmental Protection Agency (2008a) Quality assurance handbook for air pollution measurement systems, Volume II: ambient air quality monitoring program. Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-08-003, December. Available at **http://www.epa.gov/ttn/amtic/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf**.

U.S. Environmental Protection Agency (2008b) Quality assurance handbook for air pollution measurement systems, Volume IV: meteorological measurements version 2.0 (final). Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-08-002, March. Available at **https://www3.epa.gov/ttn/amtic/qalist.html**.

U.S. Environmental Protection Agency (2016) Technical assistance document for the National Air Toxics Trends Stations Program, Revision 3. Prepared for the Office of Air Quality Planning and Standards, Research Triangle Park, NC, by Battelle, Columbus, OH, October. Available at **https://www3.epa.gov/ttnamti1/files/ambient/airtox/NATTS%20TAD%20Revision%203_FINAL%20October%202016.pdf**.

U.S. Environmental Protection Agency (2017) Quality assurance handbook for air pollution measurement systems, Volume II: ambient air quality monitoring program. Prepared by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/B-17-001, January. Available at **https://www3.epa.gov/ttnamti1/qalist.html**.

# 6. Campbell Visibility Sensor Audit Record Example

**Visibility**
**As Found**

| | | | | |
|---|---|---|---|---|
| **Site Name:** | Field Site Name | | **Date:** | January 1, 2024 |
| **Site Latitude:** | 12.345678 N | | **Technician:** | Tech Name |
| **Site Longitude:** | -123.456789 W | | **Reference Make:** | Campbell Scientific |
| **Sensor Make:** | Campbell Scientific | | **Reference Model:** | CS125 |
| **Sensor Model:** | CS120A | | **Reference Serial No:** | E21192 |
| **Sensor Serial No:** | E1234 | | **Reference Cal Date:** | N/A |

| | **Reference** | **Site Sensor** | **Error (%)** | **PASS/FAIL** |
|---|---|---|---|---|
| **Extinction Coefficient (km$^{-1}$)** | 48.4 | 50.0 | 3.3 | PASS |
| **Visibility (m)** | | 60.0000 | | |

| | | | | |
|---|---|---|---|---|
| Overall system status: | No faults | | Calibration value factory offset: | -0.041 |
| Emitter dirty window alarm: | -1% | | Calibration value factory scale: | 0.02619 |
| Emitter internal temperature: | 30.8 | | Calibration value cal offset: | 0.064 |
| Detector dirty window alarm: | 0% | | Calibration value cal scale: | 0.029 |
| Detector internal temperature: | 25.7 | | | |
| Hood heater temperature: | 20.9 | | | |

**Notes:**

Sensor found to be within specification.
Will clean sensor lenses with alcohol wipes, lint-less lens tissue, and a blast of compressed air.

# Visibility
# As Left

| | **Reference** | **Site Sensor** | **Error (%)** | **PASS/FAIL** |
|---|---|---|---|---|
| **Extinction Coefficient (km$^{-1}$)** | 48.4 | 52.6 | 8.7 | PASS |
| **Visibility (mi)** | | 57.0000 | | |

| | |
|---|---|
| Overall system status: | No faults |
| Emitter dirty window alarm: | -1% |
| Emitter internal temperature: | 31.2 |
| Detector dirty window alarm: | -1% |
| Detector internal temperature: | 26.1 |
| Hood heater temperature: | 21.2 |

| | |
|---|---|
| Calibration value factory offset: | -0.041 |
| Calibration value factory scale: | 0.02619 |
| Calibration value cal offset: | 0.064 |
| Calibration value cal scale: | 0.029 |

**Notes:**

Sensor left within specification